U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

2017 Buildings Technology Office Peer Review Report

APPENDIX

November 2017

(This page intentionally left blank)

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy

2017 Building Technologies Office Peer Review Report

APPENDIX

March 13–16, 2017
Arlington, Virginia

(This page intentionally left blank)

Notice

(This page intentionally left blank)

Table of Contents

Final List of Reviewers

Abramson, Alexis
Case Western Reserve University, Great Lakes Energy Institute

Adifon, Leandre
Ingersoll Rand

Alvarado, Jorge
Texas A&M University

Amann, Jennifer
ACEEE

Aoki-Kramer, Michael
RDH Building Science, Inc.

Bach, Christian
Oklahoma State University

Balbach, Chris
Performance Systems Development of NY, LLC

Barooah, Prabir
University of Florida

Behl, Madhur
University of Virginia

Blissard, Laureen
GreenBuilder Coalition

Bradshaw, Craig
Oklahoma State University

Brandemuehl, Michael
University of Colorado

Campbell, Brad
University of Michigan

Cetin, Kristen
Iowa State University

Chang, Chih-hung
Oregon State University

Chen, Yitung
University of Nevada, Las Vegas

Chude, Ricson
Southern California Edison

Cioc, Sorin
University of Toledo

Coulter, Jonathan
Advanced Energy

Deng, Song
Bee

Doria, Jordan
NAIMA

Eger, Bill
City of Alexandria

Fitzgerald, Garrett
Urban Sustainability Directors Network

Fronk, Brian
Oregon State University

Gheewala, Sapna
U.S. Department of Energy

Greyson, William
Bent Branch Strategies

Hasher, John
Virginia Beach Schools

Healy, Bill
National Institute of Standards and Technology

Horsey, Mary
MCH Consulting

Hostler, Steve
Case Western Reserve University

Karaguzel, Omer
Carnegie Mellon University

Khounsary, Ali
IIT

Klausner, James
Michigan State University

Lee, Hohyun
Santa Clara University

Lydon, Pat
Legacy Health

McCurdy, Rick
McCurdy & Associates, LLC

Moghaddam, Saeed
University of Florida

Murphy, William
University of Kentucky

Musho, Terence
West Virginia University

Novoselac, Atila
The University of Texas at Austin

Orosz, Michael
University of Southern California Information Sciences Institute

Pate, Michael
Texas A&M University

Pivo, Gary
University of Arizona

Powell, Kevin
US General Services Administration

Rainey, Teresa
EYP Architects & Engineers

Roy, Robin
Next Energy US

Sherif, S.A.
University of Florida

Smyth, Edward
DNV GL Energy Services USA

Wang, Xudong
AHRI

Weber, Robert
Bonneville Power Administration

Worek, William
Texas A&M University - Kingsville

Yuzugullu, Elvin
CSRA

Analysis Methodology

For all projects, reviewers were given five evaluation criteria and asked to score them on a 1–4 scale, with four being the highest. In addition to numeric scores, reviewers were asked to provide qualitative comments and feedback regarding the project's strengths and weaknesses, and any suggestions relating to the scope of the work. Reviewers were also asked to evaluate the value of the deliverables to the target audience/market and whether the key research areas/deployment activities relevant to the project scope are receiving sufficient emphasis. Please refer to the Project Evaluation Form on page 5 for full evaluation criteria.

Scores were based on the following criteria and weights:

Score 1: Relevance (standalone metric) – Degree to which the project supports BTO goals and objectives. *(Note: this metric is not included in the weighted score for each project, as it does not reflect on the performer of the work.)*

Score 2: Approach (30%) – Degree to which the project is focused on the critical barriers (15%), and the degree to which the project's design addresses the barriers identified (15%).

Score 3: Accomplishments/Progress/Impact (40%) – Degree to which the project has made progress toward achieving the stated project goals (20%), and the degree to which the project will significantly contribute to the achievement of relevant BTO program goals (20%).

Score 4: Project Integration and Collaborations (20%) – Degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate the movement of technologies or practices into the market (10%), and the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders (10%).

Score 5: Proposed Future Work (10%) – Degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering impediments to its goals, and, when sensible, mitigating risk by providing alternate pathways.

For each project, relevance was assessed as a standalone metric. The other four criteria were used to calculate a weighted average using the equation shown in Figure 1.

$$\left[\left(\frac{\sum_1^n Score\ 2.1}{n}\right)x(0.15)\right]+\left[\left(\frac{\sum_1^n Score\ 2.2}{n}\right)x(0.15)\right]+\left[\left(\frac{\sum_1^n Score\ 3.1}{n}\right)x(0.2)\right]+\left[\left(\frac{\sum_1^n Score\ 3.2}{n}\right)x(0.2)\right]$$
$$+\left[\left(\frac{\sum_1^n Score\ 4.1}{n}\right)x(0.1)\right]+\left[\left(\frac{\sum_1^n Score\ 4.1}{n}\right)x(0.1)\right]+\left[\left(\frac{\sum_1^n Score\ 5}{n}\right)x(0.1)\right]$$

(n equals the number of reviewers per scoring metric)

Figure 1. Equation used to calculate each project's weighted average score

Project Evaluation Forms

This evaluation form was used by reviewers to provide ratings and comments for projects showcased at the 2017 Building Technologies Office Peer Review.

Evaluation Criteria: Building Technologies Office (BTO) Program Peer Review 2017

A. Relevance (Stand Alone Metric): Degree to which the project supports BTO's goals.

1. Poor - Project provides little or no support to BTO's goals.
2. Fair - Project provides some support to BTO's goals.
3. Good - Most project aspects align with BTO's goals.
4. Outstanding - Project is critical to the BTO and fully supports BTO's goals.

Comments on Relevance:

B. Approach (30%):

1. Degree to which the project is focused on critical market barriers. (**15%**)

1. Poor - Project has identified few, if any relevant barriers.
2. Fair - Project has identified some of the relevant barriers; no critical barriers identified.
3. Good - Most of the critical barriers are identified, but a few relevant barriers were omitted.
4. Outstanding - All critical barriers are identified; difficult to identify missed barriers.

2. Degree to which the project's design addresses the market barriers identified. (**15%**)

1. Poor - Project is unlikely to contribute to overcoming the barriers.
2. Fair - Has significant weaknesses; but may have some impact on overcoming barriers.
3. Good - Generally effective but could be improved; contributes to overcoming most barriers.
4. Outstanding - Sharply focused on overcoming critical barriers; difficult to improve the project approach.

Comments on Approach:

C. Accomplishments / Progress / Impact (40%):

1. Degree to which the project ***has*** supported the achievement of the stated ***program performance*** goals. (Note: New projects should be scored in relation to the length of time the project has been active.) (**20%**)

    1. Poor - Little or no demonstrated support, either quantitative or qualitative, for the achievement of the program performance goals.
    2. Fair - Modest qualitative support for the projects contribution to the stated program performance goals.
    3. Good – Strong qualitative and some quantitative support of the programs contribution to the stated program performance goals.
    4. Outstanding - Excellent, Strong qualitative and quantitative support for the programs contribution to the program performance goals.

2. Degree to which the project ***will*** significantly contribute to the achievement of its ***program's*** interim market goal. (Note: New projects should be scored in relation to the length of time the project has been active.) (**20%**)

    1. Poor - Weak evidence presented, contribution to program's interim market goal is unlikely.
    2. Fair - Some evidence presented, contribution to program's interim market goal will likely be small.
    3. Good - Substantial evidence presented, meaningful contribution to program's interim market goal is likely.
    4. Outstanding - Strong evidence presented, transformative contribution to program's interim market goal is likely.

Comments on Accomplishments / Progress / Impact:

D. Project Integration and Collaborations (20%):

1. Degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market. (**10%**)

    1. Poor - The presenter has demonstrated a rudimentary familiarity with the key stakeholders, many stakeholders are omitted.
    2. Fair - The presenter has demonstrated a basic understanding of the key stakeholders, a few stakeholders were omitted.
    3. Good - The presenter has demonstrated a deep understanding of the key stakeholders, no key stakeholder were omitted from the presentation.
    4. Outstanding - The presenter demonstrated an exceptional level of understanding of the key stakeholders, no key stakeholders were omitted from the presentation.

2. Degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders. (**10%**)

    1. Poor - Most work is done at the sponsoring organization with little outside collaboration or coordination.
    2. Fair - Collaboration and coordination exist, but could be significantly improved.
    3. Good - Good collaboration exists; partners are fairly well coordinated.
    4. Outstanding - Close, appropriate collaboration with industry and/or other institutions; partners are full participants and are well coordinated.

Comments on Project Integration and Collaborations:

E. Proposed Future Work (10%): Degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

1. Poor - Current plans are unrelated to past work, have little likelihood of eliminating barriers or meeting project or BTO objectives.
2. Fair - Plans build on past work and may lead to improvements, but need better focus on overcoming barriers; many risks are not addressed in future plans that threaten the achievement of project or BTO objectives.
3. Good - Plans build on past progress and focus on overcoming barriers, some risks exist that could prevent the achievement of project or BTO objectives.
4. Outstanding - Plans clearly build on past progress and are sharply focused on barriers; risks that could prevent the achievement of project or BTO objectives are appropriately addressed.

Comments on Proposed Future Work:

Please substantiate your score with comments about the project's strengths:

Please substantiate your score with comments about the project's weaknesses:

Please offer any additional recommendations you have for the project:

How would you rate the value of the deliverables produced by the project to the key target audience(s)/market(s) of the program?

☐ High
☐ Average
☐ Low

Explain:

Are the key research areas/deployment activities relevant to the project's and program's objectives receiving sufficient emphasis?

☐ Yes
☐ No

Explain:

Reviewer Comment Summaries and Raw Reviewer Comments

BTO solicits input on its projects via an annual Peer Review process to ensure that projects are relevant, effective, and productively assisting the Office in meeting its goals. Independent review is an important part of BTO's overall portfolio management process, as it provides alternative viewpoints from leaders in industry and academia on current project activities and strategies. Reviewers that participate in Peer Review evaluate projects and provide crucial, targeted feedback on progress-to-date as well as proposed future work. This feedback informs BTO's understanding of its portfolio's approach, effectiveness, and potential impact from current investments in technology research and development, validation and verification, and other related activities.

Emerging Technologies
HVAC, Water Heating, and Appliances

Project # 30006: Development of an Innovative, High-efficiency Radon Fan (SBIR)

Presenter: Edward Bennett, Mechanical Solutions
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project, though there was some disagreement on its potential energy and market impacts. On one side, several reviewers commented that—because radon fans need to operate continuously—there is need to reduce their energy demand. On the other side, however, some reviewers felt that the energy market for this technology was small, such that even large efficiency improvements would still have minimal impact. Other reviewers flagged that the project could end up having a large impact relative to its cost, and was thus very relevant to the BTO goals, while another noted that improvements in fan efficiency could provide a significant offset in energy consumption as the market for improved air quality grows.

Reviewers also agreed with the approach taken by the project team, noting that this approach was appropriate, clearly identified the source of deficiencies in fan design, and was using the right tools to address these shortcomings. One reviewer agreed with the presenter that consumer sentiment was shifting towards an interest in higher efficiency, but this reviewer was not convinced that there was sufficient economic justification for consumers to adopt the new fan technology. Another reviewer cautioned that the project was addressing efficiency concerns, but not other fan characteristics that consumers care about (e.g. cost, sound, vibration). One reviewer recommended investigating opportunities to modify the fan for other applications, such as kitchen hoods and bathroom exhaust fans.

Reviewers concurred on the progress being made by the project team, noting that the presentation clearly conveyed strong technical achievements. One reviewer felt that insufficient detail was shared on the actual modeling approach used to design and simulate the performance of the new fan, while another reviewer recommended that simulated savings from the new fan design should be presented alongside data on the field-tested performance of conventional fan units.

Regarding collaboration, several reviewers highlighted the working relationships between the project team and industry leaders, commenting that that integration and collaboration appeared to be good. However, while one reviewer noted that the project team had identified a commercial partner that could help take the product to market, another felt that better integration with this company would be useful.

Given that the project was a time-limited SBIR Phase I project and was reaching its conclusion, most reviewers acknowledged that future work would not be carried out under the current solicitation. One reviewer still commented, however, that the next steps for development of the new fan design—securing funding for prototype development and testing—were a logical extension of the current project.

Weighted Average: 3.39 # of Reviewers: 7
Relevance: 3.14[1] Approach: 3.36 Accomplishments: 3.57 Project Collaboration: 3.07 Future Work: 3.43

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.14** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project's objectives include the redesign, construction and characterization of a radon fan. Since radon fans need to operate continuously, there is a need to reduce their energy demand.
- The energy market for this technology is tiny, even with a large improvement of efficiency the impact is minimal.
- SBIR project is investigating improved fan design for always-on radon fans to reduce energy consumption in residential buildings. Current installed capacity is 0.001 quad, although project team notes perhaps 10x homes would benefit from radon mitigation.
- Radon fan performance is a home appliance that has been neglected from an R&D perspective. Improvements in fan efficiency will provide a significant offset in energy consumption as the market for improved air quality grows.
- The project identifies a clear need in the industry. Although the overall energy saving might be considered limited, but it deals with enhancing IAQ with significant healthcare cost savings.
- The project has a very large impact relative to the cost of the project. It is very relevant for the BTO goals as the improved design can be used not only for radon fans but for in-duct bathroom fans, too. For the energy efficient homes, radon and bathroom fans play a significant role in building energy consumption.
- This project looks to develop a more efficient radon fan. Since radon fans are operated 24/7, this would have significant impact in energy savings.

B. Approach

This project was rated:

1) **3.29** for the degree to which it focuses on critical market barriers, and
2) **3.43** for the degree to which the approach addresses the market barriers identified.

- The approach proposed by the team members is a sound one. It involves optimizing the performance of a radon fan, while minimizing noise and energy consumption. The approach relies on computational fluid dynamics and experimental activities for developing and characterizing the best design.
- The project will address an improved energy efficiency but does not address other items that a consumer may care about (e.g. cost, sound/vibration).
- The project team notes that there is a potential market of 6 million homes, with 600K already installed. The approach of designing an improved fan that reduces energy consumption is in line with BTO goals. However, it is not clear what the realistic market is for an improved fan. Will 600K installed user basis have any incentive to upgrade their units? What would the ROI on such an upgrade be? The reviewer agrees with the project team that some consumer sentiment is shifted towards an interest in higher efficiency, but it is not clear from the information presented that there is an economic justification for the consumer. This casts doubt on the commercialization potential of the project team's technology.
- The improved fan technology aims to be a drop in replacement for existing fans. The biggest market barrier is developing a fan that is too big that cannot be dropped into an existing installation. Therefore, the constraint that the size cannot have greater than a 5% increase in volume is appropriate. Also, in order to be accepted by the market, fan performance testing must be done to ACMA standards. This is being done.

- The project has clearly identified the source of deficiency in fan design and is using the right CFD tools to address shortcomings.

- When the prototype is developed and fan performance verified, the inline duct fan manufacturer will happily use the provided solution to enhance their products.

- This technology looks to replace existing radon fans with a new fan that is more efficient. The fan looks very similar so market barriers should be minimal.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.71** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.43** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team members have been able to design and simulate the performance of the new fan computationally. They have also been able to run experiments to confirm the numerical results and the efficiency of the new fan. Apparently, the efficiency of the new radon fan is superior to the conventional ones.

- There were good technical achievements presented and the project appears mostly on track.

- The project team has made reasonable progress considering a 06/2016 start date. They have used simulation tools to identify regions of inefficiency and produced an improved design on paper. Using simulation, the redesign appears to show improved efficiency. However, the fan curve is also much steeper. It is not clear if this will be important in the application or manifest in the physical device.

- Preliminary CFD results demonstrate the potential for significantly improved fan efficiency. It will be interesting to prototype the design and measure improved performance that can be gained with new design.

- The work and evidences of improvements were clearly presented, unlike some other projects that it wasn't clear what they were actually doing or presenting a cocktail of different things without showing tangible results.

- The project contractors delivered what they promised. The improvement in the design is demonstrated.

- The team has achieve a minimum of 25% reduction in energy consumption. This would have significant impact.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.14** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team members have initiated working relationships with industry leaders to facilitate adoption of the proposed new fan design.

- The project could use better integration with the final commercialization company. There were apparently many obstacles in setting up the relationship that created delays or other issues that could have been resolved with effort prior to the proposal submission.

- The team has identified a commercial partner that will be necessary for moving the product to the marketplace.
- PI is collaborating with industrial partner that sells fan units into the market.
- The team was following a clear workflow and discussions with manufacturers.
- The contractors work with industry leader for radon fans, and this collaboration can be expanded further to other in-duct fan manufacturers.
- Fluids Engineering Mechanical Solutions is working with Fantech on this product who is a major supplier of radon fans. Integration and collaboration appears to be good.

E. Proposed Future Work

This project was rated **3.43** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Given the nature of the project (SBIR Phase I), the project is reaching its conclusion. Nevertheless, the developed prototype has been able to show superior performance when compared to existing fans.
- N/A: Future work does not involve current solicitation.
- The project team is nearing the end of the SBIR Phase I. The next step that they propose is to secure funding for a prototype development and test, which is a logical extension. If the improved design truly has market potential, they should explore industry funding to support this engineering work.
- Prototype will be fabricated and tested.
- I am looking forward for experimental results to validate the experimental data.
- The contractors delivered design and it is up to industry partner to work on the manufacturing and cost issues to transition this product to the market. I have no doubt that this fan technology will be embraced.
- Future work will select the final design. I think field testing documenting the performance improvement would be good.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 6** reviewers

- If proven independently, the devised radon fan could result in significant energy savings in the residential sector.
- The new fan seems like it would at least technically be well received. How far it penetrates into the Radon fan market to generate impact is yet unclear.
- The proposed solution appears to significantly exceed project performance goals.
- The project addresses a clear need in the market.
- My favorite project out of 9 I reviewed: low cost, good result, great impact.
- The team delivered a more efficient product in a short time.

***Average*: 1** reviewer

- Concerns about the value of the project outcome to the market of interest were detailed in the "weakness" section.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 7** reviewers

- The team members followed an adequate research and development plan to design, fabricate and characterize a new type of radon fan.
- This is receiving enough interest, currently.
- The key research area of improving fan flow paths with CFD appear to be focus of reported work.
- Project is making good progress.
- Yes, the project seems to be on track.
- I see no market barriers for these fans. The mass production can easily make the cost competitive to the current fans.
- I believe these have been covered.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The team members used CFD and experimental tools effectively to be able to meet the project's objectives within the given amount of time.
- The CFD efforts and technical achievements were good and the updated fan looks like it will provide significant energy savings relative to the current state of the art.
- Project had clear objectives of using CFD simulation tools to redesign a radon fan. This appears to be complete.
- Project team has identified an industry partner with knowledge of the fan market.
- The project strength is that CFD analysis has been used to design a radon fan geometry that provides significantly improved efficiency.
- The project is very well defined and executed.
- The project identified an important problem (pointing out small fans as weak spot in the residential HVAC systems) and successfully addressed the problem.
- The team made significant improvements in efficiency.

2) **Project Weaknesses**

- The team members should try to commercialize the new radon fan through a patent or licensing agreement.
- The project partnership seems weak and there does not seem to be much of a plan for how to get the new product out into the field and/or sell the product. Additionally, the energy market identified is very small which reduces the impact of BTO's funding.
- The market potential for turning this technology into a successful business is unclear. The motivation for a consumer to replace their radon fan except in cases for which it breaks is not discussed. Is there a realistic ROI that would make this improvement attractive? If there was a significant market demand, why is Fantech not funding the prototype development/test, or undertaking the engineering work themselves?
- While 6 million homes have been identified as benefiting from radon mitigation, it is not clear what the likelihood of any percentage of these entering the market is.
- Limited details were provided regarding actual CFD approach. The project team did attempt to validate their code by showing reasonable agreement between baseline experimental and CFD fan curve. Any additional validation/verification cases would greatly improve confidence in results of improved design.
- This is an early stage project. It has accomplished many of the stated goals and does not have significant weaknesses.
- I did not find any particular weakness.
- None.
- None.

3) **Recommendations**

- The proposed fan could be modified for other applications in which fans are used, such as kitchen hoods and bathroom exhaust fans.
- *No Comment*
- *No Comment*
- It is not known to what extent the full shroud geometry has been accounted for. The shroud will have significant impact on the fan performance, and prototyping tests should be done as soon as possible to validate the analysis.
- The project is on track and I am looking forward to see the new fan built.
- I wish we can see these kind of improvements for “clunky” bathroom fans and horribly load kitchen hood fans.
- I think the savings should be documented by side-by-side field testing with conventional units.

Project # 30007: Advanced Hybrid Water-Heater Using Electrochemical Compression (ECC) (SBIR)

Presenter: Bamdad Bahar, Xergy
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Overall, reviewers found that this project was relevant to BTO's goals and objects, with one reviewer noting that—should the project's goals around its high-efficiency, low cost, innovative water heater be met—it had the potential to change the architecture and design of future HVAC systems and drive new designs and applications.

Regarding the project's approach, reviewers disagreed on the degree to which the project focused on critical market barriers. Positively, one reviewer found the project's use of electrochemical compression (ECC) technology to eliminate harmful refrigerants to be especially innovative. Critically, however, one reviewer commented that while the project team had addressed efficiency, cost, weight, and volume, these market barriers were not clearly described—acknowledging that confidentiality issues may have been the cause of this. One reviewer noted specifically that the life of the technology's membranes might not be competitive enough for the market, while also cautioning that other barriers could emerge during system integration and packaging.

Reviewers were split in their assessment of the projects' accomplishments and progress. One reviewer noted that, though the project was on track and had developed scale membranes, it was difficult to distinguish between this projects' accomplishments and the accomplishment of other related projects. Another reviewer commented that the ECC unit's controls were not discussed sufficiently.

Reviewers differed on their evaluation of the project's integration and collaborations. Two reviewers felt that the project had established significant collaboration with major companies, like Haier, and had developed strategic agreements with global suppliers. Reviewers also noted that these partnerships augured well for the ECC technology's ability to be commercialized. Critically, however, one reviewer felt that the project's collaboration with Haier would not be enough to overcome system integration issues, and recommended attracting other industry partners.

Most reviewers agreed that, though the project had clear future plans, there were concerns around system integration and packaging, particularly in collaboration with Haier. One reviewer emphasized that it was important to focus on system design and performance as the next step, while another commented that—once the technology was proven—the supply chain would need to define the means of production to satisfy market demand.

Weighted Average: 3.10 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.00 Accomplishments: 3.17 Project Collaboration: 3.17 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Overall high COP at a projected low cost. Next generation water heater technology.

- If successful and the project goals are met in terms of COP and Cost, the technology has the potential to change the industry. It will change the architecture and design of future HVAC systems. Noiseless systems with no moving parts will drive new design and applications.

- Project is relevant to BTO goals in that an innovative high-efficiency, heat pump water heater is being developed.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- This project focused on the design of the ECC - membrane, stacking, etc.
- Approach not clearly described (perhaps due to confidentiality issues).
- Confusing since integrates with other projects - not clear where this project ended and others started.
- Packaging issues not addressed.

- All identified market barriers are being addressed:
  - 1- Efficiency.
  - 2- Cost or Unit Price.
  - 3- Weight.
  - 4- Volume, etc.
- Still the life of the membranes, currently estimated at 20,000 hours, may not be competitive enough. Other barriers may emerge during the system integration/packaging.

- Of special importance, the approach of using electrochemical compression technology, which eliminates harmful refrigerants, is especially innovative.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Again, difficult to distinguish between this project's accomplishments and other related projects.
- Overall, on track to impact.

- The team has covered a lot of ground:
  - Continuous composite membranes and membrane Electrode assembly production capability have been established.
  - ECC plates production capability has also improved.
- Not much was said about the unit controls. That is the area where some issues may be uncovered.

- Pilot scale membranes have been developed and tested, which is a major step in the program's progress. In addition, several water-based compressors have been built and delivered to collaborators.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Great collaboration with Haier. Strategic agreements with global suppliers.

- The collaboration with Xergy and Haier does not seem enough to overcome the system integration issues. The team is encouraged to attract other partners. Especially, as the critical components are already covered with IP, the integration/packaging is where the commercial viability will be proven.

- Significant collaborations with major companies are in place.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Some concern about system and packaging issues. Need to find solutions to problems that will arise quickly - might mean additional collaboration/partners.

- Even though much was not said about the future application of electrochemical compression to replace mechanical compressors in HVAC, the current application to replace electric water heaters seems to be well understood by the team. Integration and packaging will be done with collaboration with Haier.

- Future work is system integration and endurance testing with partners.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Impressive development and innovative approach.
- Could have impact on market with additional development and partnership.

- MEA's and plates production are a huge achievement. They are likely to drive other applications.

- Significant energy savings are expected.

***Average*: 0** reviewer

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- Focused on performance (COP) and cost.

- 1- Technology being adequately developed
- 2- Partnerships in place even if the number needs to be increase.

- Project is well-balanced.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good balance of research and commercialization activities.
- Accomplishments impressive.

- 1- The critical components have been sufficiently developed in terms of their science, production and application.
- 2- The partnerships are in place to implement the applications.
- 3- The various generations of prototypes have shown progress.
- 4- The current set goals in the field of application seem achievable.
- Therefore, the project which is moving from Low TRL to 9 is expected to deliver a solution.

- The project strength is its innovativeness and the fact that it is not only resulting in the development of an energy efficient technology but has resulted in significant technological spinoffs.

2) **Project Weaknesses**

- Would have liked to see more detail about performance achievements to evaluate fully.
- Difficult to fully appreciate project with discussions intertwined about other projects.
- Important to focus on system design and performance as next step - could be a barrier to success since not addressed early on.

- 1- Not enough partners to better grasp all integration and packaging issues that will certainly emerge. It is the nature of product development.
- 2- The supply chain is still embryonic due to the technology still being developed. Once the technology is proven, the supply chain will need to define the means of production to achieve the market demand.

- None observed.

3) **Recommendations**

- Focus on packaging and system integration issues.

- The technology is a game changer for the HVAC industry and the team has very good resources to develop it. Some concerns exist for the integration and packaging. Therefore, the project team needs to include more industry partners.

- Continue project as planned.

Project # 31295: RVCC Technology: A Pathway to Ultra-Efficient Air Conditioning, Heating, and Refrigeration

Presenter: Arthur Kariya, Sandia National Laboratories
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project aligned with BTO's goals, though most noted that it was too early to determine how effective and efficient the project's technology would actually be. One reviewer noted that a clear demonstration of the technology's energy-saving potential would affirm the proposed rotary compression cycle's relevance, though two reviewers had doubts about the technology's ultimate impact on buildings' energy use.

Most reviewers agreed that the project addressed market barriers, but almost all went on to say that this was due to the early nature of the project; market barriers were less of a focus while the team was evaluating evaporator and condenser flow structures. Reviewers commented that while not a focus at this stage, the project team should be aware of potential market barriers.

Given the early stage, most reviewers agreed that reaching market goals was not a current focus for the project, but also that the project was making notable progress, particularly in relation to the condenser and evaporation heat transfer and air-side heat transfer. Reviewers deemed deployment activities to be premature at this time, but applauded the technical outcomes of the work, commenting that the novel technology—assembled by a quality technical team—showed great potential. Reviewers offered many recommendations for continued progress, including around development of an expansion valve with passive feedback, lubrication management, and manufacturability.

Reviewers were generally split as to how well the project was collaborating with stakeholders. A number of reviewers found that the project included all key participants that could help satisfy the technical challenges of the project. Other reviewers, however, felt that the project could benefit from further collaboration, especially a partner that could commercialize the technology. Although much work still remained, some reviewers felt that work completed to date needed to be shared with potential stakeholders.

Most reviewers found the project's future steps to be well-developed, clear, and critical to the project's success. One reviewer, however, felt that major milestones needed to be more clearly defined; for instance, this reviewer sought clarification on whether the next prototype would be a mature prototype or a "breadboard." Going forward, reviewers recommend that the project team consult existing knowledge from the community and concentrate on the refrigerant portion of research. One reviewer encouraged work to be done to demonstrate the basic energy-saving premise of the rotary compression cycle, while another recommended that the project team clarify their expectations for system efficiency gains.

Weighted Average: 3.04 # of Reviewers: 6
Relevance: 3.50[1] Approach: 2.75 Accomplishments: 3.08 Project Collaboration: 3.33 Future Work: 3.17

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This is a very interesting, low-TRL level project, and it seems to align well with the BTO's objectives in this area.
- The project outcome is stated as assessing viability of RVCC concept "which can lead to substantial energy savings." These energy savings are claimed as 21% over existing technology, but no justification is provided on exactly how this will be achieved. Thus, it not clear how realistic the impact would be on reduction of energy in buildings.
- This is an interesting project but it is still in its early stages and there is insufficient information in the presentation to know whether, at least in theory, the proposed rotary compression cycle has any clear advantage over existing systems; it may, and it is worth investigating. Demonstrating energy-saving potential will make this approach relevant. Fouling, frosting, and broken connections are issues that can be overcome (page 6 of the presentation), and they do not necessarily show inherent inefficacies in vapor compression systems. The potentials of the proposed technique are best demonstrated by theoretical and computational techniques at this early stage. Use of CFD is highly recommended.
- Rotating vapor compression system aims to reduce energy consumption by 21% which is well aligned with DOE's energy efficiency objectives.
- Project relates to the technology that is still in a very early stage, but it has a great potential to make a large impact on the efficiency of building cooling and heating systems.
- This project uses transfer enhancement techniques developed by another DOE project to enhance the performance of a heat pump. This follows DOE's goals to support higher efficiency technologies (reducing energy use, CO2 emissions) by having a smaller size. The size reduction enhances the heat transfer processes.

B. Approach

This project was rated:

1) **2.83** for the degree to which it focuses on critical market barriers, and
2) **2.67** for the degree to which the approach addresses the market barriers identified.

- This is a low-TRL project. Market barriers are less of a focus.
- While it is possible that it is not a component of the project, the team presented no information on market analysis or barriers that must be overcome for the technology to be viable.
- The PIs certainly are focusing on aspects of the problem that they feel are critical. This is appropriate, and the project would probably benefit by drawing upon existing know-how in the community. As an example, information about rotating blade heat transfer is available in the literature, so utilizing it would allow the team to concentrate on the refrigerant-side study – and on testing and characterization.
- Project is in very early stage and initial focus is on evaluating evaporator and condenser flow structure and effectiveness.
- The hot (condenser) and cooled (evaporator) air side heat transfer problem is very challenging, but the research team seems to have a systematic and well-balanced approach.

- This is a transformative technology. I believe it may be premature to begin addressing market barriers, however the investigators should be aware of potential market barriers.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.83** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Again, low-TRL level, so contributing to interim market goals seems unlikely. Technical progress was excellent; flow visualization work was nice. What is the weight distribution of the refrigerant relative to the structure? If the ratio is relatively high, refrigerant maldistribution could cause balance issues. Also, it was not clear how they planned to handle the issue regarding liquid distribution in the evaporator.

- The project team explored condensation/evaporation heat transfer and air-side heat transfer from a fan blade. However, the team did not show any enhancement in the coupling of these two phenomena (refrigerant-to-air). While they conclude that air-side heat transfer can be maximized by using short-chord blades, it is unclear how feasible this is when incorporating refrigerant channels. This makes potential impact and scaling unclear.

- The PIs have taken the necessary first steps in demonstrating the capabilities / potentials of the proposed technique. The manufacturing aspect can take a back seat for now to allow uninhibited exploration of the theoretical potentials of the approach.

- Project is at very early stage. Progress has been made to demonstrate the efficacy of the condenser and evaporator design. Also, HTC measurement over a moving blade have been characterized. The achievements form the building blocks for developing the proposed components into an AC system.

- It seems that this project is making progress on air and refrigerant side of the rotary vapor compression cycle.

- The project has made significant progress. They have investigated the vapor compression cycle operating in the rotating frame and the enhancement. The enhancement is possible on the air side in the heat exchangers. Also, they have begun to think about issues of manufacturability.

D. Project Integration and Collaborations

This project was rated:

1) **3.17** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team assembled seems reasonable to satisfy the technical challenges. There was not a partner which could potentially commercialize this technology.

- Collaboration with partners at CTS in Illinois was documented. Experiments were split up to effectively utilize existing experimental facilities.

- The project can further benefit from collaborating with others. There are large communities with expertise in heat transfer, computational fluid dynamics, and refrigeration whom can be drawn upon to move the exploration process along faster and identify key technical needs.

- The partnership between Sandia and UIUC is an excellent one. The PI from UIUC has significant expertise in transitioning technology to industry, and he is playing an important role in insuring the relevant collaborations are made.

- It seems that project includes all key participants (national lab, academia, industry).

- From this project and past projects, this is a very integrated and collaborative team.

E. Proposed Future Work

This project was rated **3.17** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The issues were clearly identified but it was not clear what the next major milestone would be. Will the next prototype be a breadboard or more mature prototype? What TRL level is expected at the end of the next step?

- The project ends in Feb. 2017. There is no proposed future work on this grant.

- There is still a need for significant work to demonstrate the basic energy-saving premise of the rotary compression cycle. This would have to be demonstrated before concentrating on design and fabrication.

- The next step is to develop a prototype rotating HVAC system. It is important to characterize the performance to determine to what degree COP can be improved.

- The following steps, including control, manufacturability and lubrication, seems to be logical for commercialization.

- The next step and future work on the project will be critical. This includes proof-of-concept of the system in the rotating frame including the refrigerant flow in the rotating frame and the heat transfer enhancement in the rotating frame. Key issues needing to be addressed include: development of an expansion valve with passive feedback, lubrication management, and manufacturability.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- N/A

- Good research team (great expertise in the field); novel and more efficient technology; and systematic progress towards the commercial unit.

- The project team has delivered information on all the tasks. The project plan is very sound.

***Average*: 3** reviewers

- The experimental outcomes do not clearly show how a feasible system with improved performance will be achieved. Modelling of the system (demonstration of improved COP on paper) should be explored prior to seeking funds to build a larger unit.

- As noted, much work – preliminary work – remains to be done to deliver significant results. The work that has been done can be shared by potential stakeholders and interested collaborators to help the project along. At a minimum, we need to show that if we succeed in fabricating the proposed system, it has the theoretical potential to deliver efficiencies that BTO seeks. This needs to be done, and I understand that doing so requires more work. The noted patent addresses one aspect of the project. That information, and the other

results developed in the course of the present study, are best published in peer review journals to share them with, and to receive feedback from, the technical community.

- Project is at the early stage. The project deliverables to date are adequate.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 6** reviewers
- N/A

- N/A

- Yes, but there are other aspects the need attention. For example, a bottom-up approach to show how the efficiency of the proposed system can be estimated. Also, what are the (realistic) assumptions made to arrive at those results?

- Evaporator and condenser performance on a rotating platform have not been developed before. Emphasis on these components is appropriate.

- Same comment ad the previous one.

- At this time, deployment activities are a little premature. However, the investigators are keeping the technical community aware of their efforts.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The technical outcome of this work was excellent, the co-rotating visualization in particular.

- Collaboration with CTS/Illinois is positive. Novel experimental techniques to measure heat transfer of evaporation/condensation and air-side heat transfer.

- The concept is interesting and worth exploring thoroughly for its perceived efficiency compared to existing systems. The steps taken so far are fine but have to be extended to develop a firm theoretical basis for it before moving on to implementation.

- The proposed rotating vapor compression technology is very innovative, but is at very early stage. Early stage performance shows some promise.

- Novel technology that show great potential. Very systematic approach.

- This project has assembled a top quality technical team. They are building on previous DOE-sponsored research.

2) **Project Weaknesses**

- It was less clear how the next steps will help this technology get closer to commercialization.

- No discussion of market opportunity or barrier to development. No discussion of application areas of interest. No clear justification for enhanced system performance compared to state of art. Manufacturing challenges were included as backup slides but not publically presented.

- There are no obvious weaknesses. Much remains to be explored and examined. A CFD model of the compression process – or aspects of it – seem necessary and that may require forging new collaborations.

- Both the condenser and evaporator are rather bulky. In order to have high performance over many years, the whole assembly must be well balanced. The method to keep it in balance over a long period is not clear.

- Research team still needs to resolve many issues before commercialization.

- None, however manufacturability and lubrication will be key issues.

3) **Recommendations**

- N/A

- Project team should more clearly explain where they expect to see gains in system COP. Enhanced air-side heat transfer? Eliminating defrost cycles? Are these really enough to improve by 21%? What about the increased energy required to rotate the entire device? How would this scale to a multi-ton commercial unit?

- The budget for this project compared to others I have read is small; it is perhaps a third. Yet the PIs have demonstrated some interesting work. Hopefully in collaboration with other stakeholders and experts in those areas that touch upon this project, a compelling case could be made for the project and for potential path(s) forward.

- It is important to develop an analysis to predict HTC within evaporator and condenser so that each component can be properly sized to achieve the required cooling load for a given application.

- None.

- Start looking at manufacturability early.

Project # 31296: Higher Efficiency HVAC Motors

Presenter: Stephen Nichols, QM Power
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project was relevant to BTO's goals and objectives, as it will develop and implement a new type of motor technology that could have a significant impact on energy savings. Reviewers were spilt as to whether the project addressed market barriers, however, with one reviewer noting that, while there was a good target market, it was unclear what the barriers to entry might be. All reviewers agreed, however, that key research areas were being sufficiently emphasized, highlighting that the team had focused on the right technology development steps and that project deliverables would be highly valuable to the target audience.

Reviewers were pleased with the project's accomplishments to date, calling the 89% peak efficiency and power factor results impressive and finding that they could have a significant market impact. One reviewer highlighted the technology's ability to vary speed and adapt to various applications without complicated power electronics. Beyond accomplishments, reviewers identified numerous other project strengths, including impressive prototype development and the large expected energy savings.

Overall, reviewers found that the project team did not fully demonstrate an understanding of key stakeholders, nor did the project team fully collaborate with industry. While there was collaboration with large HVAC companies like UTRC and Carrier, reviewers felt that the team should have opened itself up to many more original equipment manufacturers (OEM). One reviewer noted that, while this technology had the potential to be quickly adopted, limiting partnerships to only one OEM may have limited the opportunity to set a new market standard and drive sales.

Some reviewers found that the project's proposed future work was well planned, particularly its focus on half horsepower before expanding to one horsepower. One reviewer felt that there were not enough details provided about the next iteration of hardware and software design, however. Moving forward, reviewers recommended that the project team should consider additional market barriers and also engage with more industry partners and stakeholders. One reviewer also recommended considering a commercialization path.

Weighted Average: 3.05 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.17 Accomplishments: 3.17 Project Collaboration: 2.67 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Given the prevalence of motors, such improvements could have a significant impact on various applications and therefore energy savings.
- Fractional Horse Power (FHP) motors are used across HVAC units. Any energy saving will directly impact the loads on buildings.
- This project has the goal of developing and implementing a new type of motor technology that should result in significant world-wide energy savings.

B. Approach

This project was rated:

1) **3.33** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Good target market, but unclear what some of the barriers to entry might be. Well-conceived approach - focus on prototyping and testing.
- The proposed solution will drive energy savings with cost reductions both from the reduction of power needs and the simplified controls required. The design does not require the use of inverters as currently supplied.
- This motor technology will replace existing low-efficiency motors based on induction technology and lower PF motors of the ECM type. The impact of replacing these current motors is that the motors developed in this project will have high efficiencies and high PFs.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Peak efficiency and power factor results are impressive.
- The results obtained to date have shown that significant hurdles have been overcome. In fact, the team was able to vary the speed and adapt it to various applications without complicated power electronics.
- The progress to date indicated that motors of up to 89% efficiency can be achieved, which is a substantial increase capable of having a significant market impact.

D. Project Integration and Collaborations

This project was rated:

1) **2.67** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- It's great that UTRC/Carrier has been involved. Need to consider engaging with them in future development as well, which was not mentioned in next steps.
- With such a relevant technology, the team should have opened itself up to many more OEMs.
- The lead company collaborates with large HVAC and technology companies such as UTRC and Carrier.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Details lacking regarding next iteration of hardware and software design.
- Future work and steps are well planned by the team. In particular, the focus on 1/2 HP and control with cost competitiveness before expanding all the way to 1HP is the right way to proceed.
- The future plan is to extend the progress success to larger HP motors.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- High potential impact and impressive results position the project well.
- Excellent product design. Its release will be a game changer and will quickly be adopted. However, by working with only one OEM my limit the opportunity to set a new market standard and drive sales volume,
- Substantial energy savings is expected.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- Well aligned with program goals.
- The team has done an excellent job by focusing on the right technology development steps along the project.
- Project is well-balanced.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Impressive design and prototype development. High potential market impact.
- The team has taken all the right technical approaches to a successful product development.
- The strengths of the project is the large HVAC energy savings expected.

2) **Project Weaknesses**

- Need to consider additional market barriers through discussions with others in the market.
- Not engaged with enough OEM's.
- None observed.

3) **Recommendations**

- Consider commercialization path in future development.
- Nothing relevant beyond what was already offered.
- Continue project as planned.

Project # 31299: Energy-Efficient Clothes Dryer with IR Heating and Electrostatic Precipitator

Presenter: Stanton Weaver, GE Global Research
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that the goals of this project aligned well with those of BTO. Overall, reviewers applauded the project's sound technical approach, and found that the project addressed a number of critical market barriers. A number of reviewers were able to identify other barriers that were unmentioned by the project team, however, including ozone formation due to high voltage and this ozone's impact on building occupants and clothing. One reviewer commented that the project did not identify a price at which the market would trade cost for enhanced performance, while another noted that payback period information would be critical to gaining market acceptance.

Most reviewers agreed that the project had made progress towards its objectives, though many noted that the project had not yet achieved targeted energy savings or drying times. Positively, one reviewer noted that progress had been made on packaging the electrostatic precipitator while improving collection efficiency. Another reviewer commended the project team for being forthcoming about the concept, the challenges, and the progress made. One reviewer noted that—since a prototype had been developed and tested—the product should eventually make its way to the market, though another reviewer felt that it was too early to make this determination.

Reviewers were split on the project team's level of engagement with industry and stakeholders. Half of the reviewers noted that there was no additional need for collaboration outside of the GE partnership, as GE had experience with all aspects of product development. The remaining reviewers, however, encouraged the project team to reach out to possible technology adopters, with one reviewer noting in particular that partnerships help pave the way towards commercialization.

Most reviewers agreed that while substantial work remained, the project had identified a clear pathway to achieving their goals. One reviewer recommended a redesign of the precipitator to allow for a wider regime of flows, while another recommended investigating the impact of lint on performance. Additional items flagged by reviewers for consideration moving forward included the lack of a commercialization partner, the safety concerns of a high voltage configuration, and potential ozone emissions.

Weighted Average: 3.04 # of Reviewers: 7
Relevance: 3.29[1] Approach: 3.29 Accomplishments: 2.86 Project Collaboration: 3.00 Future Work: 3.14

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.29** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Development of more efficient clothes dryers is needed to enable energy consumption in residential units. A considerable amount of energy is used every year for simply drying clothes.
- Not a huge energy use market so impact will be low.
- The project team seeks to reduce energy consumption in household appliance (dryer), which is consistent with BTO goals of reducing energy consumption in residential and commercial buildings.
- Energy efficient clothes dryer aims to increase dryer efficiency with high EF. Project supports DOE goal of high efficiency home appliances.
- Dryers consume a significant amount of energy and development of more efficient dryers is important.
- Improvement of widely used technology with well-defined and demonstrated benefits.
- This project looks to increase the efficiency of clothes driers using IR Heating and Electrostatic Precipitation. This clothes dryer will have higher efficiency resulting in lower energy use and reduced source CO2 emissions.

B. Approach

This project was rated:

1) **3.29** for the degree to which it focuses on critical market barriers, and
2) **3.29** for the degree to which the approach addresses the market barriers identified.

- The technical approach is adequate for the proposed project's objectives. The proposed technological innovations rely on fundamental physics to enable effective clothes drying.
- The approach seems good, focusing on the ESP and particularly the nebulizer efficiency.
- Key market barriers that were indirectly discussed were that any new technology must consume less energy, while maintaining high performance (short dry time and minimal water left at cycle end). The team states the DOE MYPP target of EF 6.0 with a payback period of less than 5 years, but does not discuss the target payback period of the proposed technology. This would be critical for gaining market acceptance.
- The project goal is an EF of up to 4.8 lbs/kWh. It is presumed that the enhanced performance would enable a highly competitive home appliance. However, the cost at which the market will accept the improved performance is not clear. The team is pursuing other market applications such as industrial drying and dehumidification for A/C systems.
- The greatest weakness in this approach is use of high voltage (15-30kV). It might be argued that high voltage is used in other equipment but the environment is very different in this case. ESPs are used in the filtration industry to separate particles from the air. In this case, particles will be separated and accumulate in ESP and eventually lead to spark. Significant water greatly enhances the shorting chance. Also, high voltage suppliers and accessories needed here are expensive. These issues should be focused on and addressed early in the program.
- The project addresses all identified barriers. Potential unidentified barrier is ozone formation due to the high voltage and impact of ozone on the building occupants and on the clothing in the dryer. However, it seems that research team is aware of this issue.

- The approach is sound. I reviewed this project last year and the team had many problems. They have solved all of those problems since last year, and appear to have a workable device.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.71** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team members have been able to design and characterize the proposed clothes drying system. However, moderate energy savings have been achieved so far. Moreover, it looks like the devised drying system takes a fair amount of time to achieve the desired condition.

- The technical approach seems reasonable. It was unclear if the nebulizer efficiency could actually be high enough to achieve reasonable drying times. The addition of the IR heaters seems to be the item that would provide the ability to achieve reasonable drying times, but there was little rational provided for that.

- The project team has had some challenges in the extraction efficiency of the electrostatic precipitator. At time of presentation, they had achieved 50%. It is unclear if this is sufficient to achieve project targets. At time of presentation, project team has also conducted baseline testing of dryer and begun modifications for IR heater and electrostatic precipitator.

- The project has made good technical progress. Extensive efforts have been made on packaging the electrostatic precipitator while improving the collection efficiency.

- Performers have identified parameters impacting the efficiency, and progress made on increasing the ESP efficiency is commendable. But, the project approach is risky and it is still too early to make a judgment about its impact. However, it is encouraging that the performers have a fundamental and practical approach in analyzing this problem. It also encouraging that the performer is forthcoming about the concept, some of the challenges, and progress made. This is important as it allows reviewers to properly evaluate the project.

- Project is on schedule and it seems that the team will achieve the project goals.

- This project has made significant progress resulting in a potentially good product. This product, even though a premium product, will have significant impact on electric energy use as compared to conventional electric clothes dryers.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- At the moment, only DOE is the main collaborator. Team is encouraged to reach out to other possible technology adopters through licensing agreements.

- GE is a large industrial conglomerate; internal collaboration is sufficient for a project of this type.

- There are no key partners on this project. Unfortunately, GE has spun off their appliance group, which raises concern about the viability of this technology going forward. No appliance manufacturer has been publically identified as a partner.

- Excellent technical progress on this project. However, there does not seem to be a clear path to take this technology out of the laboratory and into commercialization. It appears to be a project that will come to an end without a push toward commercialization.

- The performer is in this business and has capabilities to conduct this project.

- This contractor has a lot of experience with all aspects of the product development from the research, prototype development, manufacturing, marketing, and sale. There is no need for additional collaborators.

- Since the contractor on this project is a manufacturer, they are well integrated and the collaborations issue is not relevant.

E. Proposed Future Work

This project was rated **3.14** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- It seems that too much emphasis is being put on laminar flow for water extraction. Perhaps a redesign of the precipitator might allow for a wider regime of flows.

- The new dryer prototype sounds good; the reason it will be successful is unclear.

- There is a significant effort required before the project period is over. However, the team appears to have identified the steps required to achieve their goals.

- Proposed future work includes incorporating Electrostatic precipitator technology into a commercial dryer. This is an important next step to validate the potential increase in energy efficiency.

- It was not clear how the efficiency was being improved further.

- Very logical future steps.

- This project is set to wrap up at the end of Sept. 2017. Key issues listed by the contractor 1) Integration of the IR Heater, 2) Blower modification or redesign for better air flow control 3) Integrate Nebulizer / Precipitator. One that should be included is the impact of lint on performance.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- Great impact on energy efficiency; project has a large potential for success.

- This is a good project. I cannot wait to see the final product.

***Average*: 5** reviewers

- A viable prototype has been developed and tested, which should eventually become a marketable product.

- *No Comment*

- Improved dryer efficiency would be of interest.

- The improved performance of the electrostatic precipitator technology is impressive.

- It is too early to judge the fate of this technology. I am looking forward to see more results and response to issues raised.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 7** reviewers

- The team members have diligently conducted all the necessary research and development steps to design, fabricate, and characterize an energy efficient clothes dryer.
- Appliances are receiving more than enough attention.
- *No Comment*
- This project is on track to be technically successful. Some open questions on market viability are a concern. For example, the safety and high voltage needed for the precipitator has not been adequately addressed.
- Yes, problems are identified and research seems to be overall on track.
- Well defined project that includes relevant stakeholders and addresses almost all issues.
- GE will pursue licensing opportunities with GE Ventures.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The team members have considered out-of-the-box technologies for drying clothes more efficiently.
- The ESP technology is an interesting take on dehumidification and certainly warrants investigation.
- Team is addressing a sector that consumes large amounts of energy. A more efficient device could have a large impact on reducing building energy consumption. Technology could be applied to industries beyond appliances.
- The team undertook a very difficult task and were able to significantly increase the water collection efficiency.
- Overall, I consider this a worthwhile effort, but performers should address safety and cost issues in parallel.
- Well-rounded project with great potential for success.
- Strong team. Good work plan.

2) **Project Weaknesses**

- It seems that there are no significant collaborators, which might limit the prospect of the technology in the long-term. Perhaps GE Global Research would put adequate resources in the future to bring the technology to market.

- The technical depth presented made it difficult to determine if the PI's had a firm grasp on the fundamental behavior of this technology. Since this is a low-TRL, novel idea, solid technical understanding will be critical for commercial success.

- No/limited discussion of expected cost and ROI for proposed technology in dryer space. No commercialization partner identified, will instead rely on licensing IP. Unclear why a state-of-the art Energy Star dryer was not chosen as the baseline. Significant concerns about market viability of the dryer concept.

- System control will be complex, and it is not clear how well control has been integrated with the dryer operation

- The use of high voltage in the presented configuration. However, the concept is worthwhile pursuing with a sharp focus on critical market entry barriers (safety, cost, etc.).

- Perhaps the team can focus more on safety when considering potential ozone emission and impact of ozone on drying material.

- The project must document the effect of lint on performance.

3) **Recommendations**

- The team members should look for ways to reduce drying time, because that's an important consideration for many consumers.

- *No Comment*

- Include discussion of water consumption required per dryer. Is this important? Include discussion of expected energy savings of IR heater. Is this expected to be reliable? Is it significant for the cost of the component?

- Some analysis on cost of implementing electrostatic technology is required. Balancing this cost against incremental dryer performance is critical to determine the market value of the technology solution.

- While continuing with increasing the performance, please address the safety and cost issues.

- See previous comments.

- None.

Project # 312100: A Combined Water Heater, Dehumidifier, and Cooler

Presenter: Saeed Moghaddam, University of Florida
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project was relevant to BTO's goals due to its major energy savings potential. One reviewer warned, however, that the technology might be limited to certain regions of the country and for certain applications. Nonetheless, reviewers found that the project was making good progress, with impressive prototypes developed. Two reviewers were impressed in particular with the progress made in demonstrations at the component level—especially for the absorber, the ionic liquids, and the overcoming of corrosion issues—as well as with the technology's innovative design and its system integration. Some concerns were expressed about the technology's size and its performance in varying climatic conditions.

Reviewers generally agreed that the project needed to focus on finding additional partnerships within the industry to accelerate the adoption of this technology. One reviewer warned that using a start-up company might not be the best route to commercialization, however, and recommended instead the involvement of external partners with extensive market experience.

Reviewers were pleased with the timeline for further prototype development, noting that system performance and associated improvements would be key for future work. In addition, one reviewer suggested that the project would benefit from better collaboration with ORNL and industry partners in order to leverage lessons learned.

Weighted Average: 2.97 # of Reviewers: 3
Relevance: 3.00[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 2.83 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Good COP but potentially limited application to certain parts of the country and for specific applications.
- Major savings vs. current water heating technologies combined with dehumidification made the goals of the project very attractive. The project has the potential to drive an outcome in line with the DOE goals.
- The relevancy of this project is that it focuses on reducing the energy consumed by hot water heating especially in humid and hot regions of the US.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Approach is very focused at the component level, but there are questions about system performance once all the pieces are put together. May find that novel components lead to novel problems at the system level.
- Approach does not seem to consider size constraints.
- A low cost gas fired water heater with double of the energy factor will make a big impact on reducing energy consumption in buildings. Then the added dehumidification will drive more savings for the consumers.
- The approach undergoing R&D for reducing hot water energy consumption is to use a gas-fired absorption cycle that not only heats water but reduces latent cooling loads.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Good accomplishments demonstrated at the component level (e.g. absorber, ionic liquid) that may be applicable to other applications.
- Impressive prototypes.
- Additional performance/characterization of system needed.
- With its novel cycle of water heater, dehumidifier, and cooler, the team has made good progress:
  - 1- The membrane based absorption technology
  - 2- The ionic liquids studies
  - 3- Overcoming the corrosion issues
- All those steps show that the basic technologies are at the point where the system can be put together; which is what the team is doing.
- A test bed system has been assembled and tested, and performance parameters measured. The results of these tests indicate that significant energy savings are possible with commercialization.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Many participants from University of Florida, but requires additional partnerships with industry.
- Start-up company may not be the best route given the market.

- The team is at the point where it should start working with external partners beyond ORNL. Instead, it has made the choice to start a new company. While that path could be attractive to the inventors, it would not accelerate the adoption of the technology and the whole initiative could suffer from not having sufficient funding and even lacking practical market experience.

- As many as 6 companies are collaborating on various aspects of this project.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- System performance and associated improvements will be key. Would benefit from deeper collaboration with ORNL and industry partners to leverage lessons learned.

- Good plan with timeline both for the prototype and as well as for the commercialization with the involvement of other partners and manufacturers.

- A prototype is being assembled and will be shipped to ORNL soon for efficiency tests in an environmental chamber.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- I personally believe that the team will be able to design a system that works technically to achieve the desired energy factor. The issue is about cost. Can the cost be low enough to attract the greater market beyond the early adopters?

- Significant energy savings are expected.

***Average*: 1** reviewer

- See comments on weaknesses.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- Project aligns with BTO goals and targets.

- The research areas are certainly receiving the right attention. The opportunity that could be missed is in non-collaborating with an experienced industry partner.

- Project is well-balanced.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Impressive performance at the component level.
- Innovative design.

- Both the shared results and the presenter expose the understanding of the enabling technologies as well as the system integration. The effort of the system integration underway will clear many hurdles for the next steps.

- The strength of this project is that low cost natural gas is to be used efficiently to perform two functions-hot water heating and cooling.

2) **Project Weaknesses**

- Concerns about market applicability both from a climate and application perspective.
- Concerns about size.
- Concerns about performance under varying climatic conditions.

- Two weaknesses of the project to consider:
    - 1- Not involving external partners soon enough in the process.
    - 2- The size of the final design would likely be much bigger than originally planned. This fact could compromise the footprint required for a quick adoption by the consumers.

- None observed.

3) **Recommendations**

- Consider an alternative path to commercialization.
- Need serious focus on system enhancements and performance.

- The need to involve external partners where there is a lot of market experience.

- Continue project as planned.

Project # 312106: High-Efficiency Low-GWP Compressor

Presenter: Frederick Cogswell, UTRC
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project aligned well with BTO's goal of developing next-generation, high-efficiency compressors using low global warming potential refrigerants, with one reviewer remarking further on the strong likelihood that this project would have a great impact.

Reviewers generally approved of the project's approach. One reviewer commented that the lack of details provided due to confidentiality issues made it difficult to fully evaluate, but also that—from what they saw—the approach appeared adequate. Another reviewer highlighted the project's work to overcome market barriers by developing technologies that would enable low global warming potential systems to be widely adopted.

Reviewers also positively rated the project's progress and accomplishments. One reviewer commented that the project's progress was excellent, in that two compressor prototypes were being developed and implemented and—most importantly—the first of these two prototypes had already been operated successfully. Another reviewer thought that the Prototype 1 results already showed that the team would be able to achieve its technical goals. A third reviewer commented that reaching a seasonal energy efficiency ratio of more than 20 was impressive at an acceptable cost premium.

Multiple reviewers noted the strong relationship between UTRC and Carrier, though one reviewer wanted more evidence of the two teams' integration in practice. One reviewer highlighted that other entities were not involved, though another felt that this would not be a problem. One reviewer expressed that mot involving other entities such as ORNL or another major vendors could delay the project.

One reviewer thought that the project's proposed future work depended on system performance results, and that some re-design might need to occur as a result. However, another reviewer commented that the Prototype 2 plans were well positioned to improve upon Prototype 1 results, noting that the integration of the system with Carrier was also well defined. One reviewer recommended carefully reviewing the compressor's operation across a wide range of operating conditions.

Weighted Average: 3.23 # of Reviewers: 3
Relevance: 3.33[1] Approach: 3.33 Accomplishments: 3.33 Project Collaboration: 2.83 Future Work: 3.33

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.33** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Aligns well with BTO's goals to develop next generation compressors using low global warming potential refrigerants.

- An HVAC system that uses low global warming potential refrigerants and has high efficiency will reduce load on buildings while significantly improving the impact on climate change.

- The relevancy of this project to BTO goals is high in that a stumbling block to implementing low global warming potential refrigerants has been compressor technology. This project focuses on developing a high efficiency compressor to solve the problem.

B. Approach

This project was rated:
1) **3.33** for the degree to which it focuses on critical market barriers, and
2) **3.33** for the degree to which the approach addresses the market barriers identified.

- Lack of details on approach (due to confidentiality issues), so difficult to fully evaluate.
- Approach adequate: CFD/Carrier software for design, demonstration, testing.

- The team is working on the enabling technologies prior to the system integration. Being able to achieve the set targets in terms of SEER, and $X/1000BUTh will have a positive impact on buildings. The team is also pursuing the scalability of the system to residential applications.

- This project is working to overcome market barriers by developing technologies that will enable low global warming potential systems to be widely adopted.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- SEER > 20 impressive at acceptable cost premium.
- Pressure-flow and efficiency-flow impressive.
- Flange-to-flange efficiency needs work (i.e. to move beyond extrapolation).
- Good to focus on RTU market first.

- Prototype 1 results already show that the team will be able to achieve the technical goals.

- The project progress is excellent in that two compressor prototypes are being developed and implemented, and most importantly, the first of these two prototypes has already been operated successfully.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- UTRC (and its relationship to Carrier) is well positioned to be successful without additional partners. However, a bit more evidence is needed to convince that true integration across UTRC/Carrier teams is occurring.
- The UTRC team is working only with Carrier in an all UTC team without the involvement of other entities.
- The project has good integration and it appears the UTRC is working alone.

E. Proposed Future Work

This project was rated **3.33** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Future work depends on system performance results. May need to do some re-design as a result.
- Prototype 2 plan is well set to improve prototype #1 results. The integration of the system with Carrier is also well defined.
- The main future work remaining is the construction and successful testing of the second prototype compressor.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Impressive accomplishments to-date.
- The goals of the project are bold and the project team is likely to achieve them with a good impact on the climate and loads on building.
- Substantial energy savings can result.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The project is very focused on performance as it should be.
- The compressor, the refrigerant, the system integration are all well planned.
- Project is well-balanced.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Well-conceived plan with strong indicators of success. Very strong team.

- 1-The project team is making good use of Modeling & Simulation.
- 2- Supply chain was already engaged at the early stages of the project at a TRL<6.

- The project strength is that it has progressed to the application stage based on constructing the first prototype, and the fact that its goal is to solve one of the most difficult problems associated with low global warming potential technology.

2) **Project Weaknesses**

- Field demonstrations are necessary to ensure performance can be achieved.

- Not involving other entities such as ORNL or other major vendors in the development of the enabling technologies could delay the project.

- None observed.

3) **Recommendations**

- Ensure that engineers on this project are communicating well with other teams within UTRC/Carrier to ensure the compressor is embraced in the marketplace in the future.

- Maximizing the compressor's operation across a wide range of operating conditions is to be carefully reviewed.

- Continue project as planned.

Project # 312107: Low-GWP HVAC System with Ultra-Small Centrifugal Compression

Presenter: Edward Bennett, Mechanical Solutions
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

One reviewer described this project as relevant to BTO's goals. Another highlighted that a small, high-speed, centrifugal compressor with low-global warming potential (GWP)—in combination with a high-performance heat exchanger—could drive significant energy savings, yield a small footprint, and be oil free. This reviewer felt that such a system would drive important load reductions in buildings and have a positive impact on climate change. One reviewer noted that specific target metrics for the project's technology were not provided, however, and that it was therefore difficult to evaluate the impact of the project in terms of its energy and cost savings.

Two reviewers agreed that the project had a good focus on applying centrifugal compressor technology to low-GWP refrigerants, and that the project's approach was overcoming market barriers by developing a compressor that was low cost and high performing. However, one reviewer felt that it was difficult to evaluate the approach, in part because targets were not well defined and alignment with market needs was not demonstrated.

One reviewer commented that the project had demonstrated good progress to date, with important design milestones completed and the prototype design ready for manufacture. Another reviewer thought that the impact of the project was evidenced by the initial analytical results showing market viability, as well as the fact that the commercial partner was interested in pursuing the technology beyond the current project. One reviewer questioned how commercial viability was defined, and wanted to know the targets and outcomes of the preliminary design review.

Multiple reviewers noted that the project team's current partnership with Lennox was good—with one highlighting that Lennox had provided project guidance on integrating the compressor into real systems. Reviewers also noted, however, that they would have liked to see other commercial interests involved, as the project team could miss an opportunity to leverage other manufacturers' experiences.

One reviewer commented that few details were provided on the project's proposed future work, while another reviewer flagged that every testing result so far had been based on simulation, and that since the compressor design was novel, the team might see some issues emerge during validation testing. A third reviewer noted that there was still work to do with the high speed motor, particularly around its cooling. This reviewer also felt that the project team's narrowing of the choice of low-GWP refrigerant to one could become an issue, should expected results not be achieved during testing.

Weighted Average: 2.82 # of Reviewers: 3
Relevance: 3.00[1] Approach: 2.83 Accomplishments: 2.83 Project Collaboration: 2.83 Future Work: 2.67

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Specific target metrics not provided, so difficult to fully evaluate impact relative to energy and cost savings (per BTO program).

- A small high speed centrifugal with low global warming potential in combination with a performant heat exchanger would drive significant energy savings, small footprint and oil free. Such a system will drive important load reduction on building and positive impact on climate change.

- This project is relevant to BTO goals in that it has the objective of developing a low-cost, high-performance compressor for low global warming potential refrigerants.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **2.67** for the degree to which the approach addresses the market barriers identified.

- Details about approach not provided, making it difficult to fully evaluate.
- Targets not well defined.
- Alignment with market needs not demonstrated.

- The project is addressing the need to reduce the load on buildings with impact on global warming while bringing savings to the consumers. The focus on the compressor design and then its integration to the system is the right approach to the system development.

- The researchers are focusing on applying centrifugal compressor technology to low-global warming potential refrigerants. Their approach overcomes market barriers by developing a compressor that is low cost and high performing.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Details not provided, making it difficult to assess accomplishments, progress and impact.
- How is commercial viability defined? What are the targets? What were the outcomes of the preliminary design review?

- Good progress has been made by the team. The completion of the ARO design followed by the whole compressor with the oil free bearings are all important milestones for the project. The prototype design being ready with its manufacturability already assessed will enable the team test the real performance of the compressor.

- The preliminary and critical design reviews have been completed, and the project is presently procuring hardware for prototype construction. The impact of the project is evidenced by the initial analytical results showing market viability, and the fact that the commercial partner is interested in pursuing the technology beyond the current project.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Great partnership with Lennox. Would like to see other commercial interest.
- The team is only working with Lennox and may miss the opportunity to leverage other manufacturers' experience. It would have been better to develop such a complex compressor with more manufacturers before leaving each one of them proceed to the integration with their own IP.
- The key stakeholders are HVAC industries and one of the partners is Lennox, and they have expressed an interest in utilizing this technology and supporting development work beyond this BTO project. Of special importance, Lennox has provided project guidance on integrating the compressor developed into real systems.

E. Proposed Future Work

This project was rated **2.67** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Few details provided. The Integrated Test Loop design will need considerable attention.
- Every result so far was only based on simulations. Since the compressor design is novel, many issues may emerge during validation testing. Therefore, the project may face unexpected headwinds with risks of delay.
- The project is reaching its final stages in that the future work still to be done is building the prototype and then testing it in a Lennox system.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer

- Substantial energy savings can result.

***Average*: 2** reviewers

- See comments about weaknesses.
- I would have rated high if the team has already produced and tested the first prototype. There is still more ground to cover with issues that will emerge and will require money and time.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The project is aligned with the program's goals.

- The team is doing all the right things but is still far from the point where the risks to the project and product will all be mitigated.

- Project is well-balanced.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- A promising project to develop an innovative compressor and heat exchanger.

- The project team has identified the potential compressor manufacturer. Such a step is important to leverage the vendor's experience. The use of modeling and simulations would keep the project cost low as the design team will avoid many iterations in a build and test cycle.

- The project strength is that it has focused on low cost and high performance technology that greatly benefits both the HVAC industry and society as a whole. Another strength is the project has met its intermediate goals, and successfully reached the final stage.

2) **Project Weaknesses**

- Many questions went unanswered during the presentation. For example, concerns were raised regarding how/whether the compressor is cooled. Unclear exactly how this compressor will perform compared to the state-of-the-art. Unclear how low global warming potential was selected. Approach (past and future) not well articulated.

- There is still more work to do with the high speed motor. In particular its cooling could be an issue. Also having narrowed the choice of the low global warming potential refrigerant to one could be an issue if the expected results are not achieved after the compressor's testing.

- None observed.

3) **Recommendations**

- While I understand information is proprietary, other projects were able to at least provide performance results in comparison to state-of-the-art. Even to attract customers, such performance information will have to be public.

- TURBOCAM should be involved in the design of the compressor.

- Continue project as planned.

Project # 312108: Membrane Based Air Conditioning

Presenter: Brian Johnson, Dais Analytic
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's goals, highlighting that the project was promoting the use of refrigerants that were not harmful to the environment while maintaining or exceeding existing equipment efficiencies. One reviewer said that this project was developing a "transformational technology that, if accepted by the market, [could] lead to significant energy savings." Another reviewer commented that the project was very attractive due to the expected outcomes of 84% energy savings and the use of water as a working fluid. One reviewer commented that this project had a distinctive approach and a thorough plan for further technology development, while another thought that the project team smartly architected the system by carefully decomposing its main functions and performing them with specific subsystems.

Reviewers agreed that the project team had made good progress. One noted impressive targets and good progress on the electrochemical compressor, but thought that the mechanical vapor compression element still needed additional testing and that membrane challenges needed to be addressed. Another reviewer commented positively on the analysis, modeling, and simulation work. This reviewer felt that the biggest challenge remained the membrane design and manufacturing method, which could require several iterations.

Two of the reviewers thought that the project team's collaboration and integration were great, involving a wide range of stakeholders. One reviewer dissented, however, noting the lack of connection with commercial partners, which would be necessary to better select a market entry point.

Looking forward, reviewers identified numerous tasks that required attention. One reviewer noted that there was still a lot of work to do to mitigate design risks, while another reviewer commented that the team still needed to finish fabrication of the bench top prototype and to perform optimization tests. A third reviewer suggested that the project team should explore additional performance enhancements with the electrochemical compressor, consider controls, and scale up with respect to market requirements.

Weighted Average: 2.80 # of Reviewers: 3
Relevance: 3.33[1] Approach: 3.00 Accomplishments: 2.67 Project Collaboration: 2.83 Future Work: 2.67

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.33** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Transformational technology that, if accepted by market, can lead to significant energy savings.

- The expected outcomes of the project:
  - 1- 84% Energy savings and.
  - 2- The use of water as working fluid.
- Make the project very attractive. If successful, the project will substantially contribute to the achievement of the BTO Goals.

- This project is relevant to BTO goals in that it is promoting the usage of refrigerants that are not harmful to the environment, while maintaining or exceeding existing efficiencies.

B. Approach

This project was rated:
1) **3.33** for the degree to which it focuses on critical market barriers, and
2) **2.67** for the degree to which the approach addresses the market barriers identified.

- Distinctive approach. Thorough plan to further development.

- The project team has smartly architected the system by carefully decomposing its main functions and performing them with specific subsystems. The design of the membrane is the most challenging step of the project.

- The low global warming potential, non-vapor compression approach taken by the researcher is to use water vapor and membrane-based technology. In addition, their system will separate latent and sensible cooling in a single, packaged unit.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Impressive targets. Good progress made on ECC.
- MVC needs additional testing.
- Addressing membrane challenges.

- The team has covered some ground toward the compressors design; both mechanical and Electrochemical. Even if they are still work in progress, there is some confidence that the modeling and simulation work was well done. The biggest challenge remains the membrane design and manufacturing method for which the team may have to go through several iterations.

- The system has been designed, motor selected and fabrication started. The analysis, which is also completed, predicts a 71% efficiency.

D. Project Integration and Collaborations

This project was rated:

1) **2.67** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Lacking in connections to commercial partners - need to better select market entry point.

- The team has a nice group of partners, subcontractors and collaborators with each bringing their strength and experience. Once the design of the major components and subsystems is complete, the team will be able to manage the integration and packaging.

- The project has assembled a first-rate team made up of numerous stakeholders, with each performing a variety of tasks.

E. Proposed Future Work

This project was rated **2.67** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Need to explore additional performance enhancements with the ECC.
- Need to consider controls.
- Need to consider scale-up size with respect to market requirements.

- There are still a lot of work to do to mitigate the design risks to even get the system to perform its major functions.

- The work still to be completed is to finish fabrication of the bench top prototype and to perform optimization tests.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- Although nothing was concluded to definite yet, the team is aware of the challenges and has the right resources to mitigate them.

- Substantial energy savings can result.

***Average*: 1** reviewer

- Many barriers yet to overcome.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- Attention given to important aspects of the project relative to BTO's goals.

- Both the design, the manufacturing and the future commercialization are being carefully managed by the team.

- Project is well-balanced.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Very innovative design with great potential for impact in energy savings.
- Unique components with impressive performance.

- Project strengths:
    - 1- Modeling and simulation of the mechanical and electrochemical compressors.
    - 2- The selection of the motors and the bench tests.
    - 3- The awareness of the challenges.
    - 4- Selection of the partners, subcontractors and collaborators.

- The strength of this project is that it will result in the first packaged, membrane A/C System.

2) **Project Weaknesses**

- Biggest weakness is concern about size. As a replacement to something in the industry already, the size cannot be bigger.
- Have not yet fully determined market entry point.

- Project weakness:
    - 1- The design and manufacturing of the membrane.
    - 2- Both project and product cost. The project cost may grow well beyond the target due to unplanned builds. The product cost growth has not also been fully mitigated since the design is still evolving.

- None observed.

3) **Recommendations**

- There are many details of the project that need (and are getting) attention. This is concerning given that all of the barriers will need to be overcome in order to realize a commercially viable product.

- This is an excellent project that has the potential to be a game changer.

- Continue project as planned.

Project # 312109: Compact Thermoelastic Cooling System

Presenter: Ichiro Takeuchi, Maryland Energy and Sensor Technologies
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Most reviewers agreed that thermoelastic cooling appeared to align with other BTO efforts related to non-vapor compression solutions. However, one reviewer noted that the project—given its history and results so far—did not seem to be achieving the performance levels required to compete with other emerging technologies. Another reviewer felt that this project was the least relevant to BTO's goals of all the projects they had reviewed.

One reviewer commented that the project's approach was based on fundamental science and that it was evident that project team members understood the technical challenges. Many reviewers agreed that market barriers had yet to be addressed, but many of these reviewers also noted that this was to be expected this early in the project. One reviewer thought that the project team had identified durability of the elastic material as the market barrier, but noted that there were far larger market barriers, such as operation, temperatures, and cost. One reviewer noted that it was unclear from the presentation what the target market of the technology was, while another reviewer suggested considering niche markets where the technology could be more viable in the near term. Many reviewers noted unclear collaboration between University of Maryland and unnamed industry partners from the U.S., China, Japan and Europe.

Reviewers disagreed on progress made to date by the project team. One reviewer noted that both significant temperature differences and direct cooling of water had been achieved. Another highlighted progress by noting that a cooling effect had been demonstrated, though a coefficient of performance (COP) had not been computed. One reviewer commented that the project had made significant progress to demonstrate the technology, but that more fundamental work was needed. Other reviewers did not observe as much progress, with one noting few differences from the previous year's Peer Review. Another thought that the innovation was the only value of the project, and they were unsure if the technology would be applicable in buildings. A different reviewer commented that it was unclear how the observed cooling effects would be harvested in an actual cooling device. Finally, one reviewer commented that results were modest and thought that the goals for the next prototype were optimistic. Additionally, this reviewer recommended that when looking at results for water cooling, the team should consider the amount of latent heat rejection expected, as it was possible that at low cooling capacities the evaporation of water from the container was contributing to the temperature lift.

Many reviewers highlighted that there was a plan to create a prototype reaching a certain COP, but some of the reviewers were not clear on how the current technology would leap from its present form to meet that COP. Multiple reviewers stated that a clear plan should be better demonstrated, while one reviewer said that a real comparison with current technology was missing.

Weighted Average: 2.37 # of Reviewers: 7
Relevance: 2.86[1] Approach: 2.14 Accomplishments: 2.36 Project Collaboration: 2.57 Future Work: 2.71

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.86** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- There is certainly a need for non-vapor compression cooling technologies to reduce the global warming potential of cooling systems.
- This seems to align reasonably well with the efforts related to non-vapor compression solutions.
- Project team is investigating methods/system for producing cooling without vapor compression, eliminating need for refrigerants.
- Thermoelastic cooling is a very novel solid state cooling concept that has a potentially high COP.
- Given the history of the project and the results it has produced so far it does not seem to achieve performance levels required to compete with other technologies.
- This is probably the most interesting presentation out of 9 I evaluated, but also the least relevant to the BTO goals. It was very interesting to learn about thermoelastic cooling systems and perhaps this can be an interesting NSF project. However, the fact that contractor don't even know how to define performance relative to competitive technology (i.e. defining targeted COP without defining source and sink temperatures) does not sound good.
- This project is to investigate a new cooling technology, thermoelastic cooling, invented at the University of Maryland. The technology, if successful, would contribute to the DOE-BTO Goals. I view this as an important project, since DOE should not only invest in the improvement of existing technologies, but also the development of new technologies.

B. Approach

This project was rated:

1) **2.14** for the degree to which it focuses on critical market barriers, and
2) **2.14** for the degree to which the approach addresses the market barriers identified.

- The approach is based on fundamental science, which should enable eventual adoption of the technology in the cooling market. It is evident that the team members understand the technical challenges of the proposed cooling scheme.
- It was not clear from the presentation but it appears that the market for this technology is refrigerator/freezers and/or other small appliances. This is an early stage project so the barriers to entry are not identified well but this is expected.
- The project is at a very low TRL and thus it is not surprising that market analysis has not been the focus of the work. However, the team does identify HVAC in residential and buildings as a target market and target a 400 W capacity and COP > 4 for their demo unit. The team does not discuss at what temperature lift this occurs.
- The claims of achieving 50% market penetration and 40% energy savings by 2025 are not realistic. Even at low TRL, there are significant market barriers (reliability, scale up, etc.) that have not been considered that would impede this reach goal. The project team may consider other niche markets where the technology may be more viable in the near term.
- The market barriers for this early stage technology are not obviously addressed. The performance goals for COP, energy density, and cost intensity are stated. However, it is not clear that performance is the only market barrier. This project has reduced the volume significantly compared with the original prototype,

thus increasing energy density. However, clear identification of market barriers is not made. The technology appears far from the commercialization stage.

- Without a clear presentation of the results and accurate comparisons with the existing technologies, clear presentation of the system configuration and issues associated with its performance, fabrication and operation, it is hard to figure out where the project is headed.

- The project identified durability of the elastic material as the market barrier. However, there are far larger market barriers, such as operation temperatures and cost.

- I believe that the investigators are mindful of the market barriers, however at this time when the technology is being developed, they are focusing on proving the technology. I think this is good. The identification of market barriers will occur in the future.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.57** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.14** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team members have been able to fabricate and characterize a compact thermoelastic cooling system. Results to date show that significant temperature differences can be achieved after 360K cycles. Also, direct cooling of water has been achieved as well.

- The technical achievements are modest. The belt design is unique and seems like a novel way to operate the mechanism. It also sounded like there was some improvements made to the belt movement to mitigate issues with trying to connect the ends of the belt. However, there are large concerns with the lack of temperature lift realized when cooling water. The 2400J/100sec (24W) of cooling capacity is very far from the target of 400W and is not presented in the context of power use. Therefore, a COP of greater than 4 with 400W of cooling capacity of the next prototype seems very optimistic.
- An additional comment on the results provided for water cooling is to consider the amount of latent heat rejection that is expected from this type of test. At low cooling capacities it is possible that the evaporation of water from the container is contributing to the temperature lift measured in a significant way.

- As presented, there appears to be little progress since the 2016 BTO Peer review. The project team should identify reasons for this slow progress and discuss mitigation strategies. There are serious concerns about the ability to meet project goals by end of 2017.

- Project is early stage and good progress has been made toward addressing performance goals. However, at the current stage a cooling effect has been demonstrated, but COP has not been computed.

- It is completely unclear how the little observed cooling effects in a part of a ribbon would be harvested in an actual cooling device. With the old twisting wire configuration at least it was clear how a heat exchanger could be made.

- The innovation is probably the only value of this project. However, at this point there is little indication that this technology will be applicable in buildings.

- The project has made significant progress to date to demonstrate the technology, however significant amount of fundamental work still needs to be done.

D. Project Integration and Collaborations

This project was rated:

1) **2.71** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.43** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- It looks like most outreach activities have been focused on academic institutions, and not necessarily on potential industry partners.
- This is early stage, it looks like most work is done at MEST. This is expected.
- University of Maryland is identified as a collaborator/consultant, but it is not clear what the nature of the collaboration is.
- The team also indicates visits from unnamed industry partners.
- This technology was initially seeded by ARPA-E. The project has received significant follow-on support, and it has been transitioned to a commercial entity. The path toward commercialization is not clear.
- The project is entirely conducted by the PI and his employees.
- The power point slides indicates some collaboration (unnamed industry from US, China, Japan, Europe), however there is no clear separation between true collaboration and just a technology demonstration.
- From the presentation, it appears the team works closely together. The team has had regular visits from potential partners from the U.S., Japan, China and Europe.

E. Proposed Future Work

This project was rated **2.71** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- It looks like a scale-up unit will be developed and characterized to show the potential of the proposed innovation. For details about future work should be reported in the future.
- It was not clear from the presentation how the technology makes the leap from its current form to a 400W prototype with a COP greater than 4. The methodology and plans to overcome technical challenges should be better presented.
- The project team demonstrates a cooling capacity of 24 W (Slide 12). The presenter did not demonstrate a clear pathway to achieving the 400 W (COP > 4) by end of 2017. This may have been due to running out of time.
- Future work includes designing heat exchangers and incorporating into cooling module. This is necessary to evaluate system performance. A benchmark of the achievable COP with the prototype is needed.
- A clear plan was not presented. Simply stating that performance will be enhanced is not a plan.
- There is a logical project plan. However, the real comparison with current technology is missing.
- The next steps and future plans as outlined on Slide 17 appears to lead to the construction of a 400 W unit and testing. It will be interesting and important to see the status of the project in one year's time.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer

- To date the information produced by the project are relevant and valuable. They lead to the construction and testing of the 400W device.

***Average*: 4** reviewers

- Outreach activities should focus on the adoption of the technology by potential industry collaborators.
- *No Comment*
- The project is focused on development of low TRL level technology. At this time, it is hard to assess value of outcomes to the market.
- Main deliverable is the development of a thermoelastic cooling module that has demonstrated stable performance over more than one hundred thousand cycles.

***Low*: 2** reviewers

- Given the history of this project, it is hard to predict it would lead to a meaningful outcome.
- The project results didn't demonstrate that this technology will be competitive.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- There are a few projects on non-vapor compression technologies. It is important to investigate these ideas but it should not take up a majority of the funding.
- *No Comment*
- Good performance with the solid state cooling module is critical for success of the cooling system. The team needs to turn its focus to system development
- At this time the deployment activities are reasonable, since this is a technology under development. Deployment, at this time, should only focus on keeping interested parties informed, presentation of results at national and international forums and in archival journals. However, this should be done considering proprietary IP.

***No*: 3** reviewers

- Plenty of fundamental research activities have already been undertaken. To enable market adoption, team members should start seeking IP protection or should seek licensing agreements for the technology.
- A system level analysis is a must. After several years of working on this concept, the performer should be able to answer this question. Assuming that certain performance metrics are achieved at the material level, how a system will be made around this concept? How big and complex would it be? How much would it cost? How reliable is it? Where is the market?
- Again, I see no comparison to the current technology.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project does rely on a state-of-the-art technological innovation. Therefore, technical challenges should be expected, which will need to be addressed comprehensively in the near future.

- The project investigates a novel and interesting concept and developed some novel methods for mechanically exploiting the elasto-caloric effect.

- + The project is very innovative and the concept of thermoelastic devices is intriguing.
- + If able to displace vapor compression, this could be an important breakthrough for BTO.

- Project strength is that the concept is extremely novel, and the project investigators have made significant progress in technology development.

- The concept has some merit but without a clear analysis of achievable performance, inefficiencies, viable configurations, system analysis, etc. we will see changes in approach for the foreseeable future without producing tangible results.

- Very innovative.

- This is a strong team and have a clearly developed path to build, test and optimize the new system.

2) **Project Weaknesses**

- The project seems to be too academic in nature. Industry collaborators should be identified as soon as possible.

- The plans to overcome technical challenges are not present and it is unclear how the major project objectives will be accomplished.

- Even though project is at low TRL and market analysis may not be the priority, the project team does not appear to have a realistic view of the technology market potential or market barriers that must be addressed prior to commercialization. The technology will need continued significant investment to achieve viability.
- There are significant concerns about ability of project team to achieve targets by end of 2017.
- While focus is understandably on system, project team must consider the importance of temperature lift and relation to COP and capacity.

- The achievable cooling effect is not large, and it may be that a multi-effect unit may be required. The system is far from commercialization, and little is known about the system performance.

- The performer should be forthcoming in presenting the results, limitations, system configuration, etc.

- Disappointing performance (cooling of ~2 degree C). No real metrics that evaluate performance for application in buildings.

- As with any new technology there are potential roadblocks and problems. I would have liked to have seen more discussion of this in the presentation.

3) **Recommendations**

- The team members should try to adjust the system conditions so the minimum temperature could reach even lower values. That way, the proposed concept could find additional potential industry collaborators in the near future.

- *No Comment*

- Project team should consider other niche applications that may have shorter term payback than HVAC&R industry.
- Project team may develop a model to show potential for scaling technology to kW scale devices of interest to HVAC&R.

- Team appears to be advancing the technology forward.

- Please strictly follow the DOE 15 slides presentation format. Please clearly explain the objectives (concept, system, metrics, etc.). Limit time spent on the concept (also, there is no need to take an entire slide to copy the first page of an article, references can all go to the end of presentation or the very bottom of slides). Explain how a system built around this concept would look like. Please clearly explain deficiencies and challenges. Please clearly present the results and compare them with other technologies. It is okay if the results are poor but need to explain planned improvements and why a better performance might be reached.

- Define COP for realistic source and sink temperatures.

- None.

Project # 312110: Low-Cost Electrochemical Compressor Utilizing Green Refrigerants for HVAC Applications

Presenter: Bamdad Bahar, Xergy
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project's technology was very relevant to BTO's goals in terms of its development of an energy-efficient and noiseless HVAC technology.

One reviewer described the project's approach as well conceived, commenting that the pre-market prototype was critical and that important testing was being conducted on components. Another reviewer noted that this technology would start with compact window air conditioners with no noise and high efficiency, and that, once scaled to other HVAC applications, it would drive a new HVAC architecture. A third reviewer commented that this system was especially innovative as it integrated two diverse, cutting-edge technologies: electrochemical compressors and ionic liquid-desiccant technology.

When considering the project's progress and accomplishments, one reviewer noted the project's impressive membrane and compressor results. Another listed out important milestones already achieved. A third reviewer remarked that a majority of the progress to date had focused on synthesizing the different ionic liquid-desiccants and conducting tests to evaluate their performance, but this reviewer also noted that a prototype testing apparatus had also been constructed and that a range of membranes had been tested.

Reviewers all agreed that the project featured significant collaboration. One reviewer highlighted the partnership with Haier, and the agreement on integrating this project's technology into Haier's system. Another noted that there were significant collaborations with as many as five different companies.

Looking toward the future, one reviewer commented that the project team needed to focus more on system integration. Another reviewer, however, recommended that next steps should be ionic liquid-desiccant commercialization, endurance testing, and compressor and heat exchanger work.

Weighted Average: 3.17 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.00 Accomplishments: 3.33 Project Collaboration: 3.17 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Potentially transformational technology with high energy savings potential.

- If successful, the technology has the potential to change the industry by introducing a new design of compression and when combined with dehumidification technologies the whole industry will start a new technology S-Curve. The BTO goals will be addressed:
    - 1- Great energy savings.
    - 2- Noiseless HVAC systems.

- This project is especially relevant to BTO goals in that it focuses on environmentally friendly technology that is efficient and noiseless.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Well-conceived approach. Pre-market prototype critical. Important testing being conducted on components.

- Consumers will be able to have compact window air conditioners with no noise and high efficiency. The system would then be scaled to other HVAC applications. Thus driving a new HVAC architecture.

- The approach being researched in this project is to form an HVAC cooling system based on integrating two diverse cutting-edge technologies, namely electro-chemical compressors and ionic liquid-desiccant technology, making the proposed approach especially innovative.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Impressive membrane and compressor results (although more quantitative proof of success would have been helpful).

- The project has achieved important milestones:
    - 1- Selection of a liquid ionic desiccant after the synthesis of a few candidates and the testing of their absorption/desorption properties.
    - 2- Membrane selection.
    - 3- ECC membrane and plates design.
    - 4- Compressor design with its compatibility assessment with different refrigerants.
    - 5- Developed controls algorithm.

- Most of the progress to date has focused on synthesizing 8 different ILD's and then conducting tests to evaluate their performance. A prototype testing apparatus has also been constructed. Also a range of membranes have been tested with ILD fluids.

D. Project Integration and Collaborations

This project was rated:

1) **3.33** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Partnership with Haier with agreement to integrate into their system is significant and positive.
- The partners, subcontractors and collaborators seem to be prepared to handle most of the technical risks of the project.
- Significant collaborations are in place with as many as 5 different companies.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Need to focus more on system integration.
- The right future steps have been explained and are being taken by the team.
- The future steps are ILD commercialization, endurance testing, compressor and HX work.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Overall on track to meeting ambitious goals.
- The team has achieved some major milestones in the design of the main components driven by the basic technologies.
- Substantial energy savings are expected.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- Well focused on important characteristics of system to have greatest impact.
- All the key research needs are being addressed.
- Project is well-balanced.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Ambitious, high impact project with significant accomplishments to date.
- Partnership with Haier is critical.

- Project strengths:
    - 1- Approach taken to design the basic technologies of the product.
    - 2- Results achieved so far by the project team.
    - 3- The cast of partners and collaborators.
    - 4- The clarity and awareness of the technical risks.
    - 5- The plan of the future steps.

- The major strength of this project is that it is especially innovative because of the application of two diverse technologies that complement each other.

2) **Project Weaknesses**

- Lack of attention to system integration.
- Many risks across various components.

- Project weaknesses:
    - 1- The focus on a window air conditioner.
    - 2- Cost, volume and weight of the first market segment.

- None observed.

3) **Recommendations**

- Focus on system integration with partner.

- The project may be better off focusing on a multi tons design instead of a window air conditioner application where the technologies may not be competitive.

- Continue project as planned.

Project # 312111: High-Efficiency Solid-State Heat Pump Module

Presenter: S. Ravi Annapragada, UTRC
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's goals, remarking that the project's focus on a high-efficiency, refrigerant-free approach to heat pump technology had the potential to be a game changer for the HVAC industry, and that it aligned well with BTO's mission.

The project's approach was also well regarded by reviewers, with one describing the approach as well conceived, particularly its use of testing validation via models and its collaboration with Carrier. Another commented that the project team was modeling the right components before proceeding to the dynamic simulation of the whole HVAC system, remarking that the use of modeling was keeping technology development costs competitive. One reviewer warned, however, that the current phase of the project should have involved other government entities with modeling capabilities, to mitigate technical risks that are not negligible. A third reviewer felt that it was unclear how novel the approach was based on the presentation, stating that an electrocaloric module concept was innovative but that few details were provided.

Reviewers rated the project's progress and accomplishment similarly well, with one noting that the technology's temperature lift, high efficiency, and demonstration of the electrocaloric module concept were all impressive. Another reviewer noted that while the temperature lift at the module level may not have appeared significant, the value obtained was already a huge success due to the fact that the technology was a breakthrough; this reviewer described the project as an "inflection point in HVAC architecture and design." One reviewer expressed concerns about technology scale up, noting in particular that performance might not be maintained, but another reviewer described their expectation of significant energy savings.

Reviewers positively viewed the project's integration and collaborations, highlighting that—although the current phase of the project was only based on modeling—the team had made the case for their future work with Carrier, and that this relationship with Carrier would help significantly with commercialization and market entry. One reviewer encouraged the project team to speak with the market-side earlier rather than later, to ensure full design considerations are taken into account.

Reviewers described the project's proposed future work, focused on the construction of two additional module prototypes and assessment of their performance, as thorough and appropriate. One reviewer warned, however, that there were quite a few technical challenges to overcome, stating that the solid state compressor might work in principle but still not yield the temperature differential expected.

Weighted Average: 3.13 # of Reviewers: 3
Relevance: 3.33[1] Approach: 3.00 Accomplishments: 3.17 Project Collaboration: 3.33 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.33** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- High COP and no refrigerant aligns well with BTO's goals.
- With no refrigerant and a high efficiency design, the proposed technologies have the potential to be a game changer for the HVAC industry.
- This project focuses on a high efficiency, refrigerant-free approach for heat pump technology, which has the potential to replace existing refrigerant-based vapor compression systems.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Unclear how novel the approach is based on presentation. Said the electrocaloric module concept was innovative, but few details provided.
- Plans for approach are well conceived -testing validated via models, collaboration with Carrier.
- The type of compression technology being considered makes global warming potential not applicable. It also drives a COP>6.0 which is equivalent to substantial savings.
- The approach undergoing R&D in this project is to utilize an innovative electro-caloric module concept. For success this project requires demonstrating satisfactory material performance over typical temperature ranges, performing simulations, testing and validating bath models and prototypes.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Temperature lift impressive.
- COP > 6 impressive.
- Demonstration of electrocaloric module concept impressive (given limited detail presented).
- Many losses in actual module that need attention.
- Although the temperature lift at module level may not seem significant, the value obtained is already a huge success due to the fact that the technology is a breakthrough that signals an inflection point in HVAC architecture and design.
- The project to date has demonstrated satisfactory temperature lifts, constructed module test facilities, and demonstrated module cooling.

D. Project Integration and Collaborations

This project was rated:

1) **3.33** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Relationship with Carrier will help significantly with commercialization and market entry.
- Although this phase of the project is only based on modeling, the team has made the case for their future work with Carrier.
- Collaborations with large HVAC research industries, such as UTRC, are taking place, which will facilitate taking the technology to market.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Thorough and appropriate future work plans (although limited details provided).
- There are quite a few technical challenges to overcome. Based on the material presented, the solid state compressor may work in principle but may not yield the temperature differential expected.
- The next steps are construction of two additional module prototypes and assessing their performance.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Great potential across various applications.
- With 2.5 degrees C cooling obtained, the team is making progress.
- Substantial energy saving are expected.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- Great focus on critical pieces of the project.
- The team is modeling the right components as planned for the project before proceeding to the dynamic simulation of the whole HVAC system. More importantly, the use of modeling keeps the technology development cost competitive.
- Project is well-balanced.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Great concept with high potential impact.
- Well-conceived approach.
- Great plan for market entry.

- Strong modeling and simulation capability.

- The strength of this project is that it targets one of the few non-vapor compression approaches for cooling.

2) **Project Weaknesses**

- Concerns about scale up - performance may not be maintained.
- Limited details provided about performance and design.

- None. Too early to tell.

- None observed.

3) **Recommendations**

- Make sure you are speaking with the market-side early rather than later to ensure full design considerations are taken into account.

- This phase of the project should involve other government entities with modeling capabilities in order to mitigate the technical risks that are not negligible.

- Continue on project plan.

Project # 312112: Solid State Magnetic Cooling

Presenter: Ahmad Abu-Heiba, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's goals related to energy savings and emissions reductions. However, reviewers were mixed in their appraisal of the project's approach. One reviewer thought that this project focused on solving some major magnetic refrigeration problems by reducing manufacturing costs and increasing system performance, but another reviewer felt that the manufacturability of this project's technology might not be fully realized through conventional manufacturing technologies, and that the technology's sliding devices might cause losses in efficiency. A different reviewer remained unconvinced that the proposed system's target performance could be achieved, especially since the project focused more on materials development than system design. Additionally, this reviewer felt that key market barriers were not discussed and that several key technical barriers were also not addressed, specifically noting the frictional effects of the sliders.

Looking at progress and accomplishment, reviewers disagreed over several issues. Two disagreed over manufacturing considerations, with one claiming the project team paid good attention to the issue, while the other felt that some significant design barriers remained in terms of manufacturing capability. Additionally, one reviewer found satisfactory progress in the project's analytical model, while another thought that the analytical model was not discussed enough. One reviewer mentioned the positive progress found in the first of two prototypes being built.

While most reviewers agreed that the project's collaborations had been optimized to address individual technology challenges, one reviewer noted that additional partner discussions were needed to ensure appropriate technical and market barriers were being addressed.

One reviewer felt there was a plan in place for future work, but that the risks were high. Another thought that many issues associated with a 500W heat pump system were not presented, so it was unclear how characterization of such a system would be completed nor how scaling up would occur. An additional reviewer felt that more manufacturing considerations and testing were needed to ensure proper functioning of the sliding-rod-system approach, and to ensure the success of the project. One reviewer brought up the question of sizing for a complete commercial system, noting that if such a system were to sit on a window, the volume would need to be comparable to existing products.

Weighted Average: 2.68 # of Reviewers: 3
Relevance: 3.00[1] Approach: 2.50 Accomplishments: 2.67 Project Collaboration: 2.83 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Relevant to BTUs goals of energy reduction, but the national energy savings is generally low (161 TBTUs).
- If achieved, the goals of the projects are relevant of the reduction/elimination of refrigerants with great impact on GHG reduction.
- Utilizing non-vapor compression technology based on magnetic refrigeration can produce a 20% energy savings. Therefore, this project has a high degree of relevancy.

B. Approach

This project was rated:
1) **2.67** for the degree to which it focuses on critical market barriers, and
2) **2.33** for the degree to which the approach addresses the market barriers identified.

- Unconvinced that performance can be achieved. Seems like the focus is more on the materials development than the design.
- Key market barriers not discussed.
- Several key technical barriers not discussed (e.g. frictional effects from sliding).
- The manufacturability of the technology may not be fully realized through the current conventional manufacturing technologies. Sliding devices require a very low friction environment. And with heat there is expansion of the sliders which require more gap between the two surfaces causing losses in efficiency.
- This project focuses on solving some major magnetic refrigeration problems by reducing manufacturing costs and increasing system performance. Of special note, this project will reduce the complexity of magnetic cooling systems.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Very interesting results. Innovative design. Good attention to manufacturing considerations.
- Not much discussion about analytical model.
- There are still some significant design barriers to overcome being the project about manufacturing capability.
- The project progress is satisfactory in that an analytical model has been achieved, MCM tape casting shows great potential, and the MCM rod surface roughness has been reduced. Also, the first of two prototypes has been built.

D. Project Integration and Collaborations

This project was rated:

1) **2.67** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Need additional partner discussions to ensure appropriate technical and market barriers are being addressed.
- The team has identified and is working with Vacuumscmelze Inc. to leverage the firms MCM manufacturing experience.
- Collaborations have been optimized to address individual technology challenges.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Many issues associated with 500 W heat pump that were not presented (as future work).
- How will characterization be completed - only limited details presented.
- The plan is in place but the risks are high especially the tape casting procedure.
- Additional building and testing steps are needed to ensure the proper functioning of the "sliding" rod system approach and to ensure the success of the project.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer

- Project success will contribute to the development of an energy efficient magnetic refrigeration system.

***Average*: 1** reviewer

- More barriers to overcome may drive the project beyond the stated duration.

***Low*: 1** reviewer

- High risk project for not big payoff.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- Project is focused on elements that will result in energy savings demonstration of a unique technology.
- The project team is aware of the challenges and is focusing on them taking the right steps.
- Project is well-balanced.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Very innovative. Great progress made on materials aspects of device.
- The only project strength is the collaboration of the MCM manufacturer which experience could meet success of failure of the whole initiative.
- The strength of this project is that it will solve several major barriers that stand in the way of implementing magnetic refrigeration.

2) **Project Weaknesses**

- Significant energy savings may not be achieved even if realized. 500 W prototype is a good next step, but will need to be larger (and scale-up problems may result). Analytical model not discussed much.
- There are still a lot of technical risks to mitigate not limited to manufacturing but back to the design itself. Then the cost advantage for a market viability may be another hurdle.
- None observed.

3) **Recommendations**

- Please see weaknesses.
- Another hurdle to consider is the size of the whole commercial system. If it is to seat on a window, the volume has to be comparable to the existing systems.
- Continue on project plan.

Project # 32219: High Performance Cold-Climate Multi-Stage Heat Pump

Presenter: Bo Shen, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

All reviewers agreed that this project demonstrated strong relevance to BTO's objectives, and further that it was addressing an important target market with good commercial opportunity and energy savings impact.

Reviewers agreed that the project successfully demonstrated technical achievements, having developed two technology configurations for a high efficiency, cold climate heat pump system demonstrating higher performance at very low ambient temperatures. While reviewers felt that technical barriers had been met, however, they agreed that some market barriers remained to be addressed. One reviewer identified the market barriers as performance, operating cost, first cost, and lifespan, and expressed that three of these had already been addressed. A different reviewer felt that barriers related to refrigerants were not mentioned. One reviewer was quite concerned about the first cost of the heat pump due to the first-cost sensitivity of the residential market, but other reviewers felt that the technology could be marketed even with a higher cost.

Based on the strong data shown from the testing of the system in different environments, reviewers felt the project had clearly delivered and demonstrated a cold-climate heat pump that significantly reduced operating costs and energy use. One reviewer noted that it was not clear whether the industry would have done this work on its own without DOE support.

All of the reviewers noted great collaboration between ORNL and industry partners. One reviewer thought that university collaboration could have added greater value to the project. Another reviewer saw great collaboration with Emerson Climate Technology, but was unclear as to the roles of Copeland Scroll and the Unico System based on the presentation.

A few reviewers saw next steps as continued testing—possibly in more extreme conditions—to test the life and performance of the unit, flagging that the training of field personnel to service the unit might also be needed. Other reviewers felt that proposed future work was commercializing the technology. One reviewer noted that while there is no clear commitment from Emerson Climate Technology and other partners to commercialize the product, it was probable that Emerson would provide compressor solutions to U.S. OEMs who were interested in developing cold climate heat pumps.

Weighted Average: 3.79 # of Reviewers: 5
Relevance: 3.80[1] Approach: 3.70 Accomplishments: 3.90 Project Collaboration: 3.80 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project has successfully demonstrated the important relevance of BTO's objectives.
- Quite a large number of households use electric heating even in colder climates. The subject research will provide energy savings where it was not possible before.
- Significant-sized target market with good commercial opportunity.
- Outstanding (4) – This is a necessary project for BTO to invest in.
- This is an important market. Approximately 2.6M electric heated dwellings exist in cold regions. The project complements DOE's goals by 3,664,405 MMBtu in energy savings and 470,000 tons in reduced CO2 emissions.

B. Approach

This project was rated:

1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.80** for the degree to which the approach addresses the market barriers identified.

- PI has developed two configurations to demonstrate the high efficiency, cold climate heat pump system. One is to use two identical fixed-speed compressors and the other one is to use two vapor injection compressors.
- While there might have been other approaches, the demonstrated success of this approach speaks for itself.
- Almost exclusively targets technical achievements, with modest attention paid to first cost.
- Good (3) – Most of the critical barriers have been identified. There was not mention of barriers associated with refrigerant. Outstanding (4) – This project sharply focused on the cost barrier associated with the technology. This will be a tremendous barrier for market penetration.
- The major market barriers will be performance, operating cost, first cost and lifetime. Working with the manufacturer, the first three barriers have been addressed and the benefit of the technology assessed by consumers. The lifetime of the compressors and the system relies on the previous experience of the manufacturer.

C. Accomplishments/Progress/Impact

This project was rated:

1) **4.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.80** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- PI has successfully delivered and demonstrated the project goals which are >75% capacity at -13 F with COP>4.0 at 47 F. One prototype of using tandem vapor injection compressors has been tested in Alaska which the system is operated at -30F and achieved 75% capacity with a COP value of 1.8. There are a few data bars show that compressor running time fractions are low or high between -5 to 0 F and 25 to 30 F, respectively, compared to all temperature ranges.

- The team took on a challenge and met it successfully and the project is now completed. DOE's long term commitment and support of the project is very much appreciated as it is not clear whether the industry would have done this on its own without the DOE support.

- Regarding first cost, it says "ORNL prototypes are much less expensive (estimated cost: $4k for a 3-ton split CCHP). This certainly can't be the customer's cost, so I don't know what this $4k cost refers to. However, a cost-benefit analysis compared to traditional electric resistance auxiliary heat should be performed. A heat pump that meets all technical targets but which costs too much will make no contribution to the program's goals if it is never sold. Heat pump water heaters are a prime example of first cost sensitivity in the residential market.

- Outstanding(4) – Strong quantitative and qualitative data provided. The testing of the system in different environments has provided proof of concept. Outstanding(4) – There is strong evidence that the programs interim goals are likely. I think this technology can be marketed even with higher cost compressors.

- The project has clearly developed a cold climate heat pump that significantly reduces operating costs and energy use below 17F. The system also still has reasonable COPs at low temperatures (i.e., 3 at 17F and 2 at -13F). The system is projected to have a 30 to 50% cost increment. This increased cost should be easily realized by improved efficiency at the lower temperatures.

D. Project Integration and Collaborations

This project was rated:

1) **3.80** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.80** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- PI and Emerson Climate Technology have been working closely, but PI didn't address the collaboration with other two key partners Copeland Scroll and The Unico System during the review presentation.

- While I am not privy to the inner workings of the group (the in-kind contributions for reasons I do not understand are noted as confidential), the team seems to have the right components. Some university collaboration might have even been better.

- First-rate commercialization partners.

- Outstanding (4) – Presenter demonstrated good level of understanding. Outstanding (4) – Excellent collaboration proven by extension beyond CRADA

- From the presentation, it appears the PI works close with the manufacturer. The test unit almost looks like a final product.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- There is no clear commitment from Emerson Climate Technology and other two key partners to commercialize the product. Emerson Climate Technology will provide compressor solutions to US OEMs who are interested in developing CCHPs. The reviewer observes that Emerson Climate Technology is the best partner who is willing to work with national labs and the government agency such as DOE.

- The next step is commercialization. Although from here on the prospects are determined by the market, I hope that DOE remains tuned in to see this product make it to the market. I would also like to see some stickers on products such as this to identify government (DOE) Industry partnership.

- Project will probably extend beyond September 2017 if extreme cold conditions are desired for the Alaska tests.

- Production-ready seems like a logical step.

- I suggest future work would be to demonstrate life of the unit and if performance would degrade with time. Also, training may be needed by field personnel to service this unit, however I am not sure.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers
- PI has not only achieved the project goals of >75% capacity at -13 F with a COP >4.0 at 47 F, but also further developed it down to -30 F with achieving 75% capacity and a COP of 1.8.

- There is a market-ready product.

- Appears to be thorough lab and field tests.

- Excellent and tangible deliverables.

- The project's objective was to develop a economic cold climate heat pump. Even though the presentation did not include any economic calculations, they achieved their performance goals and I believe the system will be economic.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- This project of research areas and activities relevant to the program's objectives has received sufficient emphasis.

- Notwithstanding potential future refinements and improvements, the key objectives of the project have been achieved, demonstrated, and verified.

- Technical issues are certainly being emphasized, but I am unsure that the cost issues have received appropriate emphasis.

- The compressor could use some emphasis in the redesign of them or using different type of compressor.

- The team has documented performance. My only question is if additional training will be needed by field service personal to repair and service this unit.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- PI has successfully developed, delivered, and demonstrated the CCHP prototypes under the cold climate conditions and achieved the project objectives and goals.
- Energy saving with reasonable payback periods in market segment where it was not deemed feasible is an achievement and is recognized as such.
- Well-documented field results.
- These are necessary technologies that have been successful in meeting all milestones.
- The primary strength is the document performance of the device at the low temperatures and the energy savings. Also, having a cost increment of 30 to 50% is reasonable.

2) **Project Weaknesses**

- The testing cycle needs to be extended in order to obtain the system reliability under the extreme cold weather conditions. The new technology of single screw compressor which has many advantages such as the volume efficiency is about 92%, the higher efficiency at partial loading, the lowest noise and vibration, and oil-free lubrication over the scroll type should be considered. Also, the overall cost is projected 30% to 50% higher than the current technology and product in the market. It needs to be lowered down before customers can accept it.
- I do not see any weaknesses in this project. A more critical review requires one to study this (on and off?) 7-year project in some detail. Regarding the IP, a cynic might say that the partners' in-kind contribution is kept confidential because it is minimal compared to the DOE's / public's, but the partners' want the IP. Maybe the knowledge developed from projects paid (substantially) by the tax payers should be available to the public, so anyone including project partners can take advantage of it. For their contributions, the partners are the first in the know, and that might be a sufficient reward when the tax payers pay substantial part of the bill. Also, IP ownership might be impediment to market entry by the rest of the world.
- Dual compressors have been used for many years in high end residential units, so I am not exactly sure what was so unique about the design of that system. Vapor injection is a new technology, but it showed little advantage over the simpler fixed speed dual compressors.
- I would expect a larger hit on the COP when the two compressors are running because you have twice the work. This was not evident from plot during presentation.
- I see no weaknesses.

3) **Recommendations**

- This is a great project, and the reviewer thinks the DOE funding has been wisely spent on this project.
- I think DOE should be commended for supporting projects like this over the years, and hopefully its work will be widely recognized and acknowledged.
- A competitive first cost will be critical to the success of these systems. While that is the purview of the commercialization partner, it needs to be addressed throughout the project development.
- Maybe the compressor needs to be redesigned for this application instead of running tandem compressors. I am surprised this was not possible with two compressor companies collaborating.
- I have listed my recommendations in the section on future work.

Project # 32223: Modeling Tools for Flammability Ranking of Low-GWP Refrigerant Blends

Presenter: Gregory Linteris, National Institute of Standards and Technology
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project to BTO's goals. One reviewer felt that the project had good relevance, but highlighted that it was more about safety than reducing energy use. Another reviewer felt that the project would produce multiple benefits, however, including energy conservation. One reviewer questioned the project's relevance, expressing doubt about the project's added value given that NIST was already using well-proven, peer-reviewed flammability models in in its refrigerant screening process.

Reviewers also generally agreed that the project's approach was good, though with some reviewers expressing reservations. One reviewer noted that the project was planning to address most market barriers and that the technical approach was fine. Another reviewer even recommended sharing the approach model with other BTO project teams. One reviewer, however, was not clear on the value of evaluating the flammability of pure refrigerants compounds, questioning the scenarios in which non-premixed refrigerants would be used. Another reviewer thought that existing science was sufficient to determine the flammability of refrigerants, citing existing models for predicting and measuring flammability (e.g., ASTM E681-98) and recommending that the project's scope be carefully evaluated.

Regarding the project's progress and accomplishments, most reviewers agreed that—though early in the project cycle—the project team had accomplished many small tasks and had performed well. One reviewer felt that the project team had gained a good handle on the problems and was taking all the right steps to address them. Another said that progress was outstanding, and that strong evidence had been presented on the work performed to date. One reviewer flagged a few technical issues around which they wanted more information before evaluating the project's progress, while another felt that the scale of expenditures to date was incongruent with limited work reported and that it was surprising that NIST's extensive prior work on the subject was not presented as background.

Reviewers positively rated the project team's integration and collaborations, with reviewers expressing that the project team had identified key stakeholders and was working with the right people. One reviewer commented on the project's good collaborations, but was not sure what the actual contributions were of the different collaborators.

Looking forward, many reviewers felt that the project team's proposed future work was good, with one reviewer describing it as "on the mark." Another reviewer saw some room for improvement, encouraging the project team to seek out existing facilities with the tools and sensors needed to perform experimental work, rather than developing this infrastructure in house. One reviewer expressed disappointment that no technical material had been presented about proposed future work.

Weighted Average: 2.92 # of Reviewers: 5[1]
Relevance: 3.00[2] Approach: 2.80 Accomplishments: 3.00 Project Collaboration: 3.00 Future Work: 2.80

[1] One reviewer was not present during the Peer Review presentation.
[2] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The current HFCs used in the HVAC industry have high GWP and it will eventually be phased out from the well-developed and developing countries. As we know that low GWPs are flammable, so safety codes and standards are urgently needed.

- This project, if successful, has multiple benefits. Not only in the area of energy conservation (using more efficient refrigerants that can be used but are not due to flammability consideration) but also for developing charge/ flammability information for refrigerants that are environmentally friendly - even if not most energy efficient.

- In a recent publication from NIST (M. O. McLinden et al., Nature Communications, 2017) a comprehensive study is presented on finding alternative refrigerants. The study which involves high throughput screening of different refrigerant designs includes a model that very well predicts the flammability. A section of the paper abstract is copied below:
- "Here we show that only a few pure fluids possess the combination of chemical, environmental, thermodynamic, and safety properties necessary for a refrigerant and that these fluids are at least slightly flammable"
- In page 6, 2nd paragraph, the authors further explain "Most of the candidate fluids identified are flammable or mildly flammable. The refrigerant classification standards4,5 assign a fluid to one of four flammability groups based on their lower flammability limit, heat of combustion and burning velocity. Ranging from nonflammable to most flammable". Figures 3&4 compares different refrigerants based on their flammability.
- The model is based on the enthalpy of formation. In an earlier paper (Kazakov, A., McLinden, M. O. & Frenkel, Ind. Eng. Chem. Res., 2012), it is shown (Figure 6) that the model accurately predicts flammability. There are other tested models for predicting flammability. In fact, Kazakov and McLinden cite a review paper (Vidal, M.; Rogers, W.; Holste, J.; Mannan, M. A review of ..., Process Saf. Prog. 2004) on different ways of predicting flammability.
- If NIST is already using well-proven flammability models in their refrigerants screening process, what is being done under this project?

- Will likely become the standard by which flammability of new refrigerants will be characterized.

- Good(3) – The proposal is more safety than reducing energy usage per square foot.

B. Approach

This project was rated:
1) **2.80** for the degree to which it focuses on critical market barriers, and
2) **2.80** for the degree to which the approach addresses the market barriers identified.

- PI has proposed the detailed numerical simulations of burning velocity test methods which will be used to validate the models and understand the controlling parameters in the test methods. The droplet sizes will certainly affect the combustion flame shape, stability, and flame propagation. Currently, PI hasn't considered it in the numerical simulations.

- I really liked the approach this team took. They indicate they reviewed the literature, existing standards, and held a workshop. They also reached out to foreign organizations. This model has obvious merits and if I can make one single recommendation to BTO colleagues is to share this model with other teams.
- The technical approach is quite fine. The only comment is about "CFD tools might not be readily usable." Of course. CFD tools, and in fact all commercial computational tools are broad based core program which

need to be adapted to specific needs. That is the job of the analyst. Some useful CFD results were provided in the presentation; however, I cannot tell where the said bottle neck is.

- The existing science is sufficient to determine flammability of refrigerants.

- Still early in the project, so some stumbling blocks will no doubt arise which may result in a course correction.

- Good(3) – Most barriers are identified. Doesn't focus on premixed but that is ok.
- Good(3) – Addresses the combustion part of the market barriers.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- This is a new project funded in 2016. PI has accomplished many small tasks such as updated the NIST 1- and 2-carbon HFC combustion model, burning velocity measurements and simulations for R-32 and air mixtures, assessment of influence of flame curvature on the measurements, modifications to the NIST shock tube for kinetic studies.

- The team has taken all the right steps, gained a good handle on the problems and the solution approaches, and has taken the early steps in addressing these. It would have been helpful to include a summary of lesson learned (form the reviews and the workshop).
- A couple of issues I did not understand:
- Why the size of the assumed leak for computation is so large. Leaks are much smaller. What was the pressure and what was the flow rate into the confined space?
- In the measurement results (Page 10), what sort of sensors / techniques were used to measure concentration and were these refrigerant specific?

- Performers have spent $700k but did not report anything beyond a few graphs from the literature. Also, it is surprising that extensive prior work on this subject by NIST is not presented as prior background.

- Too early to tell, but so far, so good.

- Outstanding(4) – Strong quantitative evidence. Granted this is a new project. I like the charts and how you explained fundamentals.
- Outstanding(4) – Strong evidence presented.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- PI has identified nine key partners and he is working and communicating with those partners.

- This has been nicely done.
- I presume that the team has run into industry that has information developed over years regarding flammability and does not want to share it. If so, is there a work around for everyone's benefit? A national lab can play a useful role here.

- Project hasn't made any progress. So, it is not possible to answer this question.

- Knows and works with all the right people.

- Outstanding (4) – Presenter identified the key stakeholders and has narrowed down to low-GWP refrigerants.
- Good(3) – Good collaboration. Not sure what each of their contributions are. What is China and Japan doing?

E. Proposed Future Work

This project was rated **2.80** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- PI has provided four major tasks which will be conducted to develop the predictive tool for the burning velocity of refrigerants and codes and standards for low GWP refrigerant blends.

- I think what they have planned is on the mark.
- It would be great to seek out existing facilities with the tools and sensors needed to do the desired experimental work (instead of creating an infrastructure in house).

- No technical material was presented about the future work.

- Did not hear the presentation, so can't comment.

- Good (3) – Future works seems fine. This is a new project. It might be worth mentioning that the turbulent case may be investigated if the laminar assumption is not appropriate.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- The vapor compression technology is still widely used in the HVAC industry. Therefore, there is an urgent need for the faster and safer codes and standards for the low GWP refrigerant blends. The successful deliverables from this project can certainly help to achieve the BTO's goals.

- The PI / the team have taken the essential steps and have delivered what is expected at this stage of development. Well done.

- Good fundamental study that others in the community will be able to use.

***Average*: 1** reviewer
- Did not hear the presentation, so can't comment.

***Low*: 1** reviewer
- There are existing models for predicting flammability and standards (e.g. ASTM E681-98) for measuring it.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- The project of research areas and activities relevant to the program's objectives has received sufficient emphasis.

- Yes, as stated before, the PI / team have correctly identified the problem, main issues, key steps to be taken, and have moved in that direction.

- Did not hear the presentation, so can't comment.

- They are relevant.

***No*: 1** reviewer
- It is not clear what additional research is done under this project.

H. Additional Comments and Recommendations

1) **Project Strengths**

- PI has great knowledge of how to conduct the study with the detailed approaches.

- The project tackles a real and important topic which the industry on its own won't unless regulations require it.
- BTO should be commended for supporting this effort and the path the team has taken is most appropriate.

- It is not clear what is being done beyond the existing knowledge on this subject.

- Did not hear the presentation, so can't comment.

- This is good fundamental study that should integrate well with other (CFD) studies being studied in BTO.

2) **Project Weaknesses**

- PI didn't consider the droplet size effect in the combustion model which could possibly deviate away from the real physics.

- I see no weaknesses. I think the team could benefit by collaborating with an experience CFD analyst if they do not have done already.
- Also, there might be stand-alone CFD program - non-commercial - developed at universities that is more suitable for this need. There is a wealth of information on CFD program to simulate accidental atmospheric discharge and transport of contaminants / pollutants, etc. The team may like to look into that literature as well.

- This has been answered before.

- Did not hear the presentation, so can't comment.

- Not sure how realistic a non premixed combustion would be. I would like to see some more justification for this scenario. The concentration also have to be pretty high, I have a feeling. At lower concentration the refrigerant will probably diffuse out.

3) **Recommendations**

- PI has clearly demonstrated his knowledge of what kind of approaches and methods need to be carried out in the study.

- Well done.

- The scope of this project needs to be carefully evaluated.

- Did not hear the presentation, so can't comment.
- Might be useful to highly the scenarios where this non-premixed cases would exist. Will air and refrigerant phase separate like you are proposing?

Project # 32225: Flammability Risk Assessment of Alternative Flammable Refrigerants

Presenter: Omar Abdelaziz, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Many reviewers felt that the objectives and approach of this project were not well-defined, were focused more on safety than energy, and were therefore not extremely relevant to BTO's goals. One reviewer, however, thought that the project had multiple benefits in terms of energy conservation and for developing flammability information for refrigerants that were environmentally friendly.

One reviewer noted that, as this project was relatively new, it had identified most market barriers and most barriers related to the flammability of new refrigerants. Another reviewer agreed that the approach of this project was great, especially the review of literature and existing standards and its organization of workshops and outreach to foreign organizations. Other reviewers were not as confident about the project's approach. One reviewer was concerned that manufacturers would have more concerns about flammable refrigerants than just that refrigerant concentration approaching flammability limits within an occupied space. Another reviewer pointed out that computational fluid dynamics (CFD) provides deterministic solutions while probabilistic risk assessment (PRA) provides stochastic solutions; this reviewer questioned how the project team was going to link or relate its CFD results to PRA? Additionally, this reviewer pointed out that in the review process, the project team did not address numerous factors, including operating conditions, temperature, pressure, species transport, chemical reactions, etc.

One reviewer noted that the project—so far—had been mainly focused on reviewing journals and reports, and that since the CFD modeling was not well presented, there was not much useful information to contribute to the industry. Another reviewer felt that there was no evidence of progress to analyze the problem. One reviewer was not convinced that scenarios used in the research were all-inclusive enough to convince standards developing organizations or manufacturers. Some reviewers were more positive, with one stating that CFD was a good approach and that the market goal was substantiated. Another reviewer felt that the team had taken all of the right steps, but also that they had questions about why the size of the assumed leak for computation was so large and what sorts of sensors/techniques were used to measure concentrations.

Reviewers thought that the project's collaboration was fine, as the team consulted foreign country resources. However, collaboration with regulatory institutions and more laboratory integration were suggested. One reviewer felt that there was no outside collaboration.

Most reviewers agreed that there was a plan in place to continue CFD simulations, though two reviewers recommended finding someone with experience in CDF simulation or seeking out an already-existing facility with the necessary tools and sensors (rather than creating the infrastructure in-house). Two reviewers felt that the parameters and leak scenarios of the experiment needed to be readdressed, while another thought the project lacked a clear research plan.

Weighted Average: 2.40 # of Reviewers: 5[1]
Relevance: 2.60[2] Approach: 2.40 Accomplishments: 2.30 Project Collaboration: 2.70 Future Work: 2.20

[1] One reviewer was not present during the Peer Review presentation.
[2] Score not included in weighted average.

A. Relevance

This project was rated **2.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The PI needs to know the definition of "probability risk assessment (PRA)" and the R&D methodology and approach doesn't meet the BTO's goals very well.

- This project, if successful, has multiple benefits. Not only in the area of energy conservation (using more efficient refrigerants that can be used but are not due to flammability consideration) but also for developing charge/ flammability information for refrigerants that are environmentally friendly - even if not most energy efficient.

- The objective and approach are not clearly defined.

- Unsure how this work will be able to alleviate the legal concerns that manufacturers may have. Also, my impression is that the greater concern may be the risk of an explosive incident during maintenance servicing, not that the refrigerant would reach a lower flammability limit within the building space as a result of a leak.

- Good(3) – This project is more concerned with safety rather than energy improvement.

B. Approach

This project was rated:
1) **2.60** for the degree to which it focuses on critical market barriers, and
2) **2.20** for the degree to which the approach addresses the market barriers identified.

- PI has tried to use CFD techniques to study the alternative flammable refrigerants. But the major question is that CFD provides the deterministic solutions and PRA provides the stochastic solutions. How would PI link or relate CFD results to PRA? PI doesn't provide any information on it. In the review process, PI didn't address the numerical modeling, boundary conditions, operating conditions, mesh independent study, temperature, pressure, velocity, RH, single-phase or two-phase modeling, laminar or turbulent modeling, species transport, chemical reactions, etc. The numerical results shown in the presentation are not fully trusted.

- I really liked the approach this team took. They indicate they reviewed the literature, existing standards, and held a workshop. They also reached out to foreign organizations. This model has obvious merits and if I can make one single recommendation to BTO colleagues is to share this model with other teams.
- The technical approach is quite fine. The only comment is about "CFD tools might not be readily usable." Of course. CFD tools, and in fact all commercial computational tools are broad based core program which need to be adapted to specific needs. That is the job of the analyst. Some useful CFD results were provided in the presentation; however, I cannot tell where the said bottle neck is.

- The project is poorly defined and executed. Once the leakage scenarios are clearly defined, proper numerical and analytical tools can be implemented to analyze the problem.

- I am not sure that refrigerant concentration approaching flammability limits within the occupied space would be the only concern that manufacturers would have about use of flammable refrigerants.

- Good(3) – Identifies most barriers related to flammability of new refrigerants. CFD is a good approach for determining the concentration.
- Good(3) – Identifies most market barriers. This is a new project so not all the market barriers have been addressed.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- PI has conducted preliminary literature review, IEC60335-40 and WG9 proposals review, workshop at ASHRAE headquarter, and initiated the CFD simulations. PI mainly focused on reviewing journals and reports. Since the CFD modeling are not well presented, the reviewer doesn't think the funded project can contribute many useful information to the industry.

- The team has taken all the right steps, gained a good handle on the problems and the solution approaches, and has taken the early steps in addressing these. It would have been helpful to include a summary of lesson learned (form the reviews and the workshop).
- A couple of issues I did not understand:
- Why the size of the assumed leak for computation is so large. Leaks are much smaller. What was the pressure and what was the flow rate into the confined space?
- In the measurement results (Page 10), what sort of sensors / techniques were used to measure concentration and were these refrigerant specific?

- Currently, there is no evidence of progress and expertise to analyze the problem.

- I'm not sure the scenarios that were used in the research would be all-inclusive enough to convince standards writing organizations or manufacturers.

- Good(3) – The approach seems ok. I am not sure why the budget is being spend to do a literature search. This should have been done in the proposal. The CFD approach seems like a good approach, however, details about the turbulence model was missing from the presentations. The presenter did mention some difficulties with the CFD software. This should be a pretty straight forward VOF CFD simulation.
- Good(3) – I think the market goal was substantiated. It is early in the project so I think this will development more as the project progresses.

D. Project Integration and Collaborations

This project was rated:

1) **2.80** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- PI provided the literature review summary which shows some additional resources from different countries such as Japan, Australia, UK, and Germany. But PI didn't address the actual collaboration among those institutes.

- This has been nicely done.
- I presume that the team has run into industry that has information developed over years regarding flammability and does not want to share it. If so, is there a work around for everyone's benefit? A national lab can play a useful role here.

- There is no outside collaboration in this project.

- Cannot comment on this since I did not hear the presentation.

- Good(3) – Understanding of the key stakeholders was presented.

- Good(3) – There could have been integration of regulation institutions.

E. Proposed Future Work

This project was rated **2.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- PI has addressed the future plan on CFD simulations and experimental validation. But PI didn't address of why charge of 14.4 kg, simulation time of 42 seconds, and Cd of 0.8 are selected. There are many unclear parameter selections and those were not addressed in the review meeting.

- I think what they have planned is on the mark.
- It would be great to seek out existing facilities with the tools and sensors needed to do the desired experimental work (instead of creating an infrastructure in house).

- The project lacks a clear research plan.

- Very limited number of leak scenarios.

- Fair(2) – It seems like the project need to work with someone that has experience in CFD simulations.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer
- The PI / the team have taken the essential steps and have delivered what is expected at this stage of development. Well done.

***Average*: 3** reviewers
- The results might be useful to the community.

- Cannot comment on this since I did not hear the presentation.

- Deliverables would be average. I feel like the study is heavily geometry and flow dependent. If you can come up with a way to non-dimensionalize the system that would make the deliverables more impactful.

***Low*: 1** reviewer
- Based on the current information and results obtained by PI it is not very useful to the HVAC industry.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- Yes, as stated before, the PI / team have correctly identified the problem, main issues, key steps to be taken, and have moved in that direction.

- Cannot comment on this since I did not hear the presentation.

- Key areas seem relevant to the project goals.

***No*: 2** reviewers
- The program's objectives didn't receive sufficient emphasis because PI didn't provide the useful information of probability of risk assessment of alternative flammable refrigerants.

- Overall, the research is poorly defined and executed.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The strength of project is that the study of the probability of risk assessment of alternate flammable refrigerants is extremely important and an urgent need for the HVAC industry.

- The project tackles a real and important topic which the industry on its own won't unless regulations require it.
- BTO should be commended for supporting this effort and the path the team has taken is most appropriate.

- The project lacks a clear direction and expertise.

- It does address a major area of concern to equipment manufacturers.

- This is an important issue related to safety. CFD simulations are the appropriate method to simulate.

2) **Project Weaknesses**

- The weakness of this project is that PI didn't clearly provide the useful information from CFD simulation results to the probability of risk assessment. Also, all CFD modeling, numerical algorithms, boundary conditions, initial conditions, mesh generation, temperature, pressure, velocity, relative humidity, species transport, chemical reactions, etc. were not clearly presented. Those CFD results may not be trusted.

- I see no weaknesses. I think the team could benefit by collaborating with an experience CFD analyst if they do not have done already.
- Also, there might be stand-alone CFD program - non-commercial - developed at universities that is more suitable for this need. There is a wealth of information on CFD program to simulate accidental atmospheric discharge and transport of contaminants / pollutants, etc. The team may like to look into that literature as well.

- This was answered previously.

- I would be surprised if the limited number of leak scenarios will be extensive enough to change any standard document or manufacturers' legal risk perspectives.

- Literature search is a waste of project budget, this should have been done prior. The PI should discuss issues with CFD expert. There is also concern with how the domain is being monitored.

3) **Recommendations**

- The reviewer would like to suggest PI to look into the journal publications of textbooks of PRA in the nuclear engineering to learn on how to do the PRA study.

- Well done.

- 1- Work with manufacturers to define different leakage scenarios in the existing systems.
- 2- Define what you are looking for. For example, are you trying to look into a scenario in which fan is off, there is leakage in the evaporator coil and refrigerant is slowly diffusing around or fan is on and refrigerant is rapidly mixed everywhere. Define risks at each situation. Which one is more critical? It seems like at a low leakage level, when air is mixed around and better there is some fresh air, we may never reach to the flammability limit. What would be the most critical situation when there is a significant leakage? The flammability limit is reached somewhere away from the leakage site where concentration is within the upper and lower flammability limits. Doesn't this necessitate solving the flow domain around the leakage

site instead of the entire room? Also, what is the probability of having a flame around that region? These and many other similar questions, should be visited to clearly define the necessary simulations.

- 3- Define the solution domain. Researchers often times make a mistake of trying to simulate the entire domain in the most complicated format. Experience in the field helps to avoid this mistake
- 4- Once the problem is defined and simple analytical tools and numerical simulations are implemented, if necessary, get help with numerical simulations.

- Get more information from manufacturers about what types of leak scenarios they need to see.

- I would suggest talking to someone that is a CFD expert related to combustion. You should be using the Oak Ridge supercomputer. You should also consider coming up with a method for quantifying high concentration regions outside of the 9 monitoring points.

Project # 32226a: Magnetocaloric Refrigerator

Presenter: Ayyoub Momen, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project fully supported BTO's goals. As the refrigeration market is large, this project's manufacturing process—magnetocaloric microchannels—can be an enabling technology with potential to enhance refrigeration efficiency.

While considering the project approach, one reviewer's main concern was cost and reliability, but they also noted that cooling rate was a very critical factor for refrigerator/freezers that needed to be addressed, and raised some questions about pressure drop, parasitic power, and system COP. Another reviewer felt that the microchannel approach was a good technique to address the key issue of heat transfer from the magnetic structure, but mentioned that prospects for mass production should be kept in mind. A third reviewer similarly noted that this technology might be difficult to scale, recommending that smaller residential units could be a possible target market. One reviewer noted that there were not any results for the goal of increasing efficiency by 25%, while another reviewer felt that the goal of 25% could be a barrier and recommended targeting a market based on current data instead of that goal.

Two reviewers noted that this project's next steps pointed in the right direction, while another noted that some key fabrication aspects might still need to be addressed. Another reviewer noted there was little quantitative data, so their recommendation was to work on understanding some of the fundamental issues and demonstrate quantitative achievements relative to fundamental quantities. A different reviewer noted that the project had already ended and that the Gantt chart showed the project meeting all of its milestones; however, one of the objectives was production of a full scale refrigerator-freezer, and this reviewer did not see that outcome.

Reviewers praised the collaboration between ORNL and General Electric Appliances, but encouraged the project team to use expertise beyond those two organizations, if appropriate.

One reviewer felt that greater understanding of materials science would be needed before the technology could achieve the desired goals. Another reviewer thought that 1,000 cycles for testing was not nearly enough, suggesting that the project needed over 100,000 cycles to obtain better reliability data. Additionally, there were discrepancies in reviewers' understanding of the project end date: reviewers alternatively thought that the project ended in December 2016, January 2017, and June 2017.

Weighted Average: 3.02 # of Reviewers: 5[1]
Relevance: 3.40[2] Approach: 3.20 Accomplishments: 2.90 Project Collaboration: 3.20 Future Work: 2.60

[1] One reviewer was not present during the Peer Review presentation.
[2] Score not included in weighted average.

A. Relevance

This project was rated **3.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project of magnetocaloric refrigerator freezer fully supports the BTO's goal in the HVAC applications and commercialization.
- Because of the potential enhanced refrigeration efficiency and the wide-spread need for refrigeration, the manufacturing process (magnetocaloric microchannels) pursued in this project can be an enabling technology.
- Development of an alternative, and more efficient, refrigeration system to the existing vapor compression cycle is in line with DOE goals.
- Residential refrigeration market is large.
- I think this fully supports the mission of BTO. I think this is a great project that is on the cusp of fundamental research and commercial engineering.

B. Approach

This project was rated:

1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- The cooling rate is a very critical factor for the refrigerator freezer development. How fast of magnetocaloric refrigerator can cool off from 100 F to 0 F? It needs to be addressed. The pressure drop could be significant if the heat transfer fluid is used in microchannels instead of solid state material. What is the parasitic power for the pump? And what is the system COP for the magnetocaloric refrigerator? Also, the main concern is still the cost and the product reliability for this kind of product.
- Clearly transfer of heat from the magnetic structure is a key issue, and to the extent that this transfer can be enhanced, the overall feasibility of the subject refrigeration technique is enhanced. Microchannel cooling is one such technique, but it comes with its own challenges.
- The microchannel approach that has been described (and its three patents) seems to be a good approach as long as the prospect for mass production is kept in mind.
- The performers do not provide any results on their goal of increasing the efficiency by 25%.
- I did not hear the presentation. The title slide said that the objectives included 100W of cooling and fabrication of an actual refrigerator unit. I saw nothing about either of these parts of the project.
- I wasn't fully certain which market this technology was trying to target. I would assume this is targeting consumer market. I am not convinced that this needs to be identified at this stages of development. Considering this is a more of a basic science investigation of the concept.
- Again, I am not sure the market barriers have been identifies. However, the PI does state a 25% lower energy consumption, which I think might be a barrier. I recommend the PI to try and target a market based on their current data. It seems like this might be difficult to scale from a physics point of view (magnetic susceptibility of non-organic particles), therefore the cross-section needs to be small. The target market seems like smaller residential units. This will help to identify this for marketing purposes.

C. Accomplishments/Progress/Ipmpact

This project was rated:

1) **3.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- PI has demonstrated in applying the 3-D printed technology in preparing the microchannels in magnetocaloric materials (MCMs). The technology of MCM microchannel has been patented and fully solid-state magnetocaloric machine also has been patented. The patent of technology of process of 3-D printing of MCM microchannels has been filed. A few publications and presentations are accomplished. General Electric Appliances has developed a few configurations of the prototype machines.

- The steps outlined in the presentation are in the right direction. Some fabrication obstacles have been overcome (e.g., sintering condition), and others remain. Again, I could not comment on some key fabrication aspects that have not been disclosed but it seems that the project is moving in the right direction addressing challenges one by one.

- Without the efficiency values it is hard to evaluate the success of this program.

- Objectives slide says that the final product will be a full scale refrigerator-freezer. The project summary slide said it had a Jan 31 2017 end date. Gantt chart shows all milestones have been met on time (project has been completed already). So where is the full scale refrigerator-freezer with the MCM? I saw nothing about that at all.

- There is strong qualitative that they could achieve the programs objective but very little quantitative data. I suggest the PI work on understanding some of the fundamental issue and demonstrate quantitative achievement relative to these fundamental quantities. For example, if you are interested in Curie temp how does the Curie temp change for a given microstructure. Same thing with magnetic susceptibility, how does this change and how is it influenced. These should be quantitative values you can measure experimentally. In the absence of this it just a guess and check approach.
- I don't think the market goal is quite relevant yet. There is more fundamental analysis to be completed before this technology can be marketed.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- PI has successfully demonstrated the close collaboration with General Electric Appliances and developed the prototypes.

- Apparently the project is a collaboration of ORNL and GE, which significant cost sharing from GE. That is often a good approach. I would encourage the team to keep an eye on the large outside world and use expertise beyond these two organizations if appropriate.

- Stability of the material, reliability issues, efficiency and cost are the key information for evaluating the technology market potential.

- Having GE appliances involved should keep the commercial objectives very clear.

- I think the PI understand the key stakeholders. However, the technology is not there yet.

- It is good that they are collaborating with GE. However, if I look at the YouTube video that you include in the presentation it looks like GE has a working prototype but it wasn't obvious this was the fact based on your presentation.

E. Proposed Future Work

This project was rated **2.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The current report of 1,000 cycles testing is not enough. PI needs to consider to conduct more than 100,000 cycles in the test in the future in order to obtain the better data of reliability.
- The outline of the future work (the project completes in June 2017) seems reasonable.
- Project has ended.
- Project is concluded since the final report was being drafted as of 12/30/2016.
- I feel like there is a lot of materials science that needs to be understood before this technology can achieve the desired goals.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The deliverables from this project have provided the important information of design and 3-D additive printing technology of MCM microchannels.
- I liked what was presented. Many steps have been taken to overcome a series of obstacles. I would need more information and more details on the fabrication techniques to describe this work anything but outstanding.

***Average*: 3** reviewers

- Some progress has been made but these systems still a long way from the market.
- I did not hear the presentation, so I cannot make further comments.
- The value is high but the technology is not there. More fundamental research is required.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- The project research areas and deployment activities relevant to the program's objectives have received sufficient emphasis.
- The key issues have been identified and addressed. This has been a three year effort and could have taken many paths and differing potential outcomes. However, the challenges that were identified in the path selected have been given proper and careful attention.
- As mentioned before, there are questions that have not been addressed.

- I did not hear the presentation, so I cannot make further comments.

***No*: 1** reviewer

- There needs to be more emphasis on materials science. The basic concept works but the materials are the weakest link.

H. Additional Comments and Recommendations

1) **Project Strengths**

- PI has successfully developed and delivered unique additive manufacturing followed by a sintering process to fabricate MCM microchannels and tested a few prototypes. PI has the strong collaboration with General Electric Appliances and obtains the full support from them.

- The project's strength lies in its identification of the transfer of heat as a technical barrier and attempting via microchannel implementation to develop a path forward.

- The project is focused on one of the main challenges of this technology.

- It would seem that the potential is very favorable in terms of system efficiency.

- I think this technology has tremendous potential. I think projects like this are where BTO should be investing money.

2) **Project Weaknesses**

- The testing cycle of 1000 is too short which cannot really provide the actual information of reliability. Also, the information of cooling rate from 100 F to 0 F is not provided.

- One would need to know a bit more about the fabrication approach used to think it through and through its ultimate viability, manufacturability, and alternative techniques. However, what the team is doing is clearly taking steps in the right direction.

- A better theoretical and optimization study on heat transfer and pressure drop characteristics of different geometries would have helped this project.

- I could not tell how manufacturing costs would impact market reception, nor how the system actually works.

- This technology needs more fundamental materials science research. There was also some lack of quantitative improvement. The PI states 10% improvement but I wasn't sure what this improvement was. I was a little disappointed in the presentation. It was difficult to understand the operational principle and the clear technical challenges.

3) **Recommendations**

- This project has been successfully performed and delivered.

- Just to be on the safe side, I would continue to look out for expertise, techniques, approaches, methodologies, and characterization techniques from outside the groups to supplement existing expertise and infrastructure. Also microchannel cooling has its own issues (e.g., fouling) and I would like to keep an eye on other approaches at the same time (as a plan B).

- The project has ended. So, things cannot be changed at this point. But, collaboration with an expert with significant knowledge of fluid and thermal transport in porous structures would have greatly enhanced the project and saved time and money.

- I did not hear the presentation, so I cannot make further comments.

- I think the PI should look at the material science aspect of the project. There need to be more understanding how the microstructure and composition influence the performance of the device. The additive manufacturing was a nice trial but I am glad the PI moved away for the time being. I recommend the PI to look and see what has been on the catalyst side for micro-channels.

Project # 32226b: Heat Pump Dryer

Presenter: Kyle Gluesenkamp, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's goals, as reducing energy use for residential clothes dryers could produce immense energy savings. Many reviewers felt that the project's approach addressed critical barriers, including first cost and fast drying time, though some reviewers were less certain about this. One reviewer noted that improvements in dryer performance would not fundamentally address market barriers. Another reviewer was confused about what the U.S. market demanded that the European market did not, given that heat pump clothes dryers already existed in Europe.

Many reviewers noted the project's strong progress, highlighting that the team had developed multiple prototypes and predictive models. However, some questions persisted about data, in terms of thermodynamic cycles, explanation of how the models used existing systems, and how some of the predicted vs analytical values were possible.

Many reviewers positively noted the collaboration between ORNL and GE Appliances. However, some reviewers were uncertain about the extent of that collaboration—with one pointing out it would be good to have GE actively fabricating the prototype units—while also scrutinizing cost issues. One reviewer liked the project's university relationship, though another questioned the extent of university collaboration. One reviewer pointed out that it would have been beneficial to have technical collaboration, or at least a liaison established, with European researchers and companies.

Two reviewers noted that the project was almost complete, with several describing the next step as commercialization, though one reviewer thought that it was hard to determine future work due to confidentiality. One reviewer said that the project team needed to work closely with GE Appliances, especially since there was no evidence of how GE Appliances would participate in the commercialization plan. Another felt that at this point in the project cycle there should be a more defined plan and greater interest from potential commercialization partners. In the absence of these things, this reviewer felt that a serious assessment was necessary to determine the project's path forward. One reviewer called out a need to focus on how to handle moisture and potential lint clogging issues in the future, with another reviewer suggested venting to the outside of the house, as most houses currently have vents for clothes dryers.

Weighted Average: 2.98 # of Reviewers: 5[1]
Relevance: 3.80[2] Approach: 3.20 Accomplishments: 2.90 Project Collaboration: 2.80 Future Work: 3.00

[1] One reviewer was not present during the Peer Review presentation.
[2] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Residential clothes dryers use immense energy. The developed residential heat pump clothes dryer has met the BTO's objectives.
- The energy saving potential finely fits BTO's goals and its attempt to reach all potential saving targets.
- Development of more efficient dryers is in line with the DOE goal of reducing energy consumption in buildings.
- Major energy user that may be a bit less sensitive to first cost if it provides premium performance.
- Outstanding (4) – This is an interesting concept and is a perfect project for BTO.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **2.80** for the degree to which the approach addresses the market barriers identified.

- PI didn't address the detailed approaches. The most of lists in approach is like goal such as fast dry time and premium price of developed heat pump dryer.
- Unless I am mistaken, the presentation made it clear that this is a solved problem in Europe ("dozens of models are available in Europe but very few in the US." If true, then the issue is one of market penetration and not technical obstacles to overcome. It is not clear what specifically the US consumer demands that Europeans do not.
- The project key milestone is "experimental validation of a model". This milestone has been achieved after 5 years under substantial amount of funding ($3.8M). The subject of modeling is operating conditions of a heat pump under different input air conditions. It is not at all clear what the model is and why it has taken so much time and funds to develop it. Little improvement achieved in performance does not fundamentally address the market barriers.
- Appears to address performance as well as first cost.
- Outstanding (4) – All critical barriers identified. I agree the drying is a large power consumer in the house hold and improve could be made.
- Outstanding (4) – Design addresses the barriers.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- PI has delivered the Gen a prototype of heat pump clothes dryer and the Gen 2b is currently under the finalized design. In the review presentation, there are a few data points calculated by the predicted or analytical way which are lower than the measured data. How could it be possible for the measured data higher than the predicted values? Also, there are no error bars associated with measured data.

- The team has developed models and compared results with measurements.

- The performers did not explain the models used to design the existing systems, their deficiencies and how the developed model is different.

- Good progress (as far as can be revealed). Impact may be less than home heating or cooling, but still a very significant energy user.

- Good (3) – No quantitative data was provided about the thermodynamic cycle.
- Outstanding (4) – There was strong evidence to achieve the market goal.

D. Project Integration and Collaborations

This project was rated:

1) **2.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- PI has identified GE Appliances as a key partner in the project. But in the review presentation, there is no any further report on how PI has been collaborating with GE Appliances. PI did offer two undergraduate interns to University of Louisville and University of Florida.

- Unless I am mistaken, GE is the key partner and is paid by the PI to do certain things. It is not clear what this partner does, how it is the most suitable partner, and what unique capabilities it has, etc. I am not also clear about the extent of the university collaborations. I would have thought that some technical collaboration or at least liaison would be established with the European researchers and companies to the benefit of the project.

- The project is a CRADA and involves GE.

- Very good to have GE actively in the mix and fabricating the prototype units, while also scrutinizing cost issues.

- Outstanding (4) – Presenter understood the stakeholders.
- Outstanding (4) – Good collaboration with GE. This has a potential to be marketed.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- PI has addressed that the commercialization will be the next step. There is no evidence of how GE Appliances will participate in this commercialization plan. PI needs to closely work with GE Appliances to find out what their plan is in the next 3 or 5 years.

- I ranked this 'good' while remaining skeptical about the lack of solid outcome and finishing plans. To be fair, one has to review the project's 7 year history and progress. I wonder if "commercialization determination" is a reasonable future plan for the project after 7 years of work. It would be great to have by now some very solid plans, solid solutions, and interested partners. In the absence of these, a serious assessment is necessary: either a clear technical path forward towards a successful conclusion or a solid argument against further work (for example, due to cost, user acceptability, technical difficulty, etc.)

- The project ends in 1-2 months.

- Nearly finished, but hard to evaluate due to confidentiality.
- Seems fine. There should be a focus on how to handle moisture and potential lint clogging issues.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- If the developed heat pump dryer has better efficiency with the competitive price of traditional gas dryer then it will be accepted by customers in the market.
- Technical progress is on target with good working prototypes.
- Good deliverable value.

***Average*: 1** reviewer
- As noted, I am not familiar with the project's past evolution but the presentation I read does not seem to identify prospects for any significant technical, intellectual, or commercial deliverables.

***Low*: 1** reviewer
- Some improvements in performance seem to have been achieved. But, it is hard to evaluate how much. To do this correctly, the changes have to be described and performance before and after changes should be compared. It is suggested that cost has been reduced without a single sentence explaining how. In the absence of such information, it is not possible to determine if this project has been successful as the performers suggest.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- I wish to answer "maybe", instead of yes here.
- Identifies a major energy user with a high priority on producing an energy efficient commercial product.
- Moisture concerns could be increased.

***No*: 2** reviewers
- This project of research areas and activities relevant to the program's objectives has received sufficient emphasis.
- The modeling and experimental studies/strategies were not explained.

H. Additional Comments and Recommendations

1) **Project Strengths**

- PI has successfully developed and demonstrated the heat pump clothes dryer technology. Also, the project goal is achieved to dry 8.45 lbs wet clothes within an hour.
- The idea behind the project - one that can result in energy saving - is the main strength of this project.
- No details about the model and its comparison with the model GE has used to design its dryer was presented. Without a clear presentation of different aspects of the model and explanation of where the improvements are made it is hard to judge the project strength.
- Appears to be on target technically and highly focused on cost containment.

- This is a good technology to improve to improve the efficiency of the household.

2) **Project Weaknesses**

- The system efficiency is not fully addressed. Also, the cost of this kind of heat pump dryer compared to the conventional gas dryer is not provided. If a family with three kids then this family may have to dry 1 to 3 loads per day. How well the compressor will be performed under this continuous and heavy loads? How this overheat problem will be solved? Adding another heat exchanger to cool off compressor will increase the total weight and cost of heat pump dryer. Does PI have any good idea to overcome this heavy loads per day? Also, user has to remember to remove condensate from the heat pump dryer. Otherwise, those condensate could wet the floor and lead molds to grow. The bottom line of concern is the price of this kind of heat pump dryer.

- I find some aspects of this project difficult to comprehend and I attribute this to my own ignorance. I would like to know more about the European products, what they cost, have they penetrated the market, what technical / marketing difficulties had they overcome and how, etc. I would like to know how many units are sold there, what are the incentives for buyers (tax breaks?). I wonder if it makes sense for residential use, would it not make even more sense for commercial usage (economy of scale).

- The performance period and funding level for this project seem to be very high.

- Weaknesses are hard to determine because of confidentiality issues.

- What happens to moisture that is collected? What about lint that might collect on heat exchangers?

3) **Recommendations**

- The dry time is critical to be synchronized with washer because customers usually take out the wet clothes from washer to dryer and make another load to washer sequentially.

- None.

- Considering that the approach is not discussed in this presentation, it is not possible to provide any constructive recommendation.

- I did not see the presentation, so I cannot make further comments.

- It might make more sense to vent the exhaust to the outside. Most houses will have a vent that can be used.

Project # 32226d: Air-Source Integrated Heat Pump System Development

Presenter: Van Baxter, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project had great energy savings potential, and was thus relevant to BTO's goals. One reviewer noted specifically that the project addressed all three main residential energy users (heating, cooling and water heating) in addition to humidity control, which is becoming a bigger issue with mandatory code ventilation requirements.

Reviewers also agreed that the technical approach for this project was reasonable. ORNL and Lennox successfully developed and demonstrated an air-source integrated heat pump (AS-IHP) for space conditioning, water heating, dehumidifying prototypes, with field tests conducted and data collected and analyzed. One reviewer commented that each of the project's three prototypes built upon the previous model's technology innovations. Another reviewer noted that, because an off the shelf dehumidifier system was used, there was room for additional innovation. One reviewer commented that control was a main issue to prioritize in future work, while another expressed that (1) the damper could be quickly redesigned; (2) a computational fluid dynamics specialist should be pulled onto the project; and (3) the water heating component should possibly be eliminated to simplify the system, decrease cost, and allow the entire hot-side of the system to just heat air.

Multiple reviewers commented that it was concerning that this technology was such a low priority for Lennox, the commercial partner, because this made it unlikely that the technology would be commercially produced within the next few years. Multiple reviewers felt that the project's future plans—especially for commercialization—were not clear, and that the delay due to Lennox should push the project lead to cuts ties with the manufacturer and seek out other industry partners.

Weighted Average: 3.09 # of Reviewers: 5
Relevance: 4.00[1] Approach: 3.50 Accomplishments: 2.90 Project Collaboration: 3.00 Future Work: 2.80

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project of AS-IHP system development certainly meets the BTO's objectives.
- The project has been in the work for about 10 years on and off with some track record. It is fair to say that if adapted, it can have measurable energy saving impact.
- Addresses all three main residential energy users in addition to humidity control which is becoming a bigger issue with mandatory code ventilation requirements.
- This project is relevant to BTO and is necessary as houses are built tighter.
- The goal is to develop and test an Air-Source Integrated Heat Pump. This device which combines both heating, cooling and water heating functions, would reduce energy use.

B. Approach

This project was rated:

1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.60** for the degree to which the approach addresses the market barriers identified.

- PI and the key partner Lennox has developed and demonstrated ASHP for space conditioning and WH/DH prototypes. The field test has been conducted and data has been collected and analyzed.
- The technical approach is reasonable. There is more than one approach but the team has selected to augment an existing ASHP system to develop a multi-function system with WH and DH functions. That seems fine.
- Addresses all the major barriers to acceptance. It is unfortunate that it has such a low priority with the commercial partner at the present time.
- Market barriers have been identified
- The approach is design, build and test an AS-IHP. The results of these tests will indicate any problems with the new device. The information will enable the improved design and control of the new device.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.80** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Three prototypes of WH/DH have been modified and developed and tested. The blazed plate WH condenser has been used to replace coaxial type heat exchanger. Also, the better insulation for WH condenser has been applied and the solid state controller has been added. There is a large amount of heat losses during WH operation. An average of 33% saving has been estimated for the field test site.
- Progress has been slow. The project itself does not seem to require or involve any breakthroughs. As I understand it, it is an engineering implementation of an integrated thermal system. The impact can be significant but information provided does not show any interest on the part of the existing partner or on the part of other potential partners (which the PI probably has sought) to further carry on with this project.

- Good progress on system design. It is unlikely that it will be commercially produced by the manufacturing partner within 3 years.

- The approach seemed good. Looks like off the shelf DH system were used and some innovation could be made here. Progress seems good. The presenter mentioned this is a low priority for Lennox, which was a little concerning. This project has good impact.

- The project developed a new AS-IHP. This development and testing identified key problems that will lead to the design of an improved unit. The major issue found was control. The control of the system has be done to maintain comfort in the space, however maximizing the hot water produced. How to prioritize these goals will be the result of future work.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The key partner Lennox has an internal urgent need for reassigning personal and physical resources to work on qualifying existing product lines to meet impending increases in minimum SEER and HSPE requirement which has caused seriously delay problem. This project started in 2008 and it is almost 10 years now. DOE should be responsible for management of this kind of serious delay.

- It seems that the PI's progress has been impacted by the unavailability of the CRADA partner. I do not have any information on the history of this project and the justifications for the delays to be able to comment on it objectively. One conference presentation and another one pending seem too few and far in between for a $4M project. I think peer review publication is in order.

- Collaboration is limited by priority placed the project by the manufacturing partner.

- Collaboration with Lennox is a start but I suggest the PI reach out to some other companies if Lennox is not moving fast enough on this project. This is a problem that can be solve with current technology and the PI shouldn't wait around for Lennox.

- From the presentation, it appeared the project team worked closely with the manufacturer. The only major issue is how to launch the improved technology, either through the participating manufacturer or licensing the technology to other manufacturers.

E. Proposed Future Work

This project was rated **2.80** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Since it is currently a low priority for Lennox in qualifying mainline products for potential low GWP refrigerant conversion, the future plan and commercialization is not clear.

- Some engineering fixes are planned. There does not seem to be any serious impediment to their solution.
- I do not know how to interpret the statements that "commercial product launch timing uncertain" due to "currently lower priority for Lennox." Does it mean there is no commercial prospect for this?
- It is not clear what the partners agreed to and if the necessary recourses will be available in the absence of the existing partner. One needs to know the background of this project to be able to provide useful feedback. It is not clear what funds the partner received and what it did or will do for it. Under normal

circumstance, I would cut the ties with the reluctant partner immediately and move on to work with a willing partner who shares DOEs and PIs project's aspirations and goals.

- Little remaining to be done.

- These seems OK. Couple of conference presentation and a damper redesign. I would suggest that you quickly look to market to other companies.

- The proposed "Next Steps and Future Plans" section is quite detailed. The only disappointment is that a proposal to DOE FOA 1632 to "Scale-up" to enable licensing to other manufacturers, was not encourage to submit a full proposal.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- A traditional approach to heat pump products using the vapor compression process that service personnel are comfortable with.

- Deliverables are high if simplified.

- The project clearly identified the issues related to the development of a successful AS-IHP.

***Average*: 2** reviewers
- Many years are still needed to make it available in the warm/humid areas. There is no commercialization plan and key partner is not willing to participate at this stage.

- My judgement is in part based on the judgement of the project partner: apparently the commercial partner is not interested in further development and commercialization of the system developed. On the other hand, it is possible that their decision is based on factors unrelated to this project and not a judgement on this project.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Research areas and activities relevant to the program's objectives have received sufficient emphasis.

- The goals of this project are consistent with BTOs objectives and the main emphasis to-date seem to have been on meeting the technical / engineering challenges. What remains to be done to fulfill DOE's objectives are a few engineering issues that are not technically insurmountable followed by plans (to be developed) to move towards adaption, implementation, and commercialization.

- They are relevant. Don't spend too much time redesigning the damper.

- If the manufacturer involved in this project decides to delay or not to develop such a unit, licensing the technology to other manufacturers are being investigated.

***No*: 1** reviewer
- Low priority to get this into the commercial market.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The proposed project of AS-IHP system is a great idea to reduce building energy use intensity and provide space conditioning with WH/DH. The concept has been patented.
- The project intention has been to provide an economically viable energy efficient integrated thermal system (with user acceptability). The project has made progress in many of these areas. The remaining technical issues do not seem to be significant.
- Good progress by attempting to develop a product that would be familiar to owners and service personnel.
- This is a necessary technology that can use off the shelf, existing technology. It is just a matter of integrating the components.
- The project had a detailed experimental program that identified the issues, especially with control, that must be addressed in such a unit to be successful.

2) **Project Weaknesses**

- The project took almost 10 years to accomplish due to the delay problem from the key partner. The reviewer expects to find an innovative design of heat exchanger during the development course. Also, what is the heat transfer performance improvement after replacing the different type of heat exchanger? There is no data provided in the review presentation.
- The project's duration and what appears to be a reluctant partner seem to be main weaknesses of the project.
- Clearly has been put on the back burner multiple times.
- I didn't see any discussion about control strategies and this might be something you can look into in 2017. It wasn't obvious if the water heater or hot side air take precedence. This could raise some issues.
- I am concerned about follow on funding to continue the work. It appears this work will have a one to two year hiatus is funding is not secured.

3) **Recommendations**

- The great idea of AS-IHP system but it takes 10 years to deliver it which is too long and not acceptable.
- From the information in the presentation it is unclear whether the system (once completed) is commercially viable. The reluctance of the commercial party lends some credence to such an assessment. But if the PIs feel that the system is economically viable, they might consider forming other partnerships to continue the work on the project towards commercialization. Has the PI reviewed the contract with the present partner to make sure the partner has fulfilled its obligations under CRADA?
- I would pursue other manufacturers. Others were aggressively developing similar products several years ago and may want to get a commercial product into the marketplace.
- I would quickly redesign the damper and move on to other aspects of the project. Maybe enlist the help of a CFD person. Another suggestion is you might be able to eliminate the WH side and simplify your system. This might decrease the cost and provide quicker access to market. It also dedicated the entire hot side to heating the air eliminating the need to share the load between the WH and heating.
- None.

Project # 32226e: Commercial Gas Absorption Heat Pump Water Heater

Presenter: Patrick Geoghegan, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Referring to its targeted 45% energy savings, reviewers praised this project's connection to BTO's overarching goals.

Reviewers agreed that the project's approach appropriately addressed technical barriers. One reviewer felt that market barriers had also been well-identified, though other reviewers thought that non-technical barriers could still could be an issue. One reviewer noted that first cost might need to be better addressed, since a 3.7 year payback might not be adequate to entice customers to buy the product. Another reviewer mentioned adaptation and user acceptance as significant non-technical barriers to consider at this stage, also suggesting a cost-versus-performance analysis.

Many of the reviewers noted the project's good progress to date, based on strong qualitative and quantitative data. One reviewer commented that the project had increased water heater performance measures from the initial 87% to 92%, and then again to 97% through beta level testing. However, a different reviewer highlighted that this 97% was based on a lower COP target (a COP of 1.45) than was initially presented (a COP of 1.63); when evaluating performance relative to the original 1.63 target, actual performance achieved was only 86.5%. One reviewer noted that the breadboard and alpha unit testing results provided key lessons learned, helping to identify that that improved component design to limit heat exchange with the surroundings was needed.

Many reviewers felt that partners AO Smith and SMTI complemented each other's work well, with AO Smith providing component design, fabrication, testing support, market research, and cost share, while SMTI provided component and system design, fabrication, testing, testing support, and market research. However, one reviewer commented that some of those capabilities might overlap instead of complement. One reviewer noted that a peer review publication might be appropriate at this time in the project to broadly share results with the public and also acknowledge DOE's support and contribution. Another reviewer felt that it might be worth ORNL trying to collaborate with a company in a warmer climate.

Reviewers noted that the next steps were beta unit testing and field testing, with one commenting that field tests will reveal practical weaknesses in the design and another offering that tests should be in a climate warmer than Tennessee. One reviewer noted that there was no clear plan for commercialization with the two key partners. Another asked what additional funding would be necessary for the project and if other partners or potential first users needed to be identified.

Weighted Average: 3.53 # of Reviewers: 5[1]
Relevance: 3.80[2] Approach: 3.50 Accomplishments: 3.60 Project Collaboration: 3.50 Future Work: 3.40

[1] One reviewer was not present during the Peer Review presentation.
[2] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project of commercial absorption heat pump water heater meets with the BTO's objectives.
- A 25% reduction (BTO MYPP) in energy usage for water heating by 2020 (cf 2010) requires considerable effort. Projects such as this with the promise of 45% energy savings are superb.
- Significant part of the energy use market with meaningful energy efficiency potential.
- Seems like a perfect technology for BTO to invest in.
- This project clearly is line with reducing energy use. The target for the AHPWH is to have a 45% energy savings as compared to Energy-Star-Certified gas storage water heaters.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- PI didn't address the detailed approaches. Why only the single-effect cycle modeling is used to predict target performance? Since the project started in 2013 the information might be provided in the previous review presentations. The reviewer didn't have this kind of information from this review presentation.
- The technical barriers have been nicely described. Non-technical barriers (e.g., to adaptation, user acceptance, etc.) are also significant and merit consideration at this stage to see if any of them have bearing on the technical developments during the rest of the project life. Example: cost vs performance analysis.
- First cost may need to be addressed more since a 3.7 year payback may not be adequate to entice customers to buy the product.
- Market barriers have been well identified.
- The project is to develop a commercial water heater using an ammonia-water absorption cycle. The project was to design build and test a first generation unit and do testing and the learn how to optimize the device. The approach is sound.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- PI has optimized the single-effect cycle model to predict target performance. The breadboard testing is completed and it achieved 87% of performance target at design condition. The alpha and beta prototypes are fabricated and tested which achieved 92% and 97% of performance target at design condition, respectively. The objective of this project is to achieve a cycle COP of 1.63 at the treated condition of 47 F ambient, but the COP of 1.41 at 47/100 F is evaluated based on 1.45 target of COP which gives 97%. It will be 86.5% if it is based on 1.63 target of COP.

- The project has nicely increased the performance measures from the initial 87% to 92 and then 97% through beta level test.

- Good progress to date on all accounts.

- This presentation had strong qualitative and quantitative data. They are also making good progress. The impact of the project was well identified.

- The project built a breadboard and alpha unit. Test results gave key lessons learned. The rectifier performance for both the breadboard and alpha units were below design. These results indicated an improved component design to limit heat exchange with the surroundings was needed. Also, pressure loss in the system must be managed for a 14 gpm water flow.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- PI has been working with AO Smith who is the OEM to provide component design, fabrication, testing support, market research, and cost share to the project and SMTI who provides component design and system design, fabrication, testing, testing support, and market research. It seems like that PI has more contacts with SMTI than AO Smith.

- The PI has teamed up with suitable partners to help achieve the project's objectives. I do see some overlap between the capabilities of the AOS and SMTI but I presume they complement each other on this project.
- Also, it seems that given the age of the project and the progress made, a peer review publication would be possible (and maybe appropriate), as a means to broadly share peer reviewed results with the public and also acknowledge DOE's support and contribution.

- Good involvement with manufacturing partner and use of familiar technology.

- Good collaboration. It might be worth trying to collaborate with a company in warmer climate. The COP argument is even more in your favor in warmer climates.

- The team worked closely. AOSmith provided component design, fabrication and testing support. Also, they did market research on the potential market introduction of such a unit. SMTI, the other manufacturer, complimented AOSmith's effort.

E. Proposed Future Work

This project was rated **3.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The Beta 2 prototype testing will be carried out at SMTI in June 2017 and the field test will be conducted in July 2017. There is no clear plan for commercialization with two key partners.

- The planned reliability tests and field tests are appropriate and should be complete by the 3rd quarter 2017 giving the team time to pursue other tasks. The presentation refers to "pursue commercial buildings integration funding." With the payback of 2-4 years, what additional funding is necessary? Are there any interested parties to license or otherwise transfer the technology for manufacturing. It would be interesting

to work with such partners to identity potential first users, those that are open to early entries. They might have technical requirements that can be addressed during the remainder of the project.

- Field test should reveal practical weaknesses in the design.
- Testing is the obvious next step. Maybe test in a climate that is a little warmer than TN.
- The future work is to build a Beta Unit at SMTI. This unit would target incremental performance improvements, controls and field testing. This unit also will be tested by ORNL.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- The deliverables included systems tested at various stages plus two additional units planned for testing this summer. The key target audiences and markets are not identified but presumably will include the existing partners on this project and others that the PI will seek. This activity is apparently earmarked for the next 12 months but the earlier the better. It would be prudent to discuss these systems with potential users to get user feedback as early as possible and incorporate the feedback in system design.
- Exceptional deliverables.
- I believe the project accomplished it goals to develop a absorption water heater using ammonia/water. The project cost is $18,800 as compared to a conventional water heater's cost of $11,500. At $1.2/therm the unit has a payback of 3.7 years.

***Average*: 2** reviewers

- The target COP of 1.63 at rated condition of 47 F is not achieved. So the total energy saving may not be as high as expected. The total weight is also a main concern.
- Good prototypes and limited performance measurements to date.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- Project's research areas and activities relevant to the program's objectives received sufficient emphasis.
- It seems so but I think there are other issues to consider at this stage: the non-technical issues that will bear on technical aspects. For example, system weight of 850 Lb. is significant and methods to reduce it should be considered. Would this be barrier to market?
- If first cost can be reduced, this has some potential to impact the commercial kitchen market.
- Deploy in warmer climates.
- Yes the project indicated that heat exchange with the surroundings should be limited and pressure loss management are key issues. With a COP of 1.63 at 47F, the performance is good and the payback period is reasonable.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- PI has successfully developed, delivered and demonstrated two prototypes of commercial absorption heat pump water heater.
- The project has set and achieved successive levels of performance and has conducted the necessary verification tests, with additional reliability and field tests pending. There does not seem to be any significant technical issue going forward, but those of integration, reliability, manufacturing packaging, marketing etc. remain.
- Uses relatively familiar technology with better efficiencies.
- Necessary technology and well executed.
- The team appears to be fully integrated, working well together.

2) **Project Weaknesses**

- The target COP of 1.63 is not achieved.
- It would have been helpful to point out whether there has been any contact with potential manufacturers for this system. That is appropriate step as soon as possible to incorporate their views and advice into tests in the 2017-18 and any additional enhancements. Are the two companies currently involved interested?
- The first cost target seems to be too high to attract much interest.
- I think an argument needs to be made about warmer climates. Maybe I missed this during the presentation.
- I see no weaknesses.

3) **Recommendations**

- PI needs to address on how to improve the cycle COP to achieve the target value. Also, the commercialization plan with key partners is needed.
- It would be interesting to include in the payback computations colder climates such as Toronto, NY, Boston, Chicago, etc.
- Is there any IP involved in this work and if so, who owns it? Would this pose any barrier to entry by others? How is the issue handled?
- No other comments since I did not see the presentation.
- As I mentioned before, I would test it in warmer climates and try to collaborate with a company that might target these geographic areas. This technology totally makes sense and is necessary.
- None.

Project # 32226f: Next Generation Rooftop Unit

Presenter: Bo Shen, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Most reviewers agreed this project aligned with BTO's goals, as there is a need for more energy efficient rooftop units (RTUs).

Reviewers also agreed with the project's approach, which focused on improving RTU performance by redesigning the location and configuration of key components, utilizing numerical simulations and experimental activities to facilitate and corroborate enhanced performance. One reviewer thought that a key barrier to utilization of next generation low-GWP refrigerants was the lack of understanding of the performance of existing equipment, commenting that this project showed that relatively minor modifications to existing products could achieve higher integrated energy efficiency ratio values. One reviewer noted that some of the research problems that the project addressed seemed very valuable (e.g. modulation of the compressor), though others seemed trivial (e.g. improvement of the airflow using three fans instead of one). This reviewer also noted that several issues were not fully addressed, including the use of the submerged intercooler and bacterial development or surface deposits and scaling. Another reviewer commented that cost increases and other potential issues should be analyzed.

Many reviewers agreed that this project met its stated goals, with one going so far as to say that the technical accomplishments were outstanding. Another reviewer commented that this project produced higher RTU performance than existing technologies were achieving using new refrigerants. However, one reviewer noted that field results were slightly lower than lab results, with another reviewer commenting that the quality of some of the developed solutions were somewhat questionable.

Most reviewers agreed there was strong collaboration between ORNL and Emerson and Trane, though one reviewer noted that details about the extent of communication and collaboration were not presented. One reviewer also commented that, at this point, the performer should be able to answer whether cost increases were going to be acceptable, as well as if there were any other issue with the new design that could impede its market entry.

Though a few reviewers identified the project as complete, others remarked that proposed future work included additional field testing, which they agreed was appropriate.

Weighted Average: 3.51 # of Reviewers: 6
Relevance: 3.67[1] Approach: 3.25 Accomplishments: 3.67 Project Collaboration: 3.75 Future Work: 3.17

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- There is certainly a need to design, fabricate and characterize more energy efficient rooftop HVAC units to save energy and reduce GWP.
- This type of project seems well suited to the HVAC group at BTO.
- This project is well aligned with BTO goals.
- It is good to support incremental improvements in HVAC systems. This has to be done carefully with the right collaborators to make sure that cost increase is acceptable for the market.
- Improves the efficiency of the most commonly used HVAC systems in commercial buildings. Makes lager impact on overall building energy consumption.
- Roof top units use about 1 quad of source energy per year. IEER target for RTU's are 22. This project is to develop a RTU that meets these goals.

B. Approach

This project was rated:

1) **3.17** for the degree to which it focuses on critical market barriers, and
2) **3.33** for the degree to which the approach addresses the market barriers identified.

- The approach consists of redesigning the location and configuration of key components within a rooftop unit. Numerical simulations and experimental activities have been undertaken to facilitate and corroborate enhanced performance.
- The approach is simple and practical with a lofty goal.
- One of the key barriers to utilization of next generation low GWP refrigerants is lack of understanding of performance in existing equipment. This project shows that with relatively minor modifications to existing product, high IEER values can be achieved.
- Cost increase and other potential issues should be analyzed.
- Some of the research problems that the project addresses seems very valuable, while other are trivial or not completely addressed. For example, modulation of the compressor seems like valuable results. However, the improvement of the airflow using three fans instead of one seems like a trivial problem. Specifically, using a single fan with a diverter (i.e. a piece of metal that directs the air flow) to equalize the flow along the heat exchanger could have the same or even better results. Also, the issues with the use of submerged intercooler are not fully addressed. Moreover, the issues of bacterial development and/or surface deposits and scaling is also not fully addressed.
- The team involves Trane and Ingersol Rand in a CRADA. These companies are major suppliers of RTU's. The approach if there is a more efficient method to arrange compressors in a more efficient design. Also, packaging the unit and fan placement was critical, which was a part of the scope.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The developed prototypes have been able to reach higher IEER values, which should make them competitive in the rooftop unit market. The approach, which involved CFD and experimental activities, has indeed led to the configuration and packaging of an energy efficient unit.

- The technical accomplishments are outstanding. The only remaining question is will Trane realize a commercial product from this project.

- Project results were well documented and positive. Higher performance than existing max tech were observed using new refrigerants.

- The project has clearly achieved its stated goals.

- The project achieved the stated project goals but the applicability and/or quality of some of the developed solutions are somewhat questionable.

- The project achieve their goals. With a laboratory prototype using R-410a reaching an IEER of 21.6 and a laboratory prototype reaching an IEER of 22.6. Field testing has shown a season EER of 20.8.

D. Project Integration and Collaborations

This project was rated:

1) **3.67** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.83** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team members have reached out to key players in the industry including Emerson Climate Technologies, Ebm-papst, Trane and Ingersoll Rand. Through an invention disclosure, the team should be able to license the technology at the appropriate time.

- The assembled team was appropriate to meet the project objectives.

- Project engaged key industrial partners including Emerson and Trane.

- The team is complete with Trane being a part of it. But, details about the extent of communication and collaborations were not presented. At this point, the performer should be able to answer if the cost increase is acceptable or if there is any other issue with the new design that may impede its market entry.

- The project seems to be well coordinated with industry partners.

- The project team appears to be fully integrated and collaboration is good.

E. Proposed Future Work

This project was rated **3.17** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The proposed future work includes further field testing and knowledge dissemination through publications.
- N/A, project complete.
- Current project is complete. Field work is planned in future.
- The next step, additional field studies, and additional work on components are being pursued. Improvements expected from new components are not clearly discussed.
- The project is finished.
- The project plans to continue field testing in 2017. This is good to gain more field data and confidence in the new design.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers

- The team members were able to achieve the stated goals. Emphasis should be given now to knowledge dissemination.
- N/A
- Performance of equipment with new refrigerants is of great interest to HVAC industry. This project can help de-risk use of new low GWP fluids.
- I assume that Trane will pick up this technology beyond this stage.
- The project exceeded the IEER Goals and Seasonal EER was very good.

***Average*: 1** reviewer

- The project will help to achieve BTO goals. However, it could achieve more.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- The team members followed a scientific and comprehensive approach that led to the development of an energy efficient rooftop HVAC unit.
- N/A
- Yes, a weakness in an existing system has been identified, an acceptable solution has been attempted and good results have been achieved.
- The collaboration with TRANE should secure good deployment.

- I just suggest that field test results be widely disseminated.

***No*: 1** reviewer

- The HVAC group at the BTO could emphasize higher impact projects like large market unit projects or enabling components more.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project relied on a sound scientific and engineering approach. As a result, a more energy efficient HVAC roof unit has been developed and validated from the performance point of view.
- The technical outcomes were good.
- Good integration of collaborators
- Promising results of using new refrigerants in existing equipment with relatively minor modifications.
- Project will yield positive market impact.
- A deficiency in an existing system is identified and improvements have been made.
- The project addresses very important aspects of building energy efficiency and provides some good solutions.
- This is a strong team that have an innovative approach on how to integrate the compressors in a trio design. Also, the design of the unit and the placement of the blowers was important.

2) **Project Weaknesses**

- Greater dissemination of the positive outcomes of the project should be pursued to enable eventual adoption in the HVAC market.
- Commercialization of this idea is the only outstanding concern from this project.
- N/A
- There is not a particular weakness only that further details are some aspect of the project were not communicated in this presentation.
- For the cost and invested efforts it could produce even better solutions. Some solutions are marginal.
- None.

3) **Recommendations**

- Prototypes should be tested under different sets of conditions.
- N/A
- N/A
- None.
- None, the project is finished.
- Dissemination of field test results will be important.

Project # 32226g: Performance Evaluation of Packaged Rooftop Unit at High Ambient Temperature Environments

Presenter: Omar Abdelaziz, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Many reviewers agreed that this project aligned with BTO's goals, though one reviewer felt that the project addressed BTO's goals only tangentially. Another reviewer questioned why this project should be a DOE initiative, stating that it was clear that understanding the performance of new low GWP fluids in RTUs was of interest to BTO, but that it was less clear why understanding the performance of devices designed and fabricated in the Middle East would be of interest to U.S. taxpayers. This reviewer then commented that the results of the study would be of interest to U.S.-based manufacturers hoping to exploit these new markets.

Most reviewers agreed that the project's approach was clearly defined to address the unknowns of using new refrigerants in high-ambient applications, and also that the accurate, third party data that would be produced would be valuable to the HVAC&R industry. However, one reviewer disagreed with this position, commenting that it was unclear why an experimental path was selected for this project, and also that this path was quite expensive given the kind of work involved.

Reviewers generally agreed that the project reached its stated performance goals, while commenting on different aspects. One reviewer stated that the work was done well at a speed that was impressive, and that while the impact was still unclear, the results echoed other studies presenting low-GWP refrigerant comparisons. Another reviewer noted that the results were of great importance and value, and that the possibility that "drop-in" refrigerants could provide comparable system performance showed great promise. A different reviewer commented that the results would have wide ranging impact, while many reviewers felt that this information should be more widely disseminated through journal publications.

All reviewers agreed that there were good collaborative relationships on this project, as the project team worked with a panel of international experts to review the research plan, the selection of refrigerants, and the results.

Reviewers agreed that future work seemed appropriate. One reviewer commented that the project team's plans—to work with original equipment manufacturers and suppliers to improve system performance using alternative refrigerants and analyze refrigerant risks—was a good strategy moving forward. Another reviewer also commented that further analysis of the flammability of refrigerants seemed appropriate.

Weighted Average: 3.43 # of Reviewers: 6
Relevance: 2.83[1] Approach: 3.25 Accomplishments: 3.50 Project Collaboration: 3.67 Future Work: 3.17

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.83** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- There is a need for developing energy efficient rooftop units including their refrigerants for high temperature environments for the U.S. and international markets.
- The project certainly seems within the purview of the BTO.
- Understanding the performance of new low GWP fluids in RTU is of interest to BTO. However, it is less clear why understanding performance of devices designed and fabricated in the Middle East is of interest to US taxpayers. The reviewer agrees that the results of the study will be of interest to US based manufacturers hoping to exploit these new markets, but it is unclear why this should be DOEs initiative.
- Evaluation of existing systems performance with low GWP refrigerants and taking action to boost performance are in line with the DOE energy saving goals.
- Seems to be an expensive project that tangentially addresses BTO's goals.
- The project supports the Buildings Technology Office Multiyear Program Plan. It addresses key technology improvement and makes data available to industry for replacement of R-22 and R-410a refrigerants.

B. Approach

This project was rated:
1) **3.33** for the degree to which it focuses on critical market barriers, and
2) **3.17** for the degree to which the approach addresses the market barriers identified.

- The project consists of evaluating low GWP refrigerants for high temperature environments. Suitable refrigerants with greater system COP values have been identified.
- It is unclear why an experimental path was selected for this project. The total project was quite expensive (~$1.7M) with the objective of performing a differential evaluation of different drop in refrigerant performance. Couldn't the public receive un-biased scientific opinion from ONRL on this topic without the expensive of importing RTU's and testing?
- Approach was clearly defined to address unknowns of using new refrigerants in high-ambient applications. Accurate, third party data will be of value to HVAC&R industry.
- The research and experiments are clearly defined and the results are clearly presented/explained.
- The project seems to have an appropriate approach for the given goals.
- This project is investigating a wide range of operating conditions up to extreme hot conditions which are especially prevalent in the Middle East and India which are the two markets that are expanding at a rapid pace.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team members have been able to organize technical workshops to disseminate information about refrigerants for locations with high ambient temperature. A technical report has been widely disseminated by HVAC&R.

- The work done and speed was impressive. It was unclear what the impact will be, the results echoed other studies which presented low-GWP refrigerant comparisons.

- Technical approach was good, results are of great importance and value. Possibility of "drop-in" refrigerants that provide comparable performance is a very promising outcome.

- The performer clearly explained strong quantitative support for the project's performance goals.

- It seems that project achieved the stated goals.

- The target market is the U.S. Building sector, providing information for the target audience which are manufacturers in the HVAC&R/Appliance Industry, AHRI/ASHRAE and Codes and Standard Committees. These results will have wide ranging impact. Nationally this is a market of 0.72 Quad.

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.83** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team members have been able to reach out to manufacturers to make them aware of the energy saving potential of refrigerants in locations with high ambient temperatures.

- Good collaborative relationships on this project.

- Project team skillfully coordinated many moving parts to ensure success. Excellent collaborative partners.

- The efforts are well-coordinated and executed efficiently. The performers have made great use of taxpayer money, congratulations.

- It seems that PI coordinated very well the work of numerous project partners.

- This work focused on alternate refrigerants that are mildly flammable. The project had a panel of international experts to review the research plan, the selection of refrigerants, and the results. The work provided much needed guidance to ensure acceptance of the results and dissemination to the Montreal Protocol Open Ended Working Group and supported a U.S. proposed amendment to the Montreal Protocol that was approved in Kigali.

E. Proposed Future Work

This project was rated **3.17** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The proposed future activities are in line with the scope of the project, including optimization of rooftop units for refrigerants that would enable energy savings. Other activities involve analysis of the flammability of refrigerants.

- N/A

- This project is complete. Next steps seem reasonable for future proposals.
- A group of stakeholders have come together under this project and are conducting the right studies.
- The major project work seems to be finished and the remaining work related to window AC unit seems to be appropriate.
- The research results have been widely disseminated and are available online. The project team plans to work with OEM and suppliers to improve system performance using alternate refrigerants, and analyze flammable refrigerant risks. This is a good strategy.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- See strengths. Assessment of drop-in potential is of great interest.
- The data produced under this project are valuable and will be used to select the right refrigerant and define future research to improve system components.
- As was stated previously, the project provided much needed information to key stakeholders (manufacturers and policy makers). It influenced information by having an amendment to the Montreal Protocol.

***Average*: 3** reviewers
- Even though the team members have participated in a good number of dissemination related activities, the result of the project should be disseminated through journal publications.
- N/A
- It seems to be very expensive project with not well explained (or identified) benefits.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 6** reviewers
- Adequate information has been provided but more journal publications should be pursued.
- N/A
- N/A
- This is a successful project.
- The major research activities relevant to the project seem to be well coordinated and implemented but the link to the program's objectives in not well defined.
- The project consisted of two major efforts. These are: 1) development of the information and 2) information dissemination. National and international manufacturers provided sample refrigerants for testing in hot climates. Information has been disseminated at a workshop at the Montreal Protocol OEWG in July of 2016, the AHR Expo in January of 2017 and two Keynote Presentations at the 2nd International Conference on Energy and Indoor Environment for Hot Climates in February of 2017.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- There is certainly a need for better refrigerants for high ambient temperatures. The project addresses that well for both the U.S. and international markets.

- The testing speed and schedule was good for this project.

- Excellent collaboration.
- Results are of value to industry with potential for high impact.
- Testing methodology appears to be technically sound.
- Impact of communications (report).

- This is a well-defined and executed project.

- Good coordination.

- The project provide timely and useful results to the HVAC&R community and to other stakeholders including policy makers in a timely fashion. The project also had international collaboration which established the U.S. as a key player in the development of unbiased information.

2) **Project Weaknesses**

- More technical information about the technical tasks of the project should be reported.

- The impact and necessity of the project seem weak. A modeling/partial-modeling strategy may have sufficed.

- N/A

- None.

- Perhaps the significance of the project goals needs better explanation.

- None.

3) **Recommendations**

- The team should consider participating in ASHRAE related activities to promote the dissemination of the project results.

- N/A

- Project is complete, no additional recommendations.

- In-depth scientific studies on system elements (e.g. heat exchangers) to boost performance.

- None.

- None.

Project # 32290: Novel Ground-Level Integrated Diverse Energy Storage (GLIDES) Coupled with Building Air Conditioning

Presenter: Ayyoub Momen, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project, noting growing interest in energy storage in the building space as well as the project's potential to reduce peak load or enable load shifting in buildings. One reviewer questioned the project's relevance to the HVAC portfolio, finding it more closely aligned with grid-related projects.

Reviewers were mixed on the project's approach. Some reviewers did find the technical approach to be appropriate. However, others agreed that the project did not adequately address market barriers or potential commercial partners, with one noting that safety needed to be a higher priority, given that high pressure vessels are hazardous when in homes. Concerns were raised about the feasibility of the project—particularly reducing AC energy consumption—as well as whether the system was commercially relevant. Given the project's early stage, one reviewer suggested field testing the technology in a national lab.

Reviewers generally agreed on the project's progress and accomplishments, and that it was on track and achieving project targets. Reviewers found that, given the timeframe, the project was well balance and managed, calling it a low-cost, large impact project. On the positive side, one reviewer appreciated the baseline computations done for the gas storage system and payback calculations. Critically, however, one reviewer questioned the comparison between energy density of the proposed technology and the energy density of compressed air storage, while also expressing concern for the potentially misleading comparison of extra heat added from waste heat when calculating system efficiency. Another reviewer highlighted that a clear market audience was not articulated.

Reviewers were mixed on the project's level of integration and collaboration. Some found that project partners were fully engaged, and that collaborators were working closely together. However, other reviewers found that the team did not represent the project's collaborations well in the presentation, and that there was a lack of clarity on who was doing what. Reviewers put forth a few suggestions for additional collaborations, including finding more efficient rotating equipment for the project (e.g. a turbine), adding a pump manufacturer expert, and adding a manufacturer to build the device and connect the project to the market.

Reviewers generally agreed that future work should focus on improving the prototype design, particularly assessing AC savings and incorporating safety considerations. Reviewers also recommended considering a model of what a heat exchanger would look like, as well what controls would be needed. One reviewer questioned the novelty of the compressed gas idea and suggested that a literature review be carried out.

Weighted Average: 2.95 # of Reviewers: 5
Relevance: 3.20[1] Approach: 2.50 Accomplishments: 3.10 Project Collaboration: 3.20 Future Work: 3.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.20** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Unclear how this fits into the HVAC groups portfolio, seems like it could also be part of the grid related projects.

- Building level energy storage is of interest for increased renewable penetration in the built environment. There are also possibilities for the proposed system to recovery waste heat and reduce peak demand. The commercial relevance of the system is unclear. The actual feasibility of reducing AC energy consumption is also unclear.

- The project goal is a feasibility study for developing a pressurized gas storage system which can run during peak demands to produce electricity. During discharge, the expanding gas can absorb heat and cool a room, etc. If successful, the system provides a good storage mechanism plus heating / cooling and help with peak demand issue.

- Small scale energy storage systems are crucial for energy management (such as demand response) and integration of renewable energy systems.

- This is an innovative technology that looks to recover waste heat, provide energy storage and reduce peak load or load shifting in buildings.

B. Approach

This project was rated:
1) **2.40** for the degree to which it focuses on critical market barriers, and
2) **2.60** for the degree to which the approach addresses the market barriers identified.

- Low-TRL level, does not address market barriers. Technical approach is fine.

- The project has a reasonable set of tasks to demonstrate technical viability, but it not clear if the investigators are solving a problem that needs solving. While it may be outside the scope of the study, they present no information on what the market potential of their device is or who a commercial partner may be. The cost for the system to achieve ROI is specified, but it is not clear if these initial costs are feasible.

- The approach is fine and consists of a mixture of activities (modeling, analysis, etc.) to develop a (predictive) cost model residential electric use, when a storage unit (a pressurized gas storage system.) is included.

- The project addresses all identified market barriers. However, there is one unidentified market barrier that may be significant. The high pressure vessels are hazard when position in the residential homes (most home users don't have the technical knowledge/culture needed for maintenance of this kind of equipment). The safety should be one of the highest priority of this project.

- This is an unusual technology. It may be too early, however some market studies may give some insight on unexpected market barriers. Also, I believe field testing such a device in one of ORNL's test houses may be a good idea.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The prototype development looks intriguing. The claim that the energy density of this technology is the same as compressed air storage seems highly suspect. For the same size tank and compressed air pressure this technology will require some liquid volume, this will create larger storage needs for this technology. This comparison should be better addressed for future reviews. Further, ignoring the extra heat added from waste heat when calculating system efficiency provides an 'apples to oranges' comparison which is misleading.

- The project plan and schedule appear to be on track.

- Various aspects of the project (which started about 6 months ago) have been describes and some baseline computations have been carried out for the gas storage system. Also included are some payback computations.

- The approach is very systematic and project progress and accomplishments are significant.

- In the presentation, partners, subcontractors, and collaborators were discussed, however a clear market was not articulated.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The PI's should consider reaching out to other collaborators with respect to more efficient rotating equipment, particularly a turbine.

- The presenter cites Blue Mountain Energy and Georgia Tech as key partners. However, their roles were not clearly stated in the presentation, making project integration/collaborations difficult to assess.

- The project is in its infancy but it seems that the partners are fully engaged and regularly meet. More information about who is doing precisely what would be great.

- Team is very competent. Perhaps the only additional member that could significantly contribute to the team is a pump manufacturer/expert.

- From the presentation, it appears the collaborators work closely together. I believe this would be a good time to get a manufacturer involved that could build the device and is connected to the market.

E. Proposed Future Work

This project was rated **3.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- See previous comment regarding finding a turbine.

- The proposed future work of alternative design using condensable gas is interesting. The project team cites AC savings (by dumping condenser heat to the tank during discharge) as a key innovation. There does not appear to be any tasks to assess this component. The project team should consider some modelling of what such a heat exchanger would look like, and how controls would work (e.g., you would likely need AC during high ambient when the sun is out, at this time you would also probably be charging the tanks). There does not appear to be a good justification for this energy savings potential.

- The future work is naturally a continuation of the preliminary work that is reported in the presentation. I wish more specific information was given. It is not clear if a porotype is part of the project and if so, what size.

- The second half of the project relates to the prototype improvement and commercialization. Perhaps the only missing part is safety consideration.

- The future work is to improve the design. This is obvious first step.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- Given that we are only a few months into the project, what has been provided seems reasonable. Much remains, however, and it is recommended to first identify what is already known and what is unknown, work on the challenges.

- Overall, well balanced and managed, low cost and large impact project.

- The project team did a good job explaining the technology and they have presented their results at numerous forums.

***Average*: 2** reviewers
- *No Comment*

- While an interesting technology, it is not apparent that residential sector is the best potential market.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- *No Comment*

- Consider more investigation of how AC is integrated, as the project team cites this as a key advantage of the technology.

- The project's main objectives are being addressed but I feel it is necessary to look at the big picture / key objectives first to identify challenges, show what they are, and why they are challenges. For example, a payback study is not a challenge if we have the input information. Do we have that information from the literature for the storage / thermal systems envisioned or must we develop this for the first time?

- Everything seems to be in place for this stage of the project.

- Again, I must reiterate that this is the time to get a manufacturer involved. I believe that it was stated 70% of the cost is due to the pressure vessel. This should be a key area that should be addressed to reduce first cost.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The prototype development was good.
- Project team has made good progress in developing a prototype.
- The idea behind the project is sound but it requires some high-level analysis to put things in perspective without being bogged down in details and equations.
- Large impact. Feasible technology. Systematic approach. Good preliminary results.
- The team is very competent and this is transformational technology. Getting it accepted into the market will be the challenge.

2) **Project Weaknesses**

- See previous comments.
- Unclear if residential is really the best market for this type of energy storage.
- Lack of information on how AC would interface with energy storage solution.
- Market barriers of pressure vessels, controls, etc., are not compared.
- Should compare with batteries and other storage on a volumetric energy density basis. Homes that have this much extra space for energy storage may be limited.
- The project presumes that what is proposed here is totally novel and every aspects of it require basic development. A review of the literature is necessary to ascertain the state of the art and use that information to put the project on firm grounds and identify the main challenges.
- As mentioned several time before, safety of the device.
- I believe this is a good time to get a manufacturer involved. This would enable easier entry into the market.

3) **Recommendations**

- *No Comment*
- Please see weaknesses with potential areas to consider in future reporting periods.
- The compressed gas idea is not new and while this is not my field I know it has been studied in recent years (I believe for both residential and commercial applications). A literature search is missing in the report and should be carried out. This is one reference (thesis): CFD Simulations and Thermal Design for Application to Compressed Air Energy Storage; Zhang, Chao (2015)
- Again, safety.
- None.

Project # 32291: Adhesive Bonding of Aluminum and Copper in HVAC&R Applications

Presenter: Patrick Geoghegan, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project supports BTO's goals, describing the project's efforts to develop high quality, high strength adhesives for joining HVAC tubing as an innovative method that could lower equipment cost, increase operating efficiency, and reduce refrigerant leakage.

Reviewers described the scientific approach undertaken by the project team as well-formulated to address the project's technical challenges. One reviewer specifically called out the use of laser structuring to improve bonding between the parts. However, another reviewer felt that a suitable adhesive has yet to be identified, and was not sure whether an adhesive could be developed to meet the project's challenging performance standards. Reviewers agreed that most market barriers were being addressed, though one reviewer pointed out that market acceptance of an adhesive for bonding pressurized metallic joints was not obvious and had not been addressed.

Some reviewers thought that great progress had been made by such a recently-started project, including joint geometry optimization, surface preparation, and characterization techniques. However, other reviewers had some concerns about the project's progress, with one reviewer feeling that the results of modeling efforts were unclear, and another reviewer concerned about the project's significant cost.

A majority of reviewers lauded the integration of academia, national laboratories, and industry in the project, noting that this collaboration could expedite the adoption of the bonding method. However, two reviewers expressed concerns about Purdue's role, with one reviewer conveying that that Purdue's expertise was not well-aligned with the project and another reviewer simply stating Purdue's rule was unclear.

A majority of reviewers also agreed that key milestones proposed in the project's work plan seemed reasonable, though with some feeling that future work would need to be further detailed as the project develops. One reviewer mentioned that the use of neutron radiography to quantify the quality of the adhesive joint would be critical to understanding whether a suitable adhesive can be identified to enable robust joining technology. Another reviewer felt that developing a clear understanding of how surface texturing would improve adhesive joint strength was necessary. A third was interested to know the approach concerning macromolecules allowing water molecules to diffuse, even at extremely low rates, which could allow other molecules to diffuse as well. Another reviewer thought that a contract needed to be put in place between DOE and 3M, as that was not clearly specified.

Weighted Average: 3.28 # of Reviewers: 7
Relevance: 3.57[1] Approach: 3.50 Accomplishments: 3.07 Project Collaboration: 3.43 Future Work: 3.14

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.57** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The development of new adhesive bonding techniques are needed to be able to fabricate robust and durable HVAC equipment.
- The project does not address direct energy savings but rather indirect energy use through the reduction of refrigerant losses.
- Project is well aligned with BTO goals for reducing refrigerant leakage.
- The development of a high quality high strength adhesive for joining HVAC tubing is innovative and can have a large impact to reduce cost and increase efficiency through reduced leakage.
- Development of a low temperature bonding technique alternative to brazing is valuable for HVAC and heat exchanger industry.
- I have no expertise in this field, but the project seems to be relevant to BTO goals.
- This project is to investigate methods to improve joining technologies for HVAC&R equipment that has the potential to increase the lifetime of equipment and its operating efficiency, decrease equipment cost and reduce HFC refrigerant leakage. This support DOE's BTO Office Goals. This project just started (10/1/2016), hence only limited information was available at this time.

B. Approach

This project was rated:

1) **3.43** for the degree to which it focuses on critical market barriers, and
2) **3.57** for the degree to which the approach addresses the market barriers identified.

- The scientific approach undertaken by the team members is adequate for the technical challenges of the project. Specifically, the use of laser structuring should enable better bonding between the parts.
- The technical approach is solid.
- Project team has identified market opportunities and potential impact of project. Project plan is well formulated to address the technical barriers.
- Most of the market barriers are being addressed through enhanced testing for performance and reliability. However, market acceptance of an adhesive for bonding pressurized metallic joints is not obvious and has not really been addressed.
- The market barrier is technical. If a high quality bonding material, the focus of this project, is developed, it can penetrate the market rather quickly.
- The project seems to be well designed and systematic.
- This project involves ORNL, 3M and Purdue's Herrick Laboratories. Manufacturer involvement is critical to allow the information to be relevant to the market and enable market transformation.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.14** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Given the fact that the project started recently, the team members have been able to characterize the effectiveness the devised adhesive bonding technique using state-of-the-art characterization techniques. They have also developed an experimental protocol to determine the effectiveness of simple lap joints.

- Given the very short time since the project began there has been very good progress made. The potential impact of improved bonding of Al-Al interfaces without brazing is very exciting.

- As this is a new project, the progress seems acceptable at this point.

- The project is at an early stage and progress entails modeling of the adhesive joint by the Purdue team. Results of the modeling effort are not clear.

- The project is at an early stage and it is early to answer this question. As mentioned before, this is a good research direction.

- The project has some accomplishments. The only concern I have is the significant cost of the project; the presentation does not indicate what contribute to this high coat.

- As mentioned before, this project began on 10/1/2016. The work has focused on brazing and joining technologies and processes, advanced component design and materials and installation, operation and maintenance. The progress to date has been excellent. Preliminary results on joint geometry optimization, surface preparation, and various experimental methods to analyze joints were presented.

D. Project Integration and Collaborations

This project was rated:

1) **3.43** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.43** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The overall team consists of key players both in academia, National Labs, and the private sector, which should expedite the adoption of the developed bonding method.

- The project has a full team of relevant stakeholders. The expertise of the PI's at Purdue does not seem well in alignment with the project aside from vast experience with the HVAC&R industry

- The collaboration between Oak Ridge and 3M was clearly stated. 3M will be a critical stakeholder with an understanding of adhesive technology. The role of Purdue (Herrick Labs) was not clearly stated.

- The team has excellent collaborations with industry, especially the world's leader in adhesive technology, 3M.

- The right team is in place. I am looking forward to results of this work.

- Seems to be an excellent collaboration between academia and industry.

- From the presentation it appears that the project is on track and has established good project integration and collaboration. The team has outlined a solid commercialization plan.

E. Proposed Future Work

This project was rated **3.14** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- It was not clearly specified, but it appears that a contract needs to be in place between DOE and 3M.
- The proposed plan seems very good.
- At this early project stage, the proposed work plan seems reasonable.
- The proposed research plan is well conceived with good milestones. The use of neutron radiography to qualify the quality of the adhesive joint will be critical to understanding whether a suitable adhesive can be identified to enable robust joining technology.
- The performers are aware of the critical aspects of this research and seem to have a good combination of modeling and experimental plans.
- There is not detailed info about future steps in the presentation but the key milestones seems to be well placed.
- I view the future work as the Commercialization Plan as outlined on page 15 of the presentation. More detail will be needed in future presentations, however the outline presented appears to be solid.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- There is certainly a need for state-of-the-art bonding technologies for metals for a host of industrial applications. The outcomes of the project so far clearly show the benefits of the proposed approach.
- This would be exciting technology to have commercially available for many reasons.
- If successful, this technology can penetrate the market successfully.
- The results of testing, consideration of new geometry designs and the commercialization plan appear to be well thought out. It is too early in the project to have results disseminated at this time.

***Average*: 3** reviewers

- If successful, the deliverables will be of high value. At present, there are no deliverables to assess.
- Successful development of adhesive for joining will have significant industrial impact.
- My reediting is reserved (average) as I am not expert in the field.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 7** reviewers

- Certainly. State-of-the-art characterization techniques have been used to ensure optimal performance of the proposed adhesive bonding technique.
- There are a few projects on this topic which seems like a sufficient amount.
- *No Comment*
- Research approach is sufficient to evaluate quality of adhesive development.
- Performers understand what it takes to perform this research.
- The project is still in the early phase but the deployment activities seem to be relevant.
- The project's activities as outlined on slide 15 is good. The project is just starting and a better evaluation will be in a year.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project has a significant scientific foundation which should enable faster adoption of the technology across the industry.
- The project includes a wide ranging team which suggests a high probability of commercialization if the project is successful.
- Potential for high impact in wide array of industries.
- Good collaboration between Oak Ridge and 3M.
- Clear project plan.
- Good use of standards to provide clear measure for success.
- The team is strong, the research plan is well conceived, and the availability of neutron radiography imaging significantly enhances the assessment of the adhesive joint.
- This is a good project and I am glad that DOE has invested on this. However, there are fundamental challenges that I would like to see addressed. At this point, no details are presented about the approach. So, it is hard to find out if the project can be successful.
- Large impact on HVAC industry.
- The primary strength of the project is the approach and the plan to disseminate the results. Also, the team is quite diverse involving ORNL, 3M and Purdue.

2) **Project Weaknesses**

- Not clear future plans at the moment.
- The team at Purdue does not have expertise well in alignment with the project.

- Role of HeatCraft and Purdue not clearly stated.
- Main weakness is that a suitable adhesive has yet to be identified, and it is not known whether an adhesive can be developed to meet the challenging performance standards.
- Macromolecules (e.g. polymer chains) allow water molecules to diffuse, even at extremely low rates. There are open path (at the molecular level) that allow water molecules diffuse. Other molecules can diffuse albeit at a lower rate. So, I am interested to know what the approach is here.
- Seems to be an expensive and very short term project. From the presentation, it is not clear what the major cost of the project is.
- None at this point.

3) **Recommendations**

- Knowledge generated through the project should be disseminated as widely as possible.
- *No Comment*
- *No Comment*
- Develop a clear understanding of how surface texturing will improve adhesive joint strength and work to optimize texturing.
- Overall, the project is taking on an important challenge. It is difficult to provide recommendations given that no details is provided on bonding materials and technique.
- None.
- Not at this time.

Project # 32292: Residential Gas-Fired Cost-effective Triple-state Sorption Heat Pump

Presenter: Kyle Gluesenkamp, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project was relevant to BTO's goals and objectives, highlighting that—if successfully implemented—the project would provide energy savings while maintaining high performance. In terms of the project's approach, however, reviewers were mixed. Some reviewers wanted more information about the approach, including design calculations, modeling, experiments that were to be conducted, analyses performed, technical challenges, and key components of the system. Others found the approach reasonable and market barriers explained, which was notable given the early stage of the project.

Generally, reviewers were positive about the project plan, but felt that the project's early stage made it difficult to identify potential setbacks. Similarly, reviewers agreed that it was difficult to assess the projects accomplishments because the project was still in the design phase, although reviewers noted that relevant niche markets were identified. Reviewers agreed that the project was addressing BTO program objectives, though they felt more emphasis on materials might be needed to hit efficiency targets.

Reviewers were somewhat divided on the value of the proposed technology to the target market. Some found the work very promising, especially the proposed technology's use of salt crystals and the efficiency of its proposed system. Others found that it was just too early to determine how an actual system would perform. One reviewer noted that the size of the unit and components could be a concern when compared to conventional gas-fired products, as could be the proposed system's use of potentially poisonous ammonia.

Most reviewers agreed that the project was collaborating well with industry and universities, particularly the original equipment manufacturer. However, one reviewer questioned the clarity of the partners' commitments and responsibilities.

Reviewers identified a few weaknesses in the project, offering recommendations. One reviewer noted that a lack of service personnel might limit adoption. Similarly, since the unit size would be bigger than a conventional product, the embedded cost may yield a higher pack back time, also limiting market adoption. Another reviewer questioned whether the system could suffer the same problems as those of an adsorption system, while two reviewers questioned the salt that was being used, recommending further explanation of that choice in the future.

Weighted Average: 2.93 # of Reviewers: 6
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 2.83 Project Collaboration: 3.00 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project is to develop and demonstrate a gas-driven residential space-heating device through the laboratory and field tests.
- The proposed system, if successfully implemented, could provide about 40% energy saving, consistent with DOE goals.
- Development of a high performance gas-fired heat pump is in line with the DOE energy saving plans.
- Targets a significant part of the energy use market with a product that can be easily integrated into familiar systems.
- Good investment of BTO. New materials (Salts) is a good investment for BTO.
- The technology is meant to save energy and maintain high performance even at the low ambient conditions. It is relevant to the DOE goal on saving energy.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- PI didn't address the details of approaches in the proposed project. Those lists under “approach” are more like goals or objectives compared with 2010 TNT (0.78 AFUE), 41% energy savings, 2030 TNT (0.92 AFUE condensing furnace), 30% energy savings, etc. The reviewer didn't find the detailed approaches from the provided PowerPoint files or the review presentation. PI needs to provide the information of what kind of design calculations will be carried out, what modeling will be used, what experiments under the different operating conditions will be conducted, what kind of analysis will be performed, etc.
- The approach has not been adequately described. Instead, several pages under 'approach' are devoted to a listing of the virtues of a system that is not fully described. The properties of the crystal salt, which is a commercially available product, are known and the crystal is not the subject of this study. The proposed system on page 14 needs a clear explanation, including its key components and the technical challengers recognized at this time.
- This project is at the early stage. The proposed plan seems reasonable.
- While they have addressed first-cost, the residential market is extremely first-cost sensitive, so they need to focus on cost reductions as much as possible.
- Seems fine. This is a new project, and the market barriers have been identified. I am still a little confused by the 140% efficiency they are reporting.
- The approach seems very reasonable.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Since this project started in 2016 all research works are still in the design phase and there are only the system conceptual drawings are illustrated.
- This project seems to have been awarded in Oct. 2016, so it is too early to expect significant accomplishments. For now, some ideas have been presented combined with pages of claims.
- The proposed system seems viable and simple.
- For a new project, they seem to have identified their niche markets.
- Project hasn't started yet so this is difficult to judge. I was a little confused on the application of the salt based material. Impact is there once the some quantitative data has been gathered.
- Target market is fuel-fired residential space heating. There was a nice analysis of market size and entry point.

D. Project Integration and Collaborations

This project was rated:

1) **2.83** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.17** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Two key partners are identified by PIs: the molten salt reactors designer and provider and the catalytic combustion chamber provider.
- Necessary collaborations have been established, however the nature of partners' commitments and responsibilities are not clear.
- The right team is in place.
- Rheem should be a good manufacturing partner, but it is too early to judge their collaboration.
- Good collaboration with universities and industry.
- Partnered with an OEM.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- PI has listed the general future plans for three-year project. Also, the Gantt chart is provided to illustrate check points and milestones and deliverables.
- The outlines of the three-year development plan are provided without anything specific.

- A good plan is proposed.

- Still too early to tell if setbacks will cause them to change directions.
- Still a lot of work to do. Seems well organized.

- Market size and barriers were identified. The future work seems reasonable.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- Since specifics were not provided, it is hard to identify challenges ahead for this project. On the face of it though, the use of the salt crystals and the efficiency that a system based on it can provide are promising.

- If successful, the project can have a good impact.

- Potentially high level of deliverable once the project has evolved.

***Average*: 3** reviewers
- Since the project started in 2016, there is no clear evidence or experimental data to support how an actual system performs.

- Too early to really tell.

- The size of the unit and extra components could be a concern when compared to conventional gas-fired product. The use of ammonia could also be a concern even though the system is hermetic and outdoor. This may have some implications when it comes to service/repair etc. as ammonia is poisonous.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- The project of research areas and activities relevant to the program's objectives has received sufficient emphasis.

- The research is defined well.

- Potentially a very good project.

- They seem fine. More emphasis on materials may be needed to hit efficiencies.

- The task emphasizes the proof of concept product to demonstrate the energy saving potential.

***No*: 1** reviewer
- It is difficult to answer this question because the presentation does not have many specifics for a reader to determine if a proper set of activities to achieve project's goals are envisioned.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project proposes to use tripe-state sorption which is neither absorption nor adsorption cycle. The system could have very high energy density and ammonia refrigerant is used with no moving seals, fully hermetic, which enables high delivery temperature at low ambient.
- The salt crystal is the key idea in this project for the advantages it offers. Making use of it in a system to support energy efficiency goals of the DOE is the project's strength at this time.
- The concept seems reasonable. There are some challenges similar to adsorption system but I look forward to the test results.
- System should be able to fit in with existing systems or be familiar enough for people to accept.
- Sounds like a new concept that integrates some new materials into the system.
- The project strength is the focus of large potential market size, the relevance to the industry, and its energy saving potential.

2) **Project Weaknesses**

- PI didn't address the stability of molten salts with nano-coated technology. Usually, the molten salt used in the solar energy application or the thermal storage has more or less degradation problem. Also, what is the heat and mass transfer effectiveness inside the salt reactors? What is the limitation of diameter of reactors due to the heat transfer performance from the coil heat exchanger surrounded outside surface of reactors?
- Too early to identify weaknesses in the project. The project, however, is in an ORNL press release in August 2016 before the award was made. So the work on such a project might have started earlier, however. https://www.ornl.gov/news/energy-high-efficiency-heating. The press release consists of claims without anything specific.
- This system may suffer from the same problems of an adsorption system.
- I am unsure of what service may be required for this system, but service personnel are critical to the success of any type system. The York-engine-driven heat pump was unsuccessful largely because they did not have service personnel in place and so no one would buy it.
- I was a little confused about the start date. The first slides say 2016 and the timeline says 2017. I was also confused by the presenter's description of the system. It wasn't obvious what the salt was doing. Is it storing thermal energy or responsible for the surface chemistry of the condensing and evaporating phase?
- One weakness could be that the extra cost embedded may have high payback time if the natural gas price keeps low. The unit size will be bigger than the conventional product.

3) **Recommendations**

- The main concern is still the cost of the proposed system compared to the traditional residential heat pump system. PI needs to provide the salt degradation test data to show how many cycles it can sustain under the different operating conditions.
- A description of the specific R&D steps that have to be taken and of the technical challenges would be helpful at this stage.
- None

- They need to keep focused on first cost and future service issues (personnel training, serviceability).
- I recommend the presenter take a little more time explaining this technology. What does the heat exchanger with the salt look like? What is the point of the salt? I know this is early in the project, but the mechanisms and properties of the materials must be understood prior to optimization.
- Maybe add a go/no go check point after the breadboard system evaluation?

Project # 32293: Advanced Serpentine Heat Exchangers to Minimize the Number of Joints and Leakage in HVAC&R Systems

Presenter: Daniel Bacellar, OTS
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers were split on this project's relevancy to BTO's goals. While one reviewer found that it contributed to BTO's goals by reducing refrigerant leakage while increasing heat exchanger performance, the other reviewer noted that major companies had already developed similar technologies. Despite this disagreement, both reviewers found the project's design for preventing refrigerant leakage to be appropriate and innovative, and agreed that the project team was aware of upcoming challenges and had a balanced approach to address them.

Reviewers found that the project work already completed had made appropriate progress, with computational fluid dynamic analyses being verified and joint manufacturing being evaluated. Critically, however, one reviewer noted that if the secondary heat exchanger did not achieve the equivalent efficiency of existing heat exchangers, the leak reduction design alone would not be enough to drive a massive adoption by original equipment managers (OEMs). This risks notwithstanding, reviewers described the project as a potentially high performance solution to a major environmental issue.

Reviewers agreed on the project's good engagement with industry partners and its demonstrated understanding of stakeholder needs to reach market. Reviewers agreed that the project team had identified relevant partners to work with, including two companies who were well-established in the heat exchanger and HVAC industries.

Although a work plan for future activities was in place, one reviewer felt that there were significant risks that needed to be mitigated before the project moved forward, recommending design changes to close the 20% performance gap between the new heat exchanger and the project's target, and warning that if cost became an issue, OEMs might not widely adopt the new heat exchanger design. This reviewer explicitly acknowledged that project plan modifications could impact the project schedule.

Weighted Average: 2.90 # of Reviewers: 2
Relevance: 2.50[1] Approach: 3.00 Accomplishments: 2.75 Project Collaboration: 3.00 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The major OEM's have all developed ways to minimize leakage through joining and brazing processes.
- This project is relevant to BTO's goals because it reduces the amount of refrigerant leaked to the atmosphere from HX joints. At the same time, airside finning is being modified to increase the HX performance.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- For the stated goal of preventing refrigerant leakage at equivalent or better efficiency. The proposed design approach is good.
- The approach being taken to reduce leakage is to reduce the number of joints that need brazing by using tube bends in a serpentine arrangement. This approach is innovative and will allow critical barriers to be overcome.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- If the SHX does not achieve equivalent efficiency of the current heat exchangers, the leak reduction design alone will not be enough to drive a massive adoption by OEM's.
- The project has progressed to the point that the CFD analysis is being verified and joint manufacturing is being evaluated. A successful completion of the project is expected.

D. Project Integration and Collaborations

This project was rated:
1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team has identified relevant partners to work with.
- The project integration is excellent and significant collaborations have been established with well-known HX and HVAC companies such as UTRC and HTT.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The plan is in place but some significant risks still need to be mitigated. Modifications to the baseline may impact the schedule.

- The future work remaining is system level testing and a market commercialization plan.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer
- Substantial energy savings are possible.

***Average*: 1** reviewer
- There is more work to do, and the technology still needs to prove itself as a viable alternative to the existing solutions.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers
- The team has demonstrated to be aware of the challenges and has a plan to address them.

- The project is taking a balanced approach.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The major strength is the choice of partners to work with.

- The project strength is that it provides a high performance solution to a major environmental issue.

2) **Project Weaknesses**

- The design still needs some changes to close the 20% gap to target. This may impact the project schedule. If cost becomes an issue, the OEM's may not widely adopt the new SHX.

- No observable weaknesses.

3) **Recommendations**

- None beyond what was already offered.

- Continue project as planned

Project # 32294: Improved Braze Joint Quality Through use of Enhanced Surface Technologies

Presenter: Ron Cosby, Trane
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's goals, commenting that the project was well aligned with the goals of reducing refrigerant loss and maintaining good HVAC equipment performance. One reviewer highlighted that this project was not focused on energy use indirectly, while another identified that small leaks were a major reason for the reduced efficiency of cooling systems, and that mitigation of these leaks would not only save energy but also reduce labor costs for repairing HVAC systems.

For the most part, reviewers agreed on the appropriateness of the project's approach, commenting that the technical approach was quite good and well thought out. One reviewer pointed out that a key market barrier would be having manufacturers adopt a new technique, but felt that, because Trane was a manufacturer, this concern would be addressed and the project would remain focused on addressing real barriers. Two reviewers agreed that the approach seemed appropriate, but had concerns about costs. One noted that the process for, and cost implications of, manufacturing had not yet been addressed, while the other was concerned that this project's costs exceeded its potential value. One reviewer remarked that the project's approach was based on the assumption that refrigerant leaks were related to brazed joint failure; this reviewer felt that they did not have the expertise to fully evaluate this assumption, but neither were they convinced that the project's proposed solution would resolve the issue. This reviewer wanted to see a more detailed investigation of the leakage problem, with particular focus on the causes of failure and whether new surface features could make things worse.

Reviewers agreed on the project's progress and accomplishments to date, commenting that project activities thus far had been good, and that at its early stage the project appeared to be on schedule. One reviewer remarked that designs for the experimental facility to study the capillary dynamics of brazing looked impressive, while another thought that the project's overall experimental design was sound and should be successful. One reviewer thought that—though the project had just started—its success would have a significant impact on the HVAC industry.

Reviewers rated the project's integration and collaborations very highly, with one reviewer highlighting the very good evidence of collaboration in the project's early stages. Another reviewer commented that collaboration between a university and a large corporation was likely sufficient to complete technical elements and commercialize the results of the project. Another reviewer felt that recruiting an industrial partner be beneficial, particularly one that was willing to provide information about product leaks and allow the project team to examine leaky samples.

Overall, most reviewers thought that planned future work looked sufficient and reasonable.

Weighted Average: 3.32 # of Reviewers: 6
Relevance: 3.33[1] Approach: 3.33 Accomplishments: 3.25 Project Collaboration: 3.42 Future Work: 3.33

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.33** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This is not a project which addresses energy use directly, rather indirectly, through reductions in leakage.
- Project is well aligned with goals of reducing refrigerant loss and maintaining good performance in HVAC equipment. Aligns well with BENEFIT FOA from 2016.
- Slow loss of charge due to small leaks is a major reason for the reduced efficiency of cooling systems. Mitigation of this problem not only saves energy but also reduces the release of the refrigerants into the environment reduces labor cost for repairing these systems.
- Goal of the project is to improve brazed joints to prevent refrigerant leakage over long duration operation. If successful, the new technology will improve HVAC efficiency.
- The project seems to be relevant to the BTO goals. However, I am not expert in this field, and this should be considered while reading my specific evaluation.
- This project is to reduce refrigerant leaks. Air-conditioning systems not operating their design pressure are more inefficient. Reducing leaks will make an air-conditioning inventory having a higher average performance.

B. Approach

This project was rated:

1) **3.33** for the degree to which it focuses on critical market barriers, and
2) **3.33** for the degree to which the approach addresses the market barriers identified.

- The technical approach is quite good with various steps involving incremental additions of complexity.
- A key market barrier will be having manufacturers adopt a new technique. As Trane is an OEM, this concern is being addressed. By having academic researchers (students), understand how brazing is actually done in the factory, this will help keep project focused on addressing real barriers.
- The approach is based the assumption that the leaks - to a large extent - are related brazed joint failure. That is an assumption that I cannot judge.
- The proposed approach is to through 'surface enhancements' that enhance braze joint strength under thermal and pressure cycles.
- I am skeptical about this because brazing is commonly employed in high and ultra-high vacuum systems holding very low pressures (~ 10^-10 Torrs) for years and passing He leak tests. So I think the reported leaks in HVAC systems may not due to brazed joints in a way that can be fixed by changing the brazing process. If they are, it means that either the braze job was not done right in the first place, or the joint has fatigued or stressed. The proposed surface enhancement brazing may address the first but not the other two causes unless additional steps such as some re-designing are undertaken.
- The market exists for ready implementation of a successful technology. However, the process for manufacturing and manufacturing costs have not yet been addressed. This is an early stage technology, and manufacturing the microstructure into the braze joints requires careful thought.
- Approach seems to be appropriate. The only issue I have is the cost. It is not clear from the presentation is the reason for the high cost of the project.

- The approach, led by a manufacturer, is well thought out. The manufacturer is keenly aware of what kind of processes can be implemented in manufacturing processes.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.17** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project thus far is been good. The design of the experimental rig looks impressive.
- At this early stage in the project, things appear to be on schedule.
- The project is new and there is not much to report. However, the IP has developed a fixture for changing the gap between the parts being brazed and examining the appropriate gap.
- Project is at an early stage and near term focus has been on setting up the experimental facility to study the capillary dynamics of brazing. Experimental design is sound and should be successful.
- The first test seems to be promising.
- This project has just started, however if it successful it would have a significant impact on the industry.

D. Project Integration and Collaborations

This project was rated:

1) **3.33** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- A university and large corporation is likely sufficient to complete the technical side and commercialize the results of the project.
- Very good evidence of collaboration in early stages. Embedding U of I researchers in Trane manufacturing plant will provide invaluable experience as project progresses.
- The PI has a UIUC collaborator. I think an industrial partner in addition is necessary. We need to find a company that is willing to provide information about leaks, provide leaked samples, and allow the PI to examine them. It is not clear what the strengths of the UIUC partner is.
- Also needed is preferably non-destructive testing of samples for joint quality. X-ray and ultrasound are possibilities.
- The key stakeholders are the entire HVAC industry, and the technology can be easily translated to industry if successful.
- The specific partnership between industry and academia seems to be very relevant for this research topic.
- The project lead, the manufacturer, had the other team member, a university participate in their existing manufacturing process so as to fully understand existing processes. It appears the team is working quite closely.

E. Proposed Future Work

This project was rated **3.33** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The future work looks sufficient for the time being.
- Again, at early project stage, proposed work plan seems reasonable.
- Too early in the project to have meaningful comments. I think the present future plan will be adjusted during the course of the research.
- Next steps include studying an easy geometry, flat plate brazing. The capillary dynamics and the strength of the braze will be characterized. The follow-on steps include implementing braze technology into tube joints.
- The project plan is well developed and future steps seems to be very appropriate.
- Since the project is just started, I believe the workplan (future work) is well thought out.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- Project success could impact a wide array of industries in improving joint integrity. Project success could impact wide array of industries in improving joint integrity.
- A solution to the leak problem is the key deliverable and a big help in the effort to reduce energy usage.
- Reducing refrigerant leakage will have a substantial impact on improving efficiency and reducing emissions.
- The project plan and deliverables are reasonable.

***Average*: 2** reviewers
- *No Comment*
- My reediting is reserved (average) as I am not expert in the field.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*:** 5 reviewers
- *No Comment*
- *No Comment*
- The research path is well thought out and is clear.
- The deployment activities seem to be relevant.

- The fact that a manufacturer is the lead on the project will help to get the results used by industry. The manufacturer should articulate the value of having this project funded by DOE versus doing the research internally.

***No*: 1** reviewer

- As noted, we need to look into:
  - 1- Causes of failure (needs samples, enough statistics) or new samples that are cycled or aged to failure.
  - 2- Metrology to understand the cause of failures.
  - 3- Development of schemes to make long lasting braze joints, and the development of appropriate ways to test them.
  - 4- Performing low and high cycle fatigue tests on the joints as a part of this project.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The experimental apparatus is a good design and the approach proposed is a good one.

- Integration of Illinois researchers with Trane staff.
- Focus on round tube plate fin coils and non-similar metals important for broad array of industries.
- Use of internal Trane procedures to verify joint integrity/reliability/etc. provide confidence in deploying joint technology.
- Potential for project to be applied to non HVAC&R industries.

- The project's strength is or should be in the identification of the cause(s) of joint failure and then the proposed study on the development of suitable brazing joints.

- Strength of the project is the Illinois team and the close industrial collaboration. The Illinois P.I. has vast knowledge in the field of microstructures and capillary dynamics and the project should yield useful results.

- Good team.

- The primary strength is that a manufacturer is leading the project. This will make implementation of the results more assured.

2) **Project Weaknesses**

- *No Comment*

- While Trane internal standards are understandably proprietary, it would be useful for a clear measure of success to be communicated to public.

- Emphasis needs to be placed on finding the causes of the failures, and then devising a solution. I am not sure if brazing at two locations on the same part will necessarily solve the problem. It may and it may not. For example, if the braze sights are to be clean, free of contaminants and exposure to the elements, how would double brazing solve it?

- Only weakness is that a clear path or multiple options for manufacturing the surface microstructure have not been identified.

- It is not clear if the value from the project is proportional to the cost.

- None.

3) **Recommendations**

- *No Comment*

- Several issues were raised by reviewers and public during Q&A period that should be considered in next presentation including (1) Will inclusion of surface features make things worse (2) How will success be measured (3) Cost (4) Technique to be used to develop surface features. It appears that these will be addressed in future work.

- I would:
    - Work with a willing industrial partner who would freely share failure information with the PI in exchange for access to PI's research work.
    - Perform traditional brazing (including in the field) and examine them to check bond strength and uniformity. Change brazing parameters including the gap to see how the quality and the strength of the joints changes. A non-destructive testing approach is needed.

- Identify and develop manufacturing options.

- None.

- None.

Emerging Technologies
Windows & Building Envelope

Project # 31312a: Core Funding R&D Probabilistic Analysis of the Performance of Air Barrier Systems

Presenter: Simon Pallin, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Multiple reviewers agreed that air barriers have a significant effect on energy consumption, and therefore that improving air barrier deployment was significant to the overall energy efficiency of residential construction. One reviewer commented that it was important for manufacturers, designers, and end-users to understand envelope performance at both the component and whole-building level, while another reviewer noted that the original purpose of this project *might* have provided this information by comparing different air barrier technologies. A third reviewer, however, commented that the relationship between the project and BTO's goals was not obvious, and that the project would have been a better fit as part of a larger project with a broader scope.

Two reviewers noted that the project had a solid approach, which focused on conducting tests using the guarded blower method to determine probabilistic performance charts and enable fast adoption. Two reviewers noted, however, that this approach missed a major market barrier—air barrier installation errors—and that at the early stages of the project, inconsistent air barrier performance measurements were found that should have refocused the research. One stated that researchers should have devised another way of evaluating air barrier performance or identifying key performance indicators of the air filtration system, while the other reviewer noted that the project's design did not address installation as a market barrier due to the incorrect focus on product instead of installation quality. One reviewer commented on the possibility that other technologies existed that could prove the original hypothesis, commenting further that if these other technologies existed, the project should be testing them.

One reviewer commented that the project's accomplishments and progress were good, but that the eventual impact of the project was unclear. Another reviewer stated that component-level analysis met the project goal of helping the construction industry select air barrier technologies that were cost efficient in terms of performance and durability, but that the whole-house level analysis data were inconclusive. A different reviewer noted that the primary project conclusion was that neither of the air barrier technologies—in their installed state—were able to meet the DOE performance target, commenting further that the project did a good job of identifying the cause of this performance shortfall by quantifying both the measured performance and variability of performance. However, this reviewer noted that in order to achieve the targeted energy savings, installation quality would need to improve or a superior technology would need to be created/identified, and neither of these things occurred. One reviewer stated that the project revealed "the uncomfortable reality….[that] the performance of energy efficient materials highly depends on the installation process." This reviewer noted that while the project's learning outcome was highly valuable, this project accomplishment was not in line with the project's goal.

Multiple reviewers noted some initial project collaboration, mentioning good initial discussions with manufacturers and homebuilders that served mostly to identify homes for the field test. One reviewer expressed a desire to see a plan to further engage builders to solve the issue of installation performance, or to engage manufacturers to improve the ease of installation. Another remarked that a larger sample size of homebuilders could yield additional insights.

Multiple reviewers noted that the project's future work was unclear. One reviewer asked how the project would help ensure that improvements were made in the industry to help guarantee that lessons learned were integrated into air barrier system design and installation. Another suggested a possible plan to benchmark a "perfect" installation—and to see where that landed on the distribution—as a way to find more linkages between individual installation imperfections and the distributions they measure.

Weighted Average: 2.40 # of Reviewers: 5
Relevance: 2.60[1] Approach: 2.40 Accomplishments: 2.30 Project Collaboration: 2.60 Future Work: 2.40

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Air barriers have a significant effect on energy consumption, and therefore improving their deployment is significant. However, this does not appear to be an emerging technologies project, per se.

- Important for manufacturers, designers, and end-users to understand envelope performance at both the component and whole building level.

- Air infiltration is a significant driver of energy usage for heating and cooling. The project quantifies the installed performance of two air barrier systems designed to limit air infiltration in residential buildings.

- The original purpose of the project is to provide the quality comparison of different air barrier technologies. Due to difficulties in quality control during installation process, the comparison could not be properly made. More explanation on how much value could be created for the BTO mission by the field-tests would be helpful.

- + Project aligns with BTO goals as improvements in reducing air infiltration are key to improving the overall energy efficiency of residential construction.
- - Project design/outcome was not very focused "help construction industry select (better) air barrier technologies…"

B. Approach

This project was rated:
1) **2.60** for the degree to which it focuses on critical market barriers, and
2) **2.20** for the degree to which the approach addresses the market barriers identified.

- The approach seems to focus on conducting the tests and then presenting performance charts to enable faster adoption. However, the plan does not address exactly how dissemination of information will occur (reports alone are not enough).

- Good approach – using the guarded blower method to determine probabilistic performance chart for components. Determining the range of the spread identifies whether the installation is robust and reliable (narrow) or problematic (wide).

- The original hypothesis appears to be that superior air barriers exist and that builders merely need to be made aware of them. The project originally sought to quantify the performance differences (lower infiltration, more consistent installed performance) between two competing air barrier technologies (house wrap and non-insulating sheathing). The project found that the performance between these two technologies was not that different and that both performed much worse than stated manufacturer performance estimates, most likely due to imperfect installation. The impact of installation deficiencies on the performance of both technologies was not fully identified in the early stages of the project, but was made clear through their work. More attention has been focused on connecting installation irregularities to measured performance and it appears that this work is continuing. The other possibility is that other technologies exist that would prove their original hypothesis; if there are other alternatives (that are potentially easier to more consistently install) they should be testing these.

- The market barriers were not clearly presented, and the approach did not lead to meet its goal. Inconsistent performance measurement was found at relatively early stage of the project, and the researcher should have devised another way of evaluating the performance or identifying key performance indicators of the air filtration system.

- - Missed major market barrier (installation, here specifically the quality of install) which should have been clear from: 1) measured cfm50/sf were so much higher (many 50 times higher) than (at least) manufacturer's claim; 2) the vast majority of homes measured exceed IECC 2012 & 2015 codes; and 3) the high variability of a builder building virtually the same home. The full measurements on all the homes were not needed to pull out quality of install as the major driver. When first expected or noticed, the project should have been redirected to focus on this market barrier.
- - If the project was focused on this element first (install quality) and it was resolved, then the discussion/work on the difference between the two air barrier systems could have been done effectively.
- - Design does not address installation market barrier due to incorrect focus on product instead of install quality.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Accomplishments are good. Progress made. Eventual impact unclear.

- Project goal is to help construction industry select air barrier technologies that are cost efficient in terms of performance and durability.
- - The component level analysis seemed to meet this goal.
- - The whole house level analysis data (performance charts) were inconclusive.

- The primary conclusion is that neither of the air barrier technologies tested (in their installed state) are able to meet the DOE performance target of < 1 ACH50. The project does a good job of identifying the cause of their performance shortfall by quantifying both the measured performance and the variability of performance due to installation differences. This information is critical to determine the path forward to improved air barrier performance.
- Based on their findings, the key to achieving the targeted energy savings centers around either improving installation quality or creating/identifying a superior technology. I do not see a solution to either of these issues in the remaining time in the project.

- The project revealed the uncomfortable reality in the building energy sector: the performance of energy efficient materials highly depends on the installation process, which advises us to have better policy or consider different research direction. Although the learning outcome is highly valuable, the accomplishment was not in line with the goal of the project.

- - Accomplishments don't really support goals in that no relevant performance difference between the two products was seen as results were swamped by the installation variability.
- - Accomplishments so far don't add much to the program goals other than identifying installation as an issue, which could have been predicted before the project start or at least after the first few measurements when the project should have pivoted.
- - Project expected to contribute little to the program other than to add a renewed focus on install quality.

D. Project Integration and Collaborations

This project was rated:

1) **2.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Good initial discussions with manufacturers and with ORNL.

- Worked with two homebuilders – a larger sample size could yield additional insights.

- All stakeholders are clearly identified. There is some interaction with a manufacturer of non-insulated sheathing. Ultimately, the results of the project point to more direct involvement with builders. I would like to see more on a plan for engaging builders to tackle the issue of installation performance or with manufacturers to improve the ease of installation.

- Collaboration was mostly done with the manufacturers to identify homes for the field test. More high level collaboration could have been beneficial to guide the project toward more constructive direction.

- - Presenter seemed surprised to discover as a result of the work the key whole house performance barrier (install quality), instead of finding it early by engaging key stakeholders. Product manufacturers typically do not offer full house performance of their products readily. Other stakeholders, for example, those in the business doing blower door tests would have made the install quality barrier clear.
- - I believe the big miss here was not having an engaged industrial partner intimately involved combined with missing some key stakeholders.
- - Once the install variability was discovered in the field (i.e. with the first few tests) the project should have been recalibrated and pivoted to focus on the root causes of the install variability.

E. Proposed Future Work

This project was rated **2.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- While this is an important study to reveal information about air barriers, the "what's next" piece is not really addressed. With this information, how will the project help ensure that improvements are made in the industry to help guarantee that lessons learned are integrated into the system, design and installation.

- Decision points for future work on the whole house model are not well defined.

- Future work focuses on the relevant issue of installation irregularities but it is not clear how the proposed steps will translate into improved installation performance in a global sense. I would like to see more on the linkage between individual installation imperfections and the distributions that they measure, something like how best to quantify the impact of different installation errors. They need a way to demonstrate that for even for the best installations in their distributions, there are sufficient recommended improvements to reach the performance targets. Maybe a plan to benchmark a "perfect" installation and see where that lands on the distribution.

- The performance variation could have been affected by many different factors. Blower door test may not be the best way to evaluate the detailed causes of the variation. Considering that the detailed method was not presented, the scope of future work may not fit within the remaining period of the project.

- - It is not clear from the future work what is left (if anything to do). All of the elements in project plan appear complete yet FY17 budget of $165k still seems unspent and available.
- - Proper risk mitigation and alternate pathways would have led to a project redirection, which did not occur.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- Developing probabilistic performance charts for existing and new air barrier systems will assist construction industry in selection of optimal systems.

- The air barrier probability distributions provide a terrific means of framing the discussion on air barrier system performance (as installed) and variability of installed performance. It is the starting point of meeting the DOE performance targets on air infiltration.

***Average*: 1** reviewer
- See weaknesses.

***Low*: 2** reviewers
- Impact of the project was originally stated as "provide performance chart" and "emphasize key issues of installation", by compiling measurements data, providing guidance on air barrier systems, and increasing industry awareness. Unfortunately, the project did not meet its own goal and could not create the value as intended.

- - The deliverable did not produce new information to the industry.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers
- No comment.

- I think air infiltration research is receiving sufficient emphasis. I would prioritize projects that examine whole-house performance (like this one) over projects over those look for small leak features. Follow-up projects on ones like this could have significant impact.

***No*: 3** reviewers
- The program's objectives are to have real impact on the industry, but this project, while the results are interesting, does not follow through in helping to identify how to have that impact.

- The relation between the project and the mission of the BTO was not obvious. Although performance survey of air barrier system could identify the unforeseen issues, but the pathways to make an impact in energy saving at large scale should have been elaborated. This project could have been a better fit, if it were a part of a larger project with broader scope of work.

- - It doesn't appear that the research activities received the correct emphasis, as the project should have been modified during Q3 of Year 1 when the air leakage data was collected. It is unclear why the project direction was not changed, as this is a 3-year effort, which would have given plenty of time for a redirection.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Very thorough investigation. Strong connection with manufacturers.

- Developing probabilistic performance charts for existing and new air barrier systems will assist construction industry in selection of optimal systems.

- The project does a really good job of quantifying the installed performance of air barrier systems. It provides an effective way to frame the state-of-the-art technologies and the progress that needs to be made to meet DOE performance targets. I think there is great value in this approach and even though it will not lead to meeting the performance targets in the near term, it can lead the way to eventually meeting the targets.

- The project identified practical issues in implementing advanced building energy materials. The learning lessons should be carefully considered to develop a roadmap of research in building envelope at BTO.

- + Project did look at reducing air infiltration, which is a subject worth studying.

2) **Project Weaknesses**

- A plan (beyond publications) is not presented to help ensure dissemination of information and real impact on the industry.

- No comment.

- The path to meeting the DOE performance targets for air barrier systems is not clear. The conclusions of the study point to workmanship as the primary driver of unrealized performance, but the steps required to improve installation performance are not clear (and this was not the original, primary focus of the project). If a competing technology existed that could meet the performance target, it was not tested.

- The performance test was not done in a controlled environment to compare different air barrier systems. Nevertheless, the field tests performed in this project have produced important learning lessons.

- - See comments above.
- - Key market barrier missed. Engagement of stakeholders was not deep enough. Project accomplishment could have been anticipated prior to doing work. Team failed to recognize from the early results that the direction of the project needed correction and therefore failed to pivot the project.

3) **Recommendations**

- Work more closely with the manufacturers to find mechanisms to ensure dissemination and real impact in the industry.

- No comment.

- I think the key is to attempt an "ideal" installation of each technology and see where that falls in terms of performance. If it meets performance, the cost and time trades required to meet this installation can be evaluated with builders. If neither still meet performance, a new approach/technology is required.

- Once the causes for performance variation are identified, a new air barrier system design should be explored in a way to enhance consistency of installation process.

- - Get deeper more engaged stakeholders.
- - Talk to different types of stakeholders. Ask their opinion of what they see as the major factor causing poor air infiltration results (i.e. product or install).
- - Be observant and receptive to redirecting the project if early experiments show unanticipated results.

Project # 31312b: Core Funding R&D Development and Validation of Fraunhofer Attic Thermal Model (FATM)

Presenter: Andre Desjarlais, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers agreed that this project was relevant to BTO's goals, as having accurate attic model simulations is relevant to the development of new building technologies and easier code compliance. A few reviewers noted that market barriers to the emergence and use of new attic models were not significant, with one reviewer commenting that the keys to market acceptance would center on user confidence in the attic model's results, as well as the features of the model relative to alternatives. This reviewer warned, however, that while this project builds confidence in its model's results by comparing the results to experiments, the target market of code bodies and designers still might not have interest. Another reviewer noted that as a plug-in module for EnergyPlus, the outcome of this project would be easily accessible to researchers or material developers. Finally, a third reviewer commented that the project supported increased use of building energy modeling by expanding the number and type of attics that could be modeled, as well as increasing the accuracy of those models.

Reviewers agreed that the project was making good progress, with one reviewer calling the attic test mockups and comparison results impressive. One reviewer questioned whether the new features proposed for the model would allow for different attic designs. Another reviewer was concerned that the project would not have a significant impact on BTO's program, as the project addressed only a narrow segment of the building energy modeling space.

Two reviewers agreed that the combination of ORNL's experimental capabilities and the unique modeling capabilities at Fraunhofer CSE, as well as the project's direct involvement with ASHRAE Technical and Standards Committees, yielded excellent collaborations. However, two other reviewers noted that additional interactions with other roof researchers, simulation developers, and future users of the modeling tool would have been beneficial to the project.

Two reviewers noted that the project's next steps were logical and would close out existing work. One reviewer noted that future work focused primarily on developing another use-case, which would strengthen the validity of the model. This reviewer also noted that creating an interface with EnergyPlus would make the outcome readily available to stakeholders, and also that a comparison of different roof models would be beneficial as well. Another reviewer commented that ceiling work would make a good addition to this effort, as it would expand the attractiveness of the model since cathedralized ceilings are a common design element.

Weighted Average: 3.10 # of Reviewers: 5
Relevance: 3.00[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 3.40 Future Work: 3.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Attic model will be helpful for more accurate building energy modeling.
- Due to the complexities of attic spaces and building interactive effects, an accurate simulation model is relevant.
- The project aims to reduce the energy used for heating and cooling that results from heat lost or gained in residential attics.
- The project provides an attic modeling tool, which can accelerate the development of the new building technologies.
- - Although directed to program goals, it is not clear how a more accurate roof calculation is critical to BTO.
- + BTO should support these efforts for easier, more accurate simulations that will lead to more energy efficient designs and easier code compliance.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Market barriers are likely not significant, but only minimal discussion presented.
- Experimental/Analytic Approach - market barriers irrelevant at this point.
- The project is targeted at energy code developers and design professionals. The keys to market acceptable will center around user confidence in the results and the features of the model relative to alternatives. The project builds confidence in the model results by comparing to experiments. It is unclear whether all of the features proposed (and not all are being implemented currently) are of interest to code bodies and designers.
- The presenter well identified the needs for a valid roof model. The project contains well-balanced efforts from modeling as well as experimental validation. As a plug-in module for Energy Plus, the outcome of the project can be easily accessible to researchers or material developers.
- Impact on market or stakeholder would better be quantified.
- + The focus of improving the calculations was concise and clear.
- + Overall simulation accuracy was noted as a market barrier.
- + The use of model attic lab measurements helps to validate the simulations.
- + The project supports the increase in use of BEM by expanding the attics that can be modeled as well as increasing the accuracy of the model.
- - Not sure there was an adequate demonstration of how this model improvement will make a significant market impact.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.80** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Attic test mockups impressive. Comparison results impressive.

- Project appears to be on track to meet development of an accurate attic simulation model.

- The project appears to show good agreement between the experiments and the models, lending confidence to the new models.
- They do not make clear how an improved attic model will help reduce the 1.3 quads used as a result of attic heat transfer. Do the new features proposed allow for different attic designs?

- Although the modeling work was well supported by the experimental work, the novelty and comparative advantage of the proposed modeling work over other existing models could have supported the value of their approach.

- + Good progress on attic simulations so far. Expect the project to meet its intended goals.
- - I'm not convinced the project will have a significant impact on the BTO program, if successful, as the project is a narrow segment of the BEM space.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Good interaction with building scientists, ASHRAE. Could benefit from additional interaction with future users of modeling tool.

- No comment.

- The project mates unique experimental capabilities at ORNL with unique modeling capabilities at Fraunhofer CSE. The direct involvement with the ASHRAE Technical and Standards Committees is really valuable.

- Although collaboration between two entities was strong, the project could have included other roof researcher or simulation developer to consider diverse aspects.

- + Project team is well integrated with the relevant ASTM and ASHRAE committees, which seem to be the appropriate stakeholders for the project.
- + Participation on the committees will make the input of key stakeholders easier.

E. Proposed Future Work

This project was rated **3.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Next steps are logical and will lead to final deliverable to DOE (if successful).

- No comment.
- Future work is basically concluding the existing work.
- The future work is mainly on providing another use-case, which strengthens the validity of the model. Creating an interface with Energy Plus can make the project outcome readily available to stakeholders. The comparison of different roof models will be beneficial as well.
- + Ceiling work is a good addition to the effort as it will expand the attractiveness of the model since cathedrialized ceilings are a common design element.
- - Ceiling work was not discussed during the review.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers
- A needed modeling module for the industry.
- An accurate attic simulation model is needed.
- Reliable simulation tool will benefit many small companies, who may not have enough resources to carry out experimental validation.
- + The addition of an expanded, more accurate attic model will enhance the capabilities of EnergyPlus, a critical element of BEM.

***Average*: 1** reviewer
- The attic model appears to fill a gap in the capabilities of EnergyPlus and provides additional functionality relative to currently-available attic models.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- Well-conceived and aligned.
- No comment.
- I didn't get a chance to see any of the other modeling projects. It is important to support the modeling efforts with experimental validation. If that isn't always the case I would suggest additional emphasis on validating code.
- The presenter pointed out the limitation of currently available simulation tools.
- + Professional approach and execution by key members and institutions in the space.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Well-conceived plan and approach for model development and validation.
- Strong experimental and analytical approach.
- The experimental approach seems sound and the facilities are unrivaled. The project does well to validate the models is experimental data. The attic modeling appears to build significantly on the functionality of existing models.
- Well balanced efforts between modeling and experimental works, carried out by strong collaboration between Fraunhofer and ORNL.
- + Well designed and executed program.
- + Good use of lab work to validate model.
- + Modules like this will make BEM more institutionalized in the industry.

2) **Project Weaknesses**

- Need to show how much better this model is than a simple R-value calculation.
- No comment.
- The presenter did not make the case for whether the features being added to the attic model (cathedral ceiling geometry, above sheathing ventilation) were in demand with designers or code bodies. How will these features impact the energy expended due to attics? Some additional features (hygrothermal treatment, phase change materials) were mentioned, but it doesn't appear that they are implemented or planned to be implemented before the end of the project. What are the most important features required to impact the 1.3 quads of energy used as a result of attics.
- From the presentation, it was not obvious why the proposed attic simulation model has comparative advantages over other tools.
- - Attics appeared on first glance to be not the most critical market barrier. Some discussion should have been directed to explaining why this is a key project for focus.

3) **Recommendations**

- See weakness.
- Suggest that the project guards against 'scope creep' in the form of overly complex analysis. It will impede the time it takes to bring this code to market as an Energy Plus plug-in.
- No additional recommendations.
- The presentation mostly focused on the experimental work, and Innovation of the simulation model was not apparent.
- + Well done. Sell the audience on the relevance of the project a bit more. It may be obvious to you, however not to those of us who are not in it as deep.

Project # 31312c: Core Funding R&D Insulated Siding for Energy Efficient Building Envelopes

Presenter: Andre Desjarlais, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Many reviewers agreed this project was relevant to BTO's goals. One reviewer commented that this project could lead to a disruption in the market that would produce significant energy savings. Others noted the great potential for the retrofit building envelope space. Another reviewer said that this product could provide an alternative means of meeting emerging continuous insulation requirements. Finally, a different reviewer noted that the application does not require a vinyl siding replacement, which will limit the market potential and that pricing could also be a market barrier.

One reviewer thought this project had a well-conceived approach, but was concerned that there might not be market acceptance. A second reviewer noted that key market barriers were identified and that cost data would be gathered this year, but a third reviewer remained concerned about the barrier posed by the cost of building materials; this reviewer suggested that more economic analysis could align the proposed approach with the cost barrier. Another reviewer commented that the project team did not provide enough information on how they planned to address modified atmosphere insulation reliability issues.

All reviewers agreed that the project appeared to be on track and had successfully achieved iterations of assembly, construction, testing, and evaluation, but multiple reviewers noted that there was an opportunity for improvement at the joints. Other reviewers commented that market barriers and acceptance would be the key challenges to overcome next.

Reviewers agreed that the project demonstrated strong collaboration among key stakeholders, with one reviewer in particular liking that the main manufacturing partner has a larger market share. One reviewer commented that the project missed an early focus on material cost, which was still substantially higher than BTO's targeted installed cost premium.

One reviewer noted that the project's proposed future work addressed potential barriers that needed to be overcome to create a market-ready product, including thermal performance of joints and non-uniform thickness of modified atmosphere insulation to accommodate existing horizontal siding product. Another reviewer felt that market acceptance needed to be considered in future work. One reviewer thought that gathering cost data, and attempting to reduce cost, would be key, while also noting that it would be good to see something addressing reliability and scrap rate for modified atmosphere insulation panels.

Weighted Average: 3.32 # of Reviewers: 5
Relevance: 3.20[1] Approach: 3.40 Accomplishments: 3.10 Project Collaboration: 3.60 Future Work: 3.40

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.20** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project could lead to a disruption in market that will have significant energy savings.
- Developing an architecturally appropriate siding that incorporates a high R value would be very beneficial for the retrofit building envelope space.
- The project aims to develop a higher R-value, insulated siding product. This product has the potential to reduce energy usage that results from the heat transfer through walls, particularly in retrofit applications. This product would provide an alternate means of meeting emerging continuous insulation requirements.
- Developing an advance building material is in line with the mission of BTO.
- + Supports directly the improvement of retrofit building envelope insulation improvement using the highest market share siding material without significantly changing the install/retrofit process.
- + R11.7 for the insulated siding assembly supports BTO's R12 2025 goal for retrofit.
- - Application does require a vinyl siding replacement, which will limit the market potential for the method.
- - Pricing still appears to be a premium with respect to the BTO goal of $0.25/sf and combined with the cost of the vinyl siding might make this a less attractive option than it appears.

B. Approach

This project was rated:

1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- Well-conceived approach, but some concern if there will be market acceptance.
- Excellent approach: get industry partners on-board to help develop modified atmosphere insulation panels bonded to vinyl siding form factor. Work with partners to reduce thermal bridging effects at joints. Evaluate with small scale experiments and simulations.
- The key market barriers (cost and reliability) are identified. Cost data will be gathered this year. There is less presented on how they plan to address modified atmosphere insulation reliability issues.
- The presenter attributes the market barriers to the cost of building materials. However, it was not clear from the presentation how proposed approach leads to reduced cost of the insulated sidings. More specifically, how much enhancement in R-value is necessary to justify xx $/square foot? The key design innovation is to reduce panel failure by a novel joint design, but how much improvement in yield will be enhanced by the proposed design? More economic analysis can align the proposed approach with the market barrier.
- + Install details are very good and low incremental cost if a vinyl siding replacement is desired (Install cost barrier).
- + Go to market partners are excellent/very good. Royal is one of the largest vinyl siding manufacturers (Route to Market Barrier).
- + Great approach: First identifying industry partner, look for synergy, and jointly design with partner.
- - Cost looks like it is still an issue. Preliminary estimates at $2-4/square foot (incremental cost over uninsulated vinyl siding is still a significant premium to BTO's goal of $0.25/square foot installed cost premium. (Material Cost Barrier).

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Impressive R values. Need to examine joint more closely.
- Project has achieved successful iterations of assembly construction, testing and evaluation.
- Development appears to be on track. Composite siding assemble has achieved its performance target (R10) and an opportunity for improvement has been identified at the joints. The key upcoming challenges will be around market acceptance.
- The project achieved its milestone but the pathway to overcome market barriers could have supported the project.
- + Proposed product almost to R12 with a commonly used vinyl profile.
- + Significantly improved product without a major change in design or installation.
- + Major manufacturing partner who could take product to market successfully.
- + Partner has large market share in siding replacement applications.
- - Barrier to overcome or adapting to cutting modified atmosphere insulation onsite & modified atmosphere insulation failure rate.
- - Upsell to modified atmosphere insulation for the vinyl siding application may be problematic based on this is already a high replacement expense for the homeowner, many times of rather modest means, so energy payback and salesmanship will be critical to successful implementation.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.80** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Great relationship with Royal Building and Newport Partners.
- Manufacturing partners on board for manufacturing and market expertise.
- All of the key stakeholders are identified and involved.
- The team is composed of diverse stakeholders, who can provide expertise in their own domain. I wish more technical innovation from the collaborators were presented during the presentation. Please disregard this comment, if such information is proprietary.
- + Presenter understood many of the key market barriers: performance, effective partnering with current market participant, design focus on minimizing complexity of install.
- - Presenter and project plan in general missed early focus on material cost, which is still substantially higher than BTO's targeted installed cost premium.
- + Great industrial partner who is actively engaged in project and modifying their product to accommodate the invention.

E. Proposed Future Work

This project was rated **3.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Well-conceived future plan. Good cost comparison. Need to consider market acceptance.

- Addresses potential barriers to be overcome to create a market-ready product: thermal performance of joints, non-uniform thickness of modified atmosphere insulation to accommodate existing horizontal siding product.

- The next seem appropriate. Gathering cost data (and attempting to reduce cost) will be key. Would have been good to see something addressing reliability and scrap rate for modified atmosphere insulation panels.

- Future work is based on the learning outcomes in the previous project period.

- + Joint work will help get over the R12 barrier.
- - Although not stated directly, the techno-economic focus should be on improving the cost structure. Still too high.
- - Big thermal bridge to fix.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- High potential impact.

- This product would substantially improve the insulative value of existing siding for the retrofit (or NC) market. It has the potential to be a cost-effective envelope efficiency measure with the added benefit that the trade ally network is already familiar with installation. This eliminates a major barrier to market uptake.

- The presentation explicitly identified older residential buildings as the target. As owners of residential units are not technically well versed, the barriers may be mostly economic benefit. Such benefits to the owner should be well elaborated to appreciate the value of the project.

- Project will deliver a product that meets the 2025 technical performance goal R-12/in. The product is a thin package, which allows installation of siding without build-out. Project has manufacturing partner already in the market who can commercialize the product quickly.

***Average*: 2** reviewer

- They have made good progress in making modified atmosphere insulation-based insulated siding a reality. It is a clever use for the technology. There is still some work to go in order to bring this to market, starting with gathering cost data.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- Good alignment with BTO's goals.

- Excellent integration of partners.

- There is sufficient emphasis on wall assembly efficiency
- The presenter well aligned the importance of the project aligned with the BTO's mission.
- In general, the proposed activities are being well addressed. Certainly the technical details, partnering, design and manufacturing are well positioned. An early focus on cost would have been my only suggestion. I'd pull the cost focus forward in the plan.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Impressive results to-date. Good partnerships.
- This product would substantially improve the insulative value of existing siding for the retrofit (or NC) market. It has the potential to be a cost-effective envelope efficiency measure with the added benefit that the trade ally network is already familiar with installation. This eliminates a major barrier to market uptake.
- The proposal presents a clever use for modified atmosphere insulation panels. There is certainly an advantage in having thinner insulated siding for retrofit applications. Insulated siding provides a convenient means for meeting continuous insulation requirements.
- The project appears to be on track for meeting thermal performance targets. Measurements and calculations are in good agreement.
- Project is well organized, and progress achieved its target values.
- + Good application for modified atmosphere insulation.
- + Very good work identifying and engaging partner early in both design and manufacturing.
- + Overall one of the model projects I've seen.

2) **Project Weaknesses**

- Need to consider how to overcome potential issues with market acceptance and cost. Issues related to joint need to be resolved.
- No comment.
- Cost data (to be gathered this year) will be critical in determining if modified atmosphere insulation-based insulated siding can be a viable product. At present, it is not clear that it will be.
- More attention could be focused on reliability issues associated with modified atmosphere insulation panel and their incorporation into composite.
- Target values would better be qualitatively justified. As the project focuses on the insulated siding development, the impact and the pathways to energy saving needs to be clarified.
- - Earlier and more direct focus on cost. Can't be pushed to Year 3 of project. As it is one of the largest market barriers, it should be worked on continuously throughout the project.

3) **Recommendations**

- Consider additional partnerships with manufacturers.

- Continue to ensure that the builders and trades are involved in the development process to minimize unanticipated barriers that could arise with installation.

- No additional recommendations.

- The project is technically sound, but preliminary economic analysis could have made the project exceptional.

- All said above.

Project # 31390: Acoustic Building Infiltration Measurement System (ABIMS)

Presenter: Ralph Muehleisen, Argonne National Laboratory
DOE Manager: Sven Mumme

One reviewer described this project's technology as potentially disruptive to the industry, with significant potential for impact. Others agreed that this was a relevant technology with potential to detect infiltration points in commercial buildings, thus accelerating the adoption of new air barrier materials. One reviewer commented that the method appeared to be effective on flat surfaces, but that it was unclear whether the method was capable of detecting the most significant infiltration points in a building. Another pointed out that this technology could be used during commercial construction, which cannot be done today with current commercial products.

Many reviewers agreed that this was an innovative approach to leak detection. One reviewer, however, noted that additional consultation with the market was critical, and also that there needed to be a better understanding of the size of the hole/crack and the resulting energy loss. Multiple reviewers agreed that various tests needed to be run in the field, as market barriers had only been addressed so far in the lab. One reviewer noted that there could be a cost and time barrier to the method in the field.

Reviewers agreed that the project had made good progress, but also that field tests were needed to ensure that any unexpected barriers could be identified and overcome before manufacturing began.

One reviewer noted that even with interviews done, there needed to be many more discussions with market stakeholders, as well as consideration given to how the technology should be developed to ensure market acceptance. Another reviewer remarked that successfully moving this technology into the market would be highly dependent on the success of field testing. A different reviewer commented that Lab-Corps participation appeared to have provided a good head start on commercialization, along with follow-on funding to support field testing and possible use at military installations. Another reviewer remarked that the presenter understood the stakeholders well, and that the project was carried out through good collaborative efforts among industry, academics, and the national lab. A final reviewer was concerned that the focus of the project was on making a startup successful instead of engaging and landing a solid commercial partner.

One reviewer commented that the project's next steps did not adequately address technology development, testing, demonstration, etc., through another reviewer noted that follow-on Department of Defense testing would offer opportunity to identify and solve any unanticipated barriers. One reviewer expressed that a commercialization plan was necessary.

Weighted Average: 2.69 # of Reviewers: 5
Relevance: 3.20[1] Approach: 2.70 Accomplishments: 2.60 Project Collaboration: 2.90 Future Work: 2.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.20** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Could be disruptive technology to the industry with potential for impact.

- Developing a non-invasive, cost-effective method to measure envelope infiltration in commercial buildings is highly relevant.

- The project addresses building infiltration which results in additional energy being needed for heating and cooling. The proposed acoustic diagnostic seeks to identify infiltration points. The method appears to be effective on flat surfaces; it is unclear whether the method is capable of detecting the most significant infiltration points in a building.

- The project explores new infiltration diagnostic technologies. Although it does not lead to reduced energy consumption, it can accelerate the adoption of the new air barrier materials.

- + Mostly aligned with respect to energy reduction goals by developing methods to determine where infiltration occurs, which may make users more apt to engage in air infiltration reduction.
- + Can be used during commercial construction, which cannot be done today.
- - Project has long timeframe (4 years) without any fieldwork three years into the project.
- - Many complications are typically found during field trials, which further add to project risk and commercialization delays. This could further extend timeline such that achievement of program interim market goals will be highly uncertain.

B. Approach

This project was rated:
1) **2.80** for the degree to which it focuses on critical market barriers, and
2) **2.60** for the degree to which the approach addresses the market barriers identified.

- Innovative approach to leak detection. Additional consultation with market is critical.
- Various issues need to be addressed:
    - Need to understand the size of the crack/hole that matters (i.e. why matter small if you don't need to know about the small leaks?).
    - Need to run various tests under real world conditions.

- Addressed market barriers in the laboratory. Field testing to identify unanticipated market barriers earlier in the project would have been preferable.

- The primary market barriers have been identified. With a technique that scans the surface area of a building, the key will be to maximize scan rate / throughput of the device. They have done well addressing this issue by developing a way to make a quick, low-resolution scan over a large area and then following up with a localized, high-resolution scan.
- I think there still is a fairly large challenge in relating the acoustic transmission to the infiltration characteristics. They mention this issue, but it isn't clear from their presentation what their approach is to resolve this.

- The presenter well elaborated barriers of infiltration measurement. More studies on the relation between the air leakage size/distribution and the energy loss by infiltration should be made to widely adopt the proposed technology.

- + No good way to do quantified infiltration measurements in commercial buildings is recognized. (Lack of Performance Measurement Techniques barrier).

- + If effective and inexpensive, there is a high expectation that infiltration requirements would be added to commercial codes.
- + Proposed method may be effective in measuring infiltration.
- - Proposed method appears neither fast nor inexpensive. (Cost barrier).
- - Proposed method has been targeted to applications where IR blower doors are not effective, indicating that it cannot compete on structures where IR blower doors are effective. This limits scope of the method. (Market Scope Barrier).

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Interesting results to-date, but many more tests need to be made to build confidence that technology will work in real world applications.

- Technical progress on track. Suggest intensive field testing as next step to ensure that any unexpected barriers can be identified and overcome before manufacturing begins.

- They have made good progress developing this acoustic device and are moving toward commercialization. At this point, it is still a stretch to say that this device will result in the stated energy savings (0.6 quads). Completion of field testing (upcoming) will go a long way toward showing whether such an energy savings is feasible.

- Excellent proof of concept. The pathway for energy saving and economic benefit to users would have made the presentation better.

- + The method, if successful, may be a way to drive more infiltration work than is done today.
- - Long project timing, project risk, scope of where the technique is the best option, and market entry (R&D only to start from commercial partner) limit the extent the project supports BTO program's interim market goals.
- - No field tests three years into project indicates the complexity of the project and the uncertain risks when real systems are measured.
- - Further algorithm development was identified as needed, indicating a not ready of field test status.
- + Project has detected small leaks in the lab.
- + This is a hard problem and the project results so far are admirable.
- - The complexity of the method and state of development appear to limit the traction that this technique will have in the marketplace in the near term.
- - Initial target market (military applications) combined with no current field trials and further need for algorithm development pushes commercialization entry into the larger commercial market well into the early 2020's at best. This timeline will not have a material impact w.r.t. program's stated performance goals (installed commercial air sealing cost premium/sf reduction from $1.40/square foot to $0.60/square foot in 2020 and $0.50/square foot in 2025.

D. Project Integration and Collaborations

This project was rated:

1) **2.80** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Even with interviews done, there needs to be many more discussions with the marketplace and considerations for how the technology should be developed accordingly to ensure market acceptance.

- Moving this technology into the market will be highly dependent on the success of field testing.

- Participation in the Lab-Corps program appears to have provided a good heat start on commercialization. They have spun out a company to commercialize the device. They have been successful with follow-on funding including funding that will support field testing and possible use at military installations.

- The presenter well understood the stakeholders, and the project was carried out through collaborative efforts among industry, academics, and national lab.

- + Many Lab-Corps interviews 80+.
- + Potential CRADA with USG is positive.
- - No discussion of if these were potential customers, stakeholders or potential commercial partners.
- - Concern is that focus is on making startup successful instead of engaging and landing a solid commercial partner.
- - If startup is best option, than this is an indication that commercial partners view this technology is in development and "pre-market", which reinforces the risk and long timeline of this technology.
- - Fact that USG CRADA limited to R&D indicates possible lack of applicability and/or risk of technology for commercialization.
- - Industry partners for commercialization other than startup minimal.
- - Not sure what USG did other than commit to initiate discussions for a CRADA.

E. Proposed Future Work

This project was rated **2.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Next steps do not adequately address technology development, testing, demo, etc.

- Upcoming DoD testing will offer opportunity to identify and solve any unanticipated barriers.

- Next steps mostly center around field testing and commercialization, which seems about right. It is not clear whether all of the technical hurdles (in a lab setting) have been cleared. There will certainly be additional technical challenges (noise rejection, etc.) encountered during field testing.

- The future work is mostly on the commercialization plan, but benefit for users must be identified to persuade customers.

- - Initial field tests only in last quarter of project.
- - Only significant external collaboration with partner is a CRADA projected to be executed in the last quarter of project.
- - No indicated joint development effort for commercialization, just a proposed R&D commitment going forward after project is finished.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- A non-invasive, cost-effective method to measure envelope infiltration in commercial buildings is sorely needed.

- I think that the market is certainly looking for a better way to quantify and diagnose infiltration issues, particularly one that could be used at various stages of construction.

***Average*: 3** reviewer
- Need to see additional proof of need for technology and technology's capabilities before a score of "high" can be given.

- I could see that the proposed technology has comparative advantage over the blower door test by removing inconvenience, but the evaluation of air leakage through hole identification must be performed to fully replace the conventional method.

- - Still in lab development after three years.
- - Not clear it will work in the field.
- - Long development time going forward.
- - No development partner committed to commercialization part of the program.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- Emphasis on technology development is important.

- It appears that building infiltration studies are receiving sufficient emphasis.

- The need for convenient infiltration measurement and the impact of infiltration were well explained.

***No*: 2** reviewers
- Field testing earlier in the project would have been beneficial.

- - Should have gotten industrial partners much quicker.
- - Too much emphasis on lab work.
- - This project was either too early to fund or too much emphasis was placed on internal efforts instead of external engagement.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Very innovative and impressive results to-date. Could have high impact on industry.

- Great science and technical development - concerns about lack of field testing earlier in the project.

- The device is a novel approach to infiltration measurements that has many advantages over current methods. They have recognized the market barriers and have focused effort on extending the basic idea to be more viable as a commercial product. They have achieved visibility with potential customers and have secured follow-on funding.

- The presentation covers well about market barriers and proof of concept was accomplished.

- + Clever method to measure infiltration.
- + Substantial progress to develop the method to detect small leaks.

2) **Project Weaknesses**

- Need to consider market in future development. Need to do parametric studies to understand what factors influence performance (e.g. size of room, environmental conditions, size of crack, etc.).

- Lack of field testing to date.

- It is not clear that the impact will be as great as they are stating. The actionable results of acoustic testing will may not have a significant impact on the primary infiltration sources. The acoustic method may not be generally applicable for all geometric features encountered in a building.

- The pathway toward energy saving potential with the help of this technology was not clear.

- - Method not at the level to do field trials after three years in development.
- - Further algorithm development is necessary.
- - Substantial challenges may be ahead once field trials are initiated.
- - First markets (military) will not have a substantial impact on BTOs programs.
- - Commercial partner is only looking at a CRADA for use as an internal R&D tool.

3) **Recommendations**

- Consider how to do additional in-the-field testing.

- None.

- No additional recommendations. This device / idea will sink or swim in field testing (which they have planned).

- Scalability of the proposed technology can be presented by showing coverage area per hour or so.

- - Project should have developed industrial partners much earlier. There has been too much emphasis on lab work without any preliminary field testing.
- - This project was either too early to fund or too much emphasis was placed on internal efforts instead of external engagement.
- - Future activity should focus on field testing just to get an idea of the unknown challenges that may be encountered.
- - Need to find an industry partner for field commercialization not just an R&D commitment.

Project # 31395: R25 Polyisocyanurate Composite Insulation Material

Presenter: Kaushik Biswas, Oak Ridge National Laboratory
DOE Manager: Sven Mume

Brief Summary of Reviewer Comments

One reviewer pointed out that the cost effective improvement of insulation with a minimum thickness increase was an important BTO goal. Another noted that the energy savings potential of this project's improvement to insulation was very large, and that focusing on cost reduction was critical and relevant. In contrast, a third reviewer remarked that it was not clear that a product of this type was necessary. This reviewer also noted that it was not clear that the manufacturing process could produce panels with a low enough failure rate to be cost-effective.

One reviewer noted that the economic and technical targets of the project were well explained, but that they were not fully persuaded why the proposed method would lead to reduced cost. Another reviewer noted that the primary market barriers of cost and performance degradation were identified, but reviewer also thought that there could have been more details provided on the plan to reduce the cost in the composite, noting that relying on economies of scale might not be sufficient. A third reviewer agreed there was a sound project approach to economic analysis and developing and testing materials, but this reviewer noted that since damage to the panels was a critical market barrier, the approach would benefit from additional work focused on how to better protect the panels. A different reviewer commented they would like to see an economic evaluation of the end user value-proposition before more work was done on the manufacturing trials. One reviewer stated that Lab Corps interviews yielded key insights, but that it was surprising how few production samples had been produced so far.

Multiple reviewers commented that the project had met impressive technical goals in terms of R-value results. A few reviewers expressed concern around cost, however, noting that final deliverables around cost projections at scale would be critical in assessing the impact of the project. Additionally, some reviewers noted that durability, and issues related to cutting panels in the field, needed to be resolved. One reviewer was also concerned about the willingness of partners to invest in a new production line.

All reviewers agreed that there was great collaboration with industry partners, with one reviewer noting that the partners were leaders in their industry. Another reviewer said that the project team needed to better consider how to influence and inform the people doing the actual installation and/or improve the product, in order to minimize damage in the field. One reviewer noted they would have liked to see more evidence that Firestone saw an economic opportunity in creating these composite panels.

Two reviewers agreed with the project's next steps of focusing on cost reduction and, in the long term, performance degradation and manufacturing defects. Another noted that there needed to be better focus on overcoming barriers. One reviewer said that manufacturability of the proposed material would be key, since the damage was already happening at a prototyping stage, which is supposed to have better quality control than mass production.

Weighted Average: 3.06 # of Reviewers: 5
Relevance: 3.00[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 3.30 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Energy savings potential is very large. Focusing on cost reduction is critical and relevant.
- Not clear that a product of this type is necessary. I'd like to see additional market and cost information on various use-cases. It's not clear that the manufacturing process can produce panels with a low enough failure rate to be cost-effective.
- The project seeks to develop improved insulation composite using modified atmosphere insulation panels. Such a material would reduce heat loss / gain through the building envelope.
- The project explores Polyisocyanurate composite insulation material with modified atmosphere insulation to combine favorable features of PIR and modified atmosphere insulation.
- - Improvement of insulation with a minimum thickness increase in a cost effective manner is an important BTO goal.

B. Approach

This project was rated:

1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **2.80** for the degree to which the approach addresses the market barriers identified.

- Sound approach to develop materials and test them. Good approach to economic analysis. Since damage of the panels is likely the most critical market barrier (besides cost), the approach would benefit from additional work focused on how to better protect the panels.
- I would like to see an economic evaluation of the end user value-prop before more work is done on manufacturing trials.
- The primary market barriers (cost, performance degradation / modified atmosphere insulation failures) are identified. They identify a large gap between the required (market-driven) and (manufacturing) expected costs. There could be more specific details on how they plan to reduce cost in the composite. Relying on economies of scale (as they move to higher production volume) may not be sufficient.
- I was not fully persuaded why the proposed method can lead to reduced cost, but the presenter well explained the economic and technical targets of the project.
- + Project directly addresses major market barriers: cost, performance, durability.
- + Lab Corps interviews yielded key barriers/insights: "reckless roofers" & avoided costs with thinner insulation.
- - Solution to robustness and durability of panels still needs to be optimized.
- + Progress: good technical progress; Good use of demo on manufacturing line. Already learning and addressing problems caused in manufacturing.
- - Only surprise was the small number of production samples made at this point.
- - Cost barrier still needs improvement.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.80** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Impressive R-value results. Important insight to modified atmosphere insulation damage. Impressive techno-economic analysis.

- Concerns about high failure rate and willingness of partners to invest in new production line.

- They have met the goals on the technical side (R12/inch). Even if the modified atmosphere insulation composite demonstrates superior insulation characteristics, the project won't have much large-scale impact unless the panels can be produced at a price that the market will pay. The final deliverables around cost projections at scale will be critical in assessing the impact of the project.

- Return on investment or payback period can be presented to engage more people with adopting the new technologies.

- + If can overcome panel durability concerns, project will make significant contribution to program goals.
- - Good understanding of issues. Was a bit weak on cost dynamic.
- - Durability and cutting panel in the field need to be resolved.
- + Expect that the project will develop a market ready product based on progress and focus on remaining issues.
- - Significant contribution to interim market goal will not be achieved unless there is radical improvement in cost as goal is a $0.35/square foot installed cost premium.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Great partnerships. Need to better consider how to influence and inform the people doing the actual installation and/or improve the product such that damage is minimized.

- Good collaboration with industry partners. Would like to see more evidence that Firestone sees an economic opportunity in creating these composite panels.

- The level of direct collaboration with the manufacturers is really good. This is critical since cost will likely be the main market barrier for this product.

- Many stakeholders were interviewed to identify practical barriers. Contribution from key collaborators could have been better elaborated.

- + Very good collaboration with industry partners. Best I saw in presentations.
- + All industry partners are leaders in their field with an established market presence.
- + Good cooperation as trial panels already produced on a manufacturing line.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Well-conceived future work plan.
- Need better focus on overcoming barriers; many risks are not addressed in future plans that threaten the achievement of project or BTO objectives.

- Next steps focus on costs and cost reduction which is the primary concern. Longer term concerns like modified atmosphere insulation performance degradation and preventing manufacturing defects are included in their future work. These are additional market barriers; I agree that they are not as pressing as cost.

- Manufacturability of the proposed material will be the key for the success. The damage already happened at a prototyping stage, which is supposed to have better quality control than mass production stage. Methods to enhance the rigidity of the composite structure or quickly detect defect should be explored.

- Field testing at very end of project. Little/no time to correct if not successful.
- Looks a bit weak on content. Predominately automation CAPEX exercise. Only $200K allocated for 2017, so this might reflect the light effort.
- Need more optimized cost but a sustained cost down focus to get over this key market barrier.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- High value project for technical and techno-economic reasons.

- If the cost-effective defect-free manufacturability can be proved, this technology can make an immediate impact.

- Product performance is clear. Grade is based on achieving a reasonable price point for the product. Grade goes down to Above Average if price point is high.

***Average*: 2** reviewer
- It's unclear that this product can be manufactured cost-effectively and that it offers an envelope solution that is appreciably better than what currently exists in the market.

- I think an improved insulation material would be well received in the market. Particularly for retrofit applications, there certainly is value in reduced insulation thickness to avoid changes to other parts of a building exterior. This product would only be appreciated in the market if it can be delivered at a competitive price. I think there is still some progress to be made on cost.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- The project is well-conceived to achieve high impact.

- Modified atmosphere insulation panels provide an effective approach to improved insulation materials and there is a potential for them to be produced at competitive cost. I think there is appropriate focus on

modified atmosphere insulation for advanced insulation. I believe that funding is appropriately aimed at unique modified atmosphere insulation configuration / implementations and at driving down cost.

- The presenter aligned the approaches well with the challenges set by BTO.

- In general key areas are seeing sufficient emphasis. I'd reiterate a more intense cost focus. Expect that commercial partners know this already but would like to see this more emphasized in project plan and activities.

***No*: 1** reviewers
- Concerns about failure during manufacturing and perceived market need.

H. Additional Comments and Recommendations

1) **Project Strengths**

- High potential impact given high R-value and low cost. Good technical characterization. Good partnerships.

- Technically complex, nice-to-have, but not necessarily can't-live-without envelope component.

- The composite concept with polyiso is a good approach to utilizing modified atmosphere insulation panels in a relatively robust installation configuration. The strong emphasis on manufacturing and costs is appropriate given the cost challenges associated with displacing existing insulation materials. The development of an in-situ manufacturing test to look for modified atmosphere insulation defects is a plus. Natural weatherization tests are good, but it would be great to see the results over a longer period of time to look for performance degradation (they have this planned as future work).

- Project has achieved its technical goal, and demonstrate good understanding on the barriers for the stakeholders.

- + Good approach to using modified atmosphere insulation in a board product to increase R value.
- + Choice and engagement with manufacturing partners has been excellent.

2) **Project Weaknesses**

- Need to consider how to address potential damage issues more.

- Not clear that a product of this type is necessary. I'd like to see additional market and cost information on various use-cases. It's not clear that the manufacturing process can produce panels with a low enough failure rate to be cost-effective.

- Cost of the composites was a known challenge going in. Maybe there was a potential for cost reduction through design changes. They focus largely on manufacturing approaches and economies of scale to bring down cost.

- It is uncertain how the project can achieve the target price other than mass production. More detailed cost analysis could have strengthen the presentation.

- - Would like to see an increased focus on material cost down efforts. Price point will drive the attractiveness of this product. Building products that depend on an avoided cost argument don't normally get full credit for the avoided costs. Cost is the most tangible driver for product choice.

3) **Recommendations**

- None.

- None.

- No additional recommendations.
- Is there any theoretical analysis on the expected insulation performance and mechanical rigidity of the composite structure? I am wondering if this project can provide a transformative theory, so that mechanical and thermal properties can be engineered for different application.

- See above.

Project # 313109: Novel Infiltration Diagnostics based on Laser-line Scanning and Infrared Temperature Field Imaging

Presenter: Xinwei Wang, Iowa State University
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers were mixed on this project's relevance to BTO's goals. One reviewer thought this project *mostly* aligned with BTO's goals with respect to energy reductions enabled by the development of methods to determine where infiltration occurs. Another reviewer acknowledged that exploring new infiltration diagnostic technologies would not lead directly to reduced energy consumption, but could accelerate the adoption of new air barrier materials. In contrast, two reviewers commented that it was difficult to determine the project's degree of impact on the market, though infiltration *was* a problem worthy of study and innovation. Another reviewer went so far as to say they had difficulty seeing the relevance of the project, since the percentage of the overall infiltration of small leaks was unclear.

Many reviewers agreed that the project's technical approach to diagnosing infiltration spots was excellent. Multiple reviewers also agreed, however, that market barriers needed to be further identified and addressed, even in such an early stage project. Additionally, a few reviewers questioned whether these small holes, in the aggregate, were significant enough to impact energy consumption. There were concerns about how readily the project's method would translate to real-world conditions, specifically looking at a scanning rate high enough to be practical as a product.

Reviewers agreed that the project had made progress in terms of technical development, but also agreed that the market barriers and the overarching question of whether addressing these small leaks was necessary were still issues that needed to be addressed. One reviewer noted that the current final deliverable was unclear and should possibly be rewritten. This reviewer was not clear whether the final deliverable was a *method* that could be used in the field (if someone would build the instrument) or the *instrument* that performed the measurement cost effectively and accurately in the field.

Reviewers noted that there had been little to no collaboration so far in the project. Reviewers expressed concern, even at this early stage, at the lack of industry engagement. One reviewer suggested Lab Corps as an avenue to identify both market partners and market drivers for this project, two main barriers that reviewers agreed should be addressed.

Multiple reviewers noted that future work should focus on market barriers. Another noted that future work should move away from testing different wall types and toward the scalability of the proposed technologies. One reviewer suggested focusing on multiple questions, including looking at where small leaks tend to occur, the cause of the leaks, the percentage of overall leakage in the envelope, how to plug the leaks, and if the process would be cost-effective.

Weighted Average: 2.05 # of Reviewers: 5
Relevance: 2.40[1] Approach: 1.90 Accomplishments: 2.40 Project Collaboration: 1.60 Future Work: 2.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- While infiltration is a problem worthy of study and innovation, this approach may not have significant impact on the market.

- Without knowing what percentage of overall infiltration/exfiltration these small leaks represent and how much impact they have on increasing building energy consumption, I have difficulty seeing the relevance of this project.

- The project seeks to develop a unique diagnostic for building infiltration detection. Infiltration leads to additional energy required for heating and cooling. The proposed method may have some impact on building infiltration; the degree of impact is questionable at this phase of the project.

- The project explores new infiltration diagnostic technologies. Although it does not lead to reduced energy consumption, it can accelerate the adoption of the new air barrier materials.

- + Mostly aligned with respect to energy reduction goals by developing methods to determine where infiltration occurs, which may make users more apt to engage in air infiltration reduction.
- + Directed to addressing the lack of a suitable measurement technique for air infiltration, especially in commercial buildings.
- - Only misalignment would be challenge of designing and using a complex method (e.g. executing the vapor work in the field), which could limit market impact.

B. Approach

This project was rated:
1) **1.80** for the degree to which it focuses on critical market barriers, and
2) **2.00** for the degree to which the approach addresses the market barriers identified.

- Sound approach to diagnosis of infiltration spots, however not much insight is presented on how large of an infiltration hole actually matters. In other words, perhaps such small holes are insignificant, even in aggregate, compared to the larger infiltration areas (such as where joints meet).
- Time for scanning seems too long to be attractive to the market.
- Seems like a solution searching for a problem.

- Technical approach is excellent. I question whether the results of this research has a practical application. While this approach allows you to identify smaller holes, do those holes contribute appreciably to increased energy consumption? Is it enough just to repair the larger leaks that can be identified with a standard blower door/thermal imaging test?

- The presentation does not address market barriers. There was some discussion of market barriers (scan rate, etc.) during the talk. The project is still in the relatively early stages, but more attention needs to be focused on identifying and addressing market barriers.

- The technical approach is sound, but the approach did not address what kinds of market barriers can be overcome. Moreover, the relation between the hole size count/distribution and infiltration performance should be defined to justify the need for the proposed techniques.

- + No good way to do quantified infiltration measurements in commercial buildings is recognized.
- + If effective, inexpensive and quick methods to do infiltration measurements were available, there is a high expectation that infiltration requirements would be added to commercial codes.
- - Doesn't have an industrial partner or significant customer overall.

- - "Doesn't know what he doesn't know" at this point (i.e. no field tests yet), however still early in project so can recover.
- + Proposed method may be effective in measuring infiltration.
- - Proposed method appears neither fast nor inexpensive.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Holes detected, but again, there seem to be key questions not being addressed such as the size of the hole that needs to be detected and/or scan time and/or whether or not the market will actually be interested in such technology (i.e. even though it has a higher resolution than infrared imaging, will the market care?).

- Great science and technical development - question whether addressing these small leaks is necessary.

- The project has shown some progress in terms of proof of concept for the diagnostic approach. The method will only have impact on energy usage if it overcomes market barriers. More needs to be done to address market barriers.

- The presenters could have better elaborated how this project can lead to the mission of BTO for energy saving. Technical feasibility was well presented, but the economic competitiveness of the technologies should have been well elaborated. Applicability of the technology in the real scale building is rather questionable. The presenter suggested that the scalability issue can be addressed by using a line laser scanning, which will add the cost significantly.

- + Method may be a way to encourage more infiltration work than is done today, thereby support program goals.
- + Project has detected small leaks in the lab.
- - Appears vapor application will be necessary for sensitivity.
- + Focused on correct goal, improving infiltration location and quantification.
- - Effort or technique addressing very small holes may not be the major contributor to overall infiltration rate.
- - Only 75% detection at lab level, would be lower in field unless dramatic improvement.
- + Early in the project.
- + Scanning system operating, but smaller scan area and time to scan (60 m2/hr) may limit application.
- - Direction with misting may be a step back (i.e. becoming too complicated).
- - Not sure how easy this will be to implement in the field based on complexity.
- - Laser warming only didn't work sufficiently, so redirection was necessary.
- - Appears to be quite a way from an integrated effective field instrument (still in method development, no validation yet, still in the lab, no field test results yet).

D. Project Integration and Collaborations

This project was rated:

1) **1.80** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **1.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- While the project is still at an early stage, there still needs to be contact made with market players to understand how best to develop the technology to help ensure market acceptance and applicability.

- No comment.

- There is currently no project integration effort. Even though the project is in the early stages, it would be good to articulate a plan for (future) project integration. In order to get this diagnostic into the market, some integration and industry collaboration will be required. Something like the Lab Corps might be helpful in identifying the market drivers for such a product.

- No strong evidence of collaboration could be identified. Plans for approaching stakeholders are strongly recommended.

- - Didn't identify any industry partners.
- - Didn't discuss customers or stakeholders. Seems too isolated in lab at this time.

E. Proposed Future Work

This project was rated **2.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The future work does not address critical market-related questions.

- I suggest that the project pivots to determine:
    - Where these small leaks tend to occur in the envelope?
    - What is the cause?
    - What percentage of overall envelope leakage do they represent?
    - How would the leaks be plugged?
    - Could this process ever be cost-effective?

- Future work follows on with additional lab proof-of-concept tests. There should be more emphasis on market barriers.

- The future plan is not based on the lessons learned from the tasks performed in the previous months. Considering short period of time, the researchers have made significant progress toward technical feasibility. As the major barriers would be the scalability of the proposed technologies, the future plan would better address how to overcome this challenge, rather than testing different type of walls.

- + Has a clear plan for second half of Year 1.
- - Didn't discuss future plans.
- - No information on Year 2.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 0** reviewers
- N/A

***Average*: 1** reviewer
- If they can make it work, there would be significant value in having an alternative to blower door tests for infiltration measurement. There are significant doubts that this approach would work for an actual building.

***Low*: 4** reviewers
- See weaknesses.

- See comments on project weakness.

- The benefit from the building owner's perspective would be helpful to justify the need for the new diagnostic techniques.

- - Very early in project so hard to assess. Need to see what the final instrument looks like and its effectiveness.
- - Rating is based on the current stage of the project (i.e. a lab based instrument) as it was not clear to me if the project's final deliverable is a method that may be used in the field (if someone would build the instrument) or an instrument that does the measurement cost effectively and accurately in the field. Maybe the Project Outcome statement for this project should be reworked.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 1** reviewers
- Projects tackling building infiltration and infiltration diagnostics are receiving sufficient attention.

***No*: 4** reviewers
- It is unclear what impact this project will ultimately have on energy savings.

- First question to be answered - is there a need for this technology?

- Although the project is at its early stage, market impact can be qualitatively evaluated. Due to this deficiency, the project sounded like pure basic scientific research project, which is also important for advancing our understanding on physics. However, impact on the building energy saving still remains questionable.

- - Need industrial engagement quickly to focus project on what would be successful in the field and marketplace.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Interesting approach to finding infiltration issues.

- Great scientific investigation, question whether addressing small leaks in the building envelope will ever be a cost-effective measure when you stack it up against other building energy efficiency measures.

- The approach provides an alternative to blower door tests. The basic concept has been proved in the lab.

- Proof of the concept was well demonstrated.

- + Addressing measuring location and quantifying air infiltration.

2) **Project Weaknesses**

- Again, the project is not considering the applicability and market barriers. A study must be done to understand the extent to which infiltration at these scales is important to detect.

- Put the cart before the horse and developed a solution to a problem that may never need to be addressed.

- There are concerns about how readily this method will translate to real-world conditions. It doesn't appear to have a scanning rate / throughput high enough for the method to be practical as a product. There is no focus on market barriers such as this. The project doesn't appear to have any motivation to get beyond a lab demonstration.

- Need for the hole size/distribution measurement must be provided. Questionable scalability of the proposed technologies.

- - Needs to engage a key stakeholder (e.g. equipment manufacturer) who will commercialize the instrument.
- - Needs feedback from current industry infiltration measurement firms on method, key issues/concerns, need, etc. Doesn't seem like the normal project prework was done sufficiently.

3) **Recommendations**

- Make connections, hold discussions with market players. Discuss infiltration with leading building scientists. Then, you may consider new directions to help ensure market applicability and acceptance.

- I suggest that the project pivots to determine:
    - Where these small leaks tend to occur in the envelope?
    - What is the cause?
    - What percentage of overall envelope leakage do they represent?
    - How would the leaks be plugged?
    - Could this process ever be cost-effective?

- Define the market barriers and then come up with a plan to address them.

- Speed of measurement, such as square feet coverage per hour, would better be tested. Cost competitiveness of the proposed technologies over conventional blower test could be helpful.

- Engage an industrial partner whose business is infiltration measurement to calibrate project.

Emerging Technologies
Solid-State Lighting

Project # 33111a: Stable, High Efficiency White Electrophosphorescent Organic Light Emitting Devices by Reduced Molecular Dissociation

Presenter: Steve Forrest, University of Michigan
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Each reviewer affirmed that this project's novel approach and "radical new strategies" for improving the durability and performance of blue phosphorescent organic light emitting diodes (PHOLED) were relevant to BTO's mission and to the solid-state lighting (SSL) subprogram's goals.

Every reviewer commented on the novelty of the project's scientific approach to discovering new classes of materials that could resolve the inherent, reduced longevity of today's blue PHOLEDs. This approach, described by reviewers as systematic and multifaceted, yielded significant beneficial results that would lead to a better understanding of the physics and chemistry involved. One reviewer thought that using excited-state sinks to protect the PHOLED from dissociation and decomposition introduced many challenges, but that effective molecular design and clear understanding of the science involved helped them achieve success. Reviewers agreed that the project showed significant achievements and early-stage progress, but two reviewers noted that this basic R&D project still had a ways to go before the technology met BTO's cost and efficiency goals—critical to overcoming market barriers for PHOLEDs—and could be commercialized.

Two reviewers described the collaboration among the project's partners as closely coordinated, and noted that strong communication contributed to a coherent project with significant results. According to reviewers, the team's next steps were clear and followed a logical progression, though one reviewer did note that the project lacked a risk mitigation plan if the robustness of the project's approach to stabilizing PHOLED's eventually wavered. Several reviewers concluded their remarks by reiterating that commercialization remains far away, despite the team's success to date.

Weighted Average: 3.48 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.50 Accomplishments: 3.17 Project Collaboration: 4.00 Future Work: 3

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Stable, high efficiency white phosphorescent organic light-emitting devices are highly relevant to BTO's mission.
- Addresses indirectly the challenges of high cost and, more directly, of performance deficiencies by aligning with strategy #1 Improve performance.
- Project focus of developing methods to increase the lifetime of blue PHOLEDs overlaps well with the SSLs MYPP goal for white OLEDs.

B. Approach

This project was rated:

1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The approach of using excited state sinks to extending OLED lifetime is novel. However the result is still far from the MYPP goal.
- Scientific and systematic approach, with clearly stated outcomes. The approach is novel to address a fundamental issue of blue PHOLEDs by introducing excited state sinks (hot state managers) to protect the PHOLED from dissociation.
- OLED durability identified as a critical market barrier, which it is. Cost and efficiencies also indicated as market barriers. Both were stated to improve with increases in lifetime. Multifaceted approach seeking novel dopant/host pairs, novel addition of "manager molecules" to reduce host decomposition and later include these managers into stacked OLEDs. Clear understanding of energetics and orbital overlap needed for effective manager candidates. Effective molecular design approach to tune target manager molecules. Novel approach to directly prevent/minimize host decompositions.
    - For manager concept to be successful, many properties/variables need to be satisfied simultaneously: proper energetics, sufficient molecular overlap, manager molecule compatibility with dopants and hosts, long term manager durability (i.e. it can't be degraded itself), etc. This complexity increases the challenge of finding a proper solution.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team has demonstrated that introducing an excited state sink into a blue PHOLED can extend its lifetime 2X. However the result is still far from MYPP goal. Not sure if this technology could get into market.
- The project showed significant achievements: demonstrated that the proposed approach (using manager molecules to protect the OLED as opposed to doping and hosts) is sound and beneficial, identified

fundamental required properties of the managers, found the optimal positioning of the managers, applied modeling of degradation paths for predicting PHOLED lifetime, identified dissociation products, developed a new, alternative class of robust, high triplet energy hosts, showing that blue PHOLED degradation is not related to increased leakage of excitons and charge. It was also shown that iridium based managers also exhaust in time and thus decrease their protection properties.

- Project has shown significant early stage progress. Completed graded blue PHOLED with EQE >15% and LT70 > 3000 hrs. Managers have shown significant improvement in lifetimes of blue PHOLEDs. Lifetime improved 5.2x over conventional devices and 3.0x over graded devices when the managers were placed at the position of highest exciton density. EQEs of blue PHOLEDs with optimum located managers increased to 9.5% over 8.0% for conventional devices and 8.9% for graded devices. Novel host system developed with good energetics with better stability. Triplet annihilation model consistent with optimum manager position and also host decomposition products. Decomposition of Ir-based managers was observed leading to consumption of the manager over time.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- This team consists of three organizations which includes University of Michigan, USC along with an industry partner Universal Display Corp.

- Two universities (U Michigan and U Southern California) and one industrial partner (Universal Display Corp) closely worked together, with clear individual tasks. UM was the coordinator. The individual tasks were well coordinated contributing to a coherent project and significant results.

- Presenter is a leading expert in the field with a thorough understanding of the stakeholders and issues. Very strong project team combining synthesis experts, modeling, device fab and testing group and a major OLED commercial partner. Close coordination and communication between partners with weekly meetings between UM and USC and quarterly meetings of both at UDC.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The team has a clear plan for next steps:
    - They will continue to find out the weakest bonds to guide new material development.
    - They will continue to develop new, high triplet energy hosts and managers.

- The project is close to its completion. The next steps continue on the paths that have been opened.

- Plan does build directly on past progress. Focus on key issue of manager development to resolve degradation issue. Project progressing from manager proof of concept lifetime increases to lifetime validation scaling. Continue development of robust manager candidates and new hosts. Risk mitigation plan if manager candidates fail to be robust not apparent.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The project audience is the PHOLED industry, which, compared to other SSL technologies, is less developed. This is a project with high scientific value.

- The stable high efficacy blue OLED result along with the manager proof-of-concept durability improvement show significant OLED material progress.

***Average*: 1** reviewer

- Not sure if this technology can be commercialized. The project seems very basic.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- *No Comment*

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- This project pursue radically new strategies by introducing excited state sinks for increasing the lifetime of blue phosphorescent light emitting devices.

- This is a strong, fundamental chemistry/physics research project which aims to overcome the issue of reduced longevity encountered by blue PHOLEDS. The approach is original and yielded significant results, leading to a better understanding of the physics and chemistry involved, as well as leading to the development of solutions that can be used in the near future in practice.

- Excellent team with novel approaches to increase durability and improve OLED performance. High quality fundamental science approach to identify mechanisms and use molecular level understanding to discover new classes of materials that resolve key technical issues. Good commercial partnering for result validation at the manufacturing level.

2) **Project Weaknesses**

- The scope of this project is more oriented towards basic science. It seems still far from hitting the target for commercialization.

- It may take a while for the project results to be directly applied in the production of PHOLEDs.

- A risk mitigation plan if manager degradation cannot be solved was not evident.

3) **Recommendations**

- It is not clear whether this technology could be commercialized. The study is very basic.
- Excellent project and impressive results.
- None.

Project # 33111b: Materials and Designs for High-Efficacy LED Light Engines

Presenter: Paul Fini, Cree Inc.
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project was relevant to BTO's goals, although all reviewers were concerned that the project's findings would not be sufficiently shared within industry, and one reviewer remain unconvinced that the project was relevant to the solid-state lighting (SSL) industry beyond Cree. Another reviewer followed this logic, remarking that Cree's relatively small cost-share could be seen by the SSL community as a subsidy of the firm's product development rather than an attempt to accomplish BTO's goal of providing the private sector with access to already-validated solutions.

One reviewer believed the project's approach was effective and practical, addressing the critical market barrier of performance improvement. One reviewer expressed concern, however, that the high-cost market barrier was not directly addressed, and that electric current density data from reliability tests did not allow for comparisons with other narrow-band downconverter synthesis approaches or other products on the market today.

Reviewers stated that Cree's project had made good progress, though with some disagreement on the specifics. One reviewer believed that accelerated reliability testing showed the color point change to be a good indicator of stability and lifetime. Another reviewer disagreed, however, claiming that successful accelerated testing had not yet been demonstrated on the improved product, and that no information had been provided to discern if the improved product was stable under Cree's LED manufacturing conditions.

Reviewers substantiated the relatively low marks they gave this project for integration and collaboration by noting that Cree conducted this research alone, without any external collaborators. All three reviewers identified this as the project's main weaknesses and asked for greater dissemination of the project's findings within industry and in public literature, saying the existing workshop presentations were too limited in scope.

The reviewers generally agreed that the project's future plan would build on recent progress, but one reviewer thought that it was not clear if the tasks addressing increased efficacy would include a passed durability test.

Weighted Average: 3.07 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.67 Accomplishments: 3.00 Project Collaboration: 2.33 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The objective of this project is to develop new narrow-band down-converter materials to enable white solid-state lighting.

- The project addresses the challenge of performance deficiencies by aligning with strategy #1 Improve performance and reduce manufacturing costs.

- Project looks to add a drop-in red narrow band downconverter (NBD) to replace the red phosphor. Project focus is for the white LED with the NB to have a 10-20% improvement in efficacy while not affecting LED reliability. Project will demo the improved LED in a demo luminaire with greater than 150 lm/W and at least 90 CRI. Higher efficacy and the development of stable and robust red NBDs support the SSLs LED cost and performance improvement goals.
    - This project is run by a single manufacturer without any external collaborators or partners and is focused on improving the firm's products. With a limited disclosure of results, it is not clear that this type of structure supports ETs SSL Subprogram Short Term Outcome "Private sector has access to validated solutions to develop or improve technologies & reduce cost".
    - The project has a DOE contribution of $1.5M with only a 20% cost share. So this could look as a $1.5M subsidy of the firm's product development without a communication requirement to the rest of the SSL community beyond SSLs R&D workshops. This does not seem to support the "private sector has access to validated solutions" goal.

B. Approach

This project was rated:

1) **3.67** for the degree to which it focuses on critical market barriers, and
2) **3.67** for the degree to which the approach addresses the market barriers identified.

- The team uses an approach that synergistically combine advances in materials synthesis, light engine configuration & processing, and reliability. The approach seems effective and practical.

- The approach was to combine synthesis and post-synthesis treatments, light engine configuration and processing, as well as accelerated reliability testing to develop new red emitting narrow-band down-converter materials with higher efficacy compared to current phosphors. The project used systematic development and testing approaches to achieve reliability and efficacy, considering that the two objectives cannot be simultaneously optimized.

- Critical market barrier of performance improvement in a stable product is supported and addressed in the plan. High cost market barrier is not addressed directly. High project focus on reliability and accelerated testing is a good approach.
    - It appears that the project is focused on low to medium power LEDs. Thermal droop is considered, however current droop is not. The only current information presented was "stress current" (baseline, 3x baseline and 7x baseline) in the reliability tests without an indication of the actual current density. This does not allow for a comparison between project reliability results and current products in the market or to other red NBD approaches.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Good progress has been made on new NBD synthesis that is promising.

- Each dimension of the multidimensional approach showed accomplishments. Material synthesis (composition purity, morphology, post treatment) influences both the efficacy and the long-term reliability. Thermal droop is important to be included as part of the final product. Accelerated reliability testing showed that color point change is a good indicator of stability and lifetime.

- A 10% efficacy improvement has been demonstrated in the lab, which roughly half of the SSL warm-white interim market goal.
    - Successful accelerated testing has not yet been demonstrated on the improved product.
    - No information if the improved product is stable under firm's LED manufacturing conditions.

D. Project Integration and Collaborations

This project was rated:

1) **2.67** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Cree is the sole member of this project. No collaboration with others.

- The project only involved one company (CREE) with no external collaborators; the only collaboration was done between the R&D group and the product development groups (located on opposite coasts).

- Presenter has a clear understanding of the subject matter and a very good understanding of the key market barrier for a successful LED product. Project has no external collaborators or partners.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The team will continue the synthesis/package/REL cycle in the drive to create robust red-emitting NBDs.

- The project is close to its conclusion (6/2017); the tasks involve evaluations of packaged solutions and demonstrations, in addition to finalizing one of the most fundamental aspects of the project (finding the failure mechanisms). After project and future research are also proposed: production, fundamental understanding, and use of the same approach for other material systems (not detailed).

- Future plan does build directly on current work. It is not clear if the future tasks 4.3 and 4.4 that address increased efficacy include a passed durability test.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The approach seems effective and focus on improving product performance.

- The project market is the LED industry related to warm white lamps and luminaires. As such, the deliverables are of strong interest to this market, contributing to the competiveness of the US industry.

***Average*: 1** reviewer
- Internal only focus without partners. Not sure what fraction of the project outcomes will be relevant or accessible to the wider SSL community.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- The key research areas/deployment activities are well aligned with the program's objectives.
- The presentation detailed as time permitted the key research areas shown above.
- yes the are

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project is running by a leading LED manufacturer using an effective and practical approach.
- The project is very applicative and thus has the potential to be quickly used by the industry, especially by CREE. A combination of mostly technological, but also scientific advancements have been made in relation to the development of new NBD materials with improved efficacy and good reliability.
- Leading firm focusing on near term efficacy improvement that can be a drop-in to the current manufacturing process.

2) **Project Weaknesses**

- No collaboration and additional partners were involved in this project.
- The project has limited impact outside the awarded business; there are no clear plans to disseminate the new knowledge other than very limited workshop presentations.
- Internal only focus without partners. Not sure what fraction of the project outcomes will be relevant or accessible to the wider SSL community.

3) **Recommendations**

- More disseminations in public literature will be great. The only communication is DOE SSL R&D workshops.
- The project needs more significant dissemination to other US companies.
- Project structures where there are academic/industry partnerships or more transparent industry projects would increase the overall value of DOE's investment to their constituents. Would like to see a task directed to a combined efficacy and reliability goal.

Project # 33111c: Luminaires for Advanced Lighting in Education

Presenter: Lynn Davis, RTI International
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

All reviewers agreed on the project's relevance to BTO's goals, specifically the goal of improving network lighting systems to reduce energy consumption and extend applications of advanced lighting systems through demonstrations to meet unrealized design potentials.

The reviewers gave average scores for the project's ability to address market barriers. One reviewer commented that the use of a two-chip solution to achieve color tuning seemed effective. However, another noted that the presentation mentioned energy savings but never quantified them, nor did the presentation speak to affordability or to value proposition for the "cost-conscious" educational market identified by the project team.

Reviewers agreed that the demonstration project showed that tunable lighting could be a useful classroom tool while reducing energy, but one reviewer could not determine if the project did or would achieve its goals because the presentation did not address cost relative to performance. This reviewer also believed that significant marketing and outreach efforts—along with more demonstrations—would be necessary for market education. Almost every reviewer wished for more quantifiable data on the project's advantages, energy-related or otherwise.
All reviewers praised the collaborative efforts between project partners and teachers, although one reviewer was concerned that the project did not reach out to educational professionals responsible for procuring lighting, which made the system's value proposition hard to grasp.

The reviewers had few comments about future work because the project was ending shortly after the presentation was given, but one reviewer said that although teachers and principals were interested, more research would be needed to examine the benefits of tunable lighting in the classroom.

Weighted Average: 3.23 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.00 Accomplishments: 3.33 Project Collaboration: 3.33 Future Work: 3.33

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project looks into the next generation integrated classroom lighting system to reduce energy use in the classroom. This is well aligned with BTO's mission.

- The project addresses the challenge of Unrealized Design Potential by aligning with SSL strategy #3 Advance SSL technology and increase market penetration and strategy #2 Improve networked lighting systems to reduce lighting energy consumption.

- Application project in education that demonstrates a very flexible lighting environment that can assist teachers in optimizing the learning environment. Supports SSLs goal of extending applications of advanced lighting systems through demonstration projects.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The use of two-chip solution to achieve color tuning seems to be an effective way.

- The approach was to demonstrate the use of an LED package in K-12 school classrooms with significant, clearly defined performance advantages: energy efficiency, white color tuning, and luminous efficacy. The project investigated 111 luminaire design variations. After significant reductions due to performance constraints, with input from teachers, principals and facility engineers, they tested them in a demonstration site, in a system architecture which included a user control platform and interface.

- Project focused on system component development to provide a high efficacy, tunable and high CRI system for the educational market. Slides refer to energy savings but not quantified. No significant comments on the affordability or value proposition for the identified "cost conscious" educational market.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Promising results were achieved at the demonstration site.

- A two-chip solution, with tunable white color range between 2700K and 6500K, and high efficacy was developed. A system architecture, with volumetric lighting, two-zone daylight harvesting, plug and play architecture and offering over 22% improvement in energy efficiency compared to fixed CCT, as well as a user interface for control, with presets, were also designed. Preliminary testing showed that tunable lighting can be a significant tool in the classroom, while at the same time offering improved efficiency.

- Very good technical and design effort for the application. Supports the program intent to demonstrate integrated system capabilities for the office environment. No discussion of cost vs. performance, which is important to ultimate success to not only the interim goal but also long term implementations. If this effort is sufficiently supported with marketing and outreach, it will contribute to the program's goals. Hard to argue that it will have a significant contribution to interim goals, as cost/benefit is unknown and significant effort/demonstration will have to be expended for market education.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Excellent collaboration between RTI international and Finelite was demonstrated in this project.

- The project was the collaborative work between RTI International (non-profit organization, lead) and Finelite Inc, with some collaboration from Pacific Northwest National Lab. The collaboration lead to the development of a qualified made in USA product, cost effective and close to being ready for commercialization.

- Project did reach out to teachers, an important stakeholder group, to get input and suggest improvements to the controller design. During the process they also received valuable feedback on the need for teacher training on how to use the system most effectively. No indicated collaboration or contact with education professionals responsible for specifying and procuring educational lighting. As the educational segment is such a cost sensitive market, this key stakeholder group should have been consulted. Without this overlap it is not clear how much of a value proposition this system provides. Important partnering with firm committed to marketing and commercializing the system.

E. Proposed Future Work

This project was rated **3.33** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- More market feedback and product improvement will be done.

- The project will reach its conclusion at the end of March 2017. In terms of future work, it is acknowledged that, although teachers and principals showed great interest, more research is needed to examine the benefits of tunable lighting in the classroom.

- Project is essentially complete other than final project report.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- The NICLS will deliver direct value to the K-12 schools.

- The target audience are the users and providers of classroom lighting: K-12 schools, architects, contractors, SSL manufacturers. The results of this project are of high value and interest to this market.

- Executed on what was asked and delivered a system meeting the requirements. Partnered with a manufacturing partner committed to commercializing the system.

***Average*:** 0 reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The deployment activities are well aligned with the program's objectives.
- The presentation detailed as time permitted the key research areas shown above.
- Key research activities were focused and delivered a system that met or exceeded performance metrics. Grade is a Yes with reservations. By not addressing system cost, energy savings potential and value prop with key educational procurement professionals, it does not appear that the project's deployment activities were complete. As a consequence, SSLs goal of expanding the use of high performance lighting systems was not fully supported.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good site demonstration and potential market feedback.
- Excellent project, leading to the development of a US, competitively priced product and contributing to improved quality of the educational system. Excellent results dissemination through workshops, conferences, and DOE publications.
- Professional application of advanced lighting products in an education setting to not only save energy but also improve the teacher and student user environments. Project hit or exceeded key milestone performance metrics. Good outreach to teachers for user input in design and use.

2) **Project Weaknesses**

- Need more quantitative market feedback data.
- The advantages, other than energy efficiency, of using tunable light need to be quantified.
- Missed key stakeholder group input from those responsible for budget, specifying and purchasing the systems.

3) **Recommendations**

- It will be good to collect energy saving data.
- Apply project results to other markets: office, commercial, home.
- Would like to have seen cost and energy savings estimates made for the system. Would like to have seen a specific task to address developing an explicit value proposition for the system with feedback from education lighting purchasing professionals on the perceived value of the system.

Project # 33111d: Stable and Efficient White OLEDS Based on a Single Emissive Material

Presenter: Jian Li, Arizona State University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Each reviewer believes this project's use of simpler devices structures—namely the single-doped white organic light-emitting diode (WOLED)—is relevant to BTO's goals of reducing manufacturing costs, which one reviewer argued is one of the most significant market barriers for OLEDs.
The approach, reviewers agreed, effectively addressed key market barriers by simplifying device design. However, one reviewer wished for a more comprehensive task list for the project, rather than the partial list of project milestones that was presented.

All reviewers believed significant performance advancements—particularly in terms of stability and external quantum efficiency for blue OLEDs—demonstrated the viability of single-doped WOLEDs. One reviewer noted, however, that more efficiency and durability progress remained to be made to significantly contribute to the project's interim goal.
The reviewers gave high marks for the presenter's understanding of OLED stakeholders and issues, but two reviewers expressed confusion about how the project's tasks were divided between Arizona State University and Universal Display Corporation because the presentation lacked information on partner activities. One of those reviewers gleaned some information about the collaboration, but described the process of assessing the partnership as challenging, and ultimately could not determine the collaboration's extent.

While all reviewers acknowledged the project's future plans and believed progress would continue, one reviewer expressed concern that the project's progress has been behind schedule, and characterized the team's milestone performance targets as "aggressive," given that only three months were left and that some milestones would be unachievable without accelerated effort. This reviewer also seemed concerned about the lack of a visible risk management plan.

Weighted Average: 3.57 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.67 Accomplishments: 3.67 Project Collaboration: 3.50 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Stable and efficient white OLEDs are highly relevant to BTO missions.
- The project addresses the challenges of high cost and technical performance deficiencies by aligning with strategy #1 Improve performance and reduce manufacturing costs.
- Project focus on development of single-doped WOLED could significantly reduce the fabrication cost of WOLEDs. Reduced cost utilizing simpler device structures and reduced manufacturing complexity is an SSL OLED R&D focus for BTO under C.3.1 Fabrication Technology Research in the SSL R&D Plan.

B. Approach

This project was rated:

1) **3.67** for the degree to which it focuses on critical market barriers, and
2) **3.67** for the degree to which the approach addresses the market barriers identified.

- The approach of using a single emissive material is novel and effective.
- The approach is to develop single-doped white stable OLEDs by synthesizing blue-emitting square planar phosphorescent emitters and fabricating and then testing the single doped WOLED and blue devices. The advantages are related to simplicity (simpler structure, easier to manufacture and thus cost effective), robustness (voltage independent spectrum, no color-aging), and platinum based (more abundant compared to iridium).
- Cost, arguably one of the largest market barriers for OLEDs, is identified and cost improvement is the focus of the project. Durability limitations and low efficacy market barriers were also identified. The design objective of a single doped WOLED through the use of high efficiency stable square planar emitters would address the key market barriers by greatly simplifying device design. Although the presentation includes partial Project Plan milestones that indicate a logical progression, without the full task list it is difficult to fully evaluate the project approach.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Several new single emissive materials were produced and show promising results.
- The approach is scientific and rigorous, using both experimental and theoretical modeling. The project demonstrated the main components of the final product: excimer-based WOLEDs (both in terms of efficiency and stability) and Pt-based blue phosphorescent OLEDs (both in terms of efficiency and accelerated testing stability, comparable to iridium based OLED which are currently on the market). The final goal of the project has not been finished yet; the project is planned to end in June 2017. The achievements are remarkable in terms of OLEDs used for general lighting and show that single doped WOLEDs are viable.
- Project supports SSLs performance goal of reducing OLED costs through progress on development of a material system for single doped WOLEDs. As efficiency and durability of these systems need efficiency and durability improvements, project is not expected to significantly contribute to the interim goal.

Research although progressing is still early stage. Progress on the Pt systems show very good stability and EQE for blue OLEDs. Balancing monomer and excimer emission to yield WOLED in the Pd3O3 appear to reduce EQE relative to monomer alone. Will this also be an issue with the Pt systems? Project shows milestones hit late and future milestones are very aggressive. Can these be met on time with current effort or is some adjustment necessary?

D. Project Integration and Collaborations

This project was rated:

1) **4.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- This project involves collaboration between ASU and Universal Display Corporation.

- The project is mostly performed at Arizona State University, with one industrial partner Universal Display Corporation. It is not clear how the project tasks were divided between the two collaborators. The results were presented in publications, workshops, and conferences.

- Presenter has a keen understanding of OLED stakeholders and issues. Collaborator with partner was challenging to assess, as presentation did not have any partner content activities. During questioning presenter did admit that the performance of these systems with the partner's proprietary transporting and blocking materials improved substantially. So some collaboration has occurred, but the extent of collaboration and coordination could not be determined.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Team will optimize the efficacy and performance of the excimer-based WOLEDS by employing the state-of-the-art transporting and blocking materials through collaboration with industrial partners.

- The future plans include optimization of excimer based WOLEDs through collaboration with the industrial partner; this collaboration implies the future commercialization of the proposed product.

- Future work will use partners transporting and blocking materials, so further progress is expected. As the milestone performance targets are substantially higher than current progress (single-doped WOLED EQE of 20% and (50% with light outcoupling) and LT50 10,000 hrs (20,000 hrs with outcoupling)). No visible risk mitigation in plan and current progress appears behind schedule with an aggressive go forward plan.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The market barriers and solutions to overcome the barriers were clearly addressed.

- The market / audience is the lighting industry, which would benefit significantly from a long-life WOLED product to compete with other SSL systems. In addition, the proposed WOLEDs use more common materials compared to other SSLs, which is attractive for mass production.

***Average*: 1** reviewer

- Blue progress on these new systems is positive. White progress on EQE and durability is behind what would be expected at this point in the project (only 3 months remaining).

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The project activities are well aligned with the project objectives.
- The presentation detailed as time permitted the key research areas shown above.
- No may be a bit harsh, but it does not appear that all the outstanding milestones can be achieved in the next 3 months without accelerated effort.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- This project uses a very innovative approach by using single emissive material. The project has made excellent progress with impressive results. Excellent communication and collaboration between university and industry.
- Excellent fundamental chemistry/physics project which aims to develop a new class of WOLEDs that are efficient and cost effective, while maintaining long term reliability and quality. The proposed materials use more abundant materials and have simpler structure compared to current WOLED devices. The results are significant and encouraging.
- Novel materials and design to substantially reduce OLED manufacturing complexity and OLED cost. Very knowledgeable industrial partner.

2) **Project Weaknesses**

- No obvious weakness.
- It is not clear how far away the commercialization of the proposed WLOEDs is, or what the most important issues that still need to be solved before commercialization are.
- Concept of balancing monomer and excimer concentrations to achieve color while also achieving high EQE and durability is a challenging task. Project plan and schedule show multiple milestones either achieved late or not progressing on time. Was this project not resourced adequately or is this an indication of the technical challenge undertaken? Transparency of partner activities was low.

3) **Recommendations**

- "N/A"
- Next steps and future plans should be more detailed.
- Include a risk mitigation plan. Present results found with collaboration partner. As they signed on as a partner, they should be responsible for some level of disclosure.

Project # 33111e: Identification and Mitigation of Droop Mechanism in GaN-Based Light Emitting Diodes (LEDs)

Presenter: Jim Speck, UC Santa Barabara
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both reviewers believed this project was highly relevant to BTO's goals to improve the cost and performance of LEDs, and the project's focus on droop in blue LEDs, green LEDs, and semi-polar blue LEDs supports the SSL subprogram's current and next-generation technologies development objective.
Both reviewers agreed that the project's use of a low-energy election cylindrical analyzer, characterized by one reviewer as a "novel measurement tool" to measure internal loss processes, was an effective, fundamental, and applied R&D research approach to understanding a fundamental performance efficiency-limiting mechanism—one reviewer referred to internal loss processes as a critical performance and cost market barrier.

Each reviewer believed the project's successful discovery of the relative droop losses of Auger, electron overshoot, and high current deficiencies in LEDs—which are being widely disseminated throughout the industry through publication and presentations—contributes significantly to the project's goals. One reviewer commented that this discover allows 'LED design and manufacturing professionals…focus their product and process improvement activities more directly and efficiently," thereby advancing the SSL subprograms' interim market goals substantially.

Both reviewers supported their high scores for project integration and collaboration by citing the strong relationship between UC Santa Barbara and Cree. One reviewer expressed confidence in the stakeholders' past industry accomplishments, adding that Cree's environment allowed researchers to validate lab results in a manufacturing environment and test commercial products.

Reviewers expressed confidence that the project's current success with blue LED droop mechanisms will extend to green and semipolar LEDs with further work, which will "accelerate the learning curve" for these technologies.

Weighted Average: 3.85 # of Reviewers: 2
Relevance: 4.00[1] Approach: 4.00 Accomplishments: 3.75 Project Collaboration: 3.75 Future Work: 4.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Reduce droop in GaN-based LEDs is critical to the BTO and fully supports BTO's goals.

- Project focus is on development of electroemission spectrometer (EES) to directly measure hot electrons for droop mechanism investigations supports SSLs goals of improving cost & performance improvements in LEDs.
- Project focus on droop in blue and green LEDs as well as semipolar blue LEDs supports the current and next generation technologies development objective of SSL.

B. Approach

This project was rated:
1) **4.00** for the degree to which it focuses on critical market barriers, and
2) **4.00** for the degree to which the approach addresses the market barriers identified.

- The approach in using low energy electron cylindrical analyzer to direct analyze hot electrons from LEDs are effective approach to understand droop mechanism.

- Project focused on understanding the fundamental efficiency limiting mechanisms for high current LEDs addresses the performance and cost market barriers.
- Project focus on semipolar blue LED performance addresses performance market barrier for next generation LED technology.
- Addresses these market barriers through fundamental and applied R&D on efficiency loss mechanisms and novel measurement tool development to directly measure internal loss processes.

C. Accomplishments/Progress/Impact

This project was rated:
1) **4.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Potential drop mechanisms have been identified and solutions were proposed.

- By understanding the relative droop loss attributed to Auger vs. electron overshoot vs. high current defects LED design and manufacturing professionals can focus their product and process improvement activities more directly and efficiently to improving LED performance. Performance improvement supports SSLs target metrics for LED efficacy improvements and price reductions.
- Extensive publication & presentations allow the entire market to benefit.
- The quality of research and the breath of the topics addressed gives confidence that the project can significantly contribute to SSLs interim market goals.

D. Project Integration and Collaborations

This project was rated:
1) **4.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Close collaboration between UCSB and industry partner CREE was demonstrated.

- Project participants have a deep understanding of the relevant issues and stakeholders as demonstrated by their past and current accomplishments to the field.
- Cree as partner allows project to test and build on Cree's supply of state of the art green LEDs.
- Participation with Cree also provides the opportunity to validate lab results in a manufacturing environment and test commercial products.
- Presenter indicated the supply of Cree's green LEDs but did not indicate any other substantial overlap.

E. Proposed Future Work

This project was rated **4.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Clear next steps were presented for key project milestones.

- Future work extends the blue LED droop mechanism work to next generation LED technologies (green and semipolar LEDs) that should lead to an accelerated learning curve for these technologies as they enter commercial manufacturing.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewers
- Progress made on reducing droop will apply to current and future LED technologies as well as advance the market development of high current LEDs.

***Average*: 1** reviewer
- This project could potential resolve the issue of efficiency droop in GaN-based LEDs which is critical to US-based LED manufacturers.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers
- The deployment activities are well aligned with the project's objectives.

- Project is making significant progress on tasks so far.
- Focus of the project is on key fundamental limiting factors directly relevant to achievement of SSLs price and efficiency improvement targets.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- This project use several state-of-the-art characterization techniques to identify droop mechanism in GaN-based LEDs. Good collaboration between university and industry.

- Excellent program. Works on the fundamental loss mechanisms of current and future LED technologies.
- Program is aggressive with milestones and executed by a highly qualified team.

2) **Project Weaknesses**

- No obvious weakness.
- Unclear if the partner overlap is as extensive or optimum as it could be.

3) **Recommendations**

- N/A
- None.

Project # 33111f: Innovative Office Lighting System with Integrated Spectrally Adaptive Control

Presenter: Meg Smith, Philips
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers believed this demonstration project met BTO's challenge to advance unrealized design potentials or advanced lighting systems, making it clearly relevant to BTO's goals. However, two reviewers questioned the project's overall approach, which to them was too vaguely described in the presentation; in particular, these reviewers questioned how the project's value proposition would help innovative office lighting systems overcome cost barriers.

While reviewers generally agreed that the project's basic objectives had been met, two reviewers again wished for more detailed and quantified data, saying that they had trouble evaluating the project's impact on BTO's interim market goals without a cost vs. performance comparison.

Two reviewers seemed generally pleased with the collaborative effort between Philips and PNNL. Two reviewers, however, expressed concern. While the project team had done an excellent job of considering how to optimize the end-user environment, one reviewer warned that the project team surprisingly did not indicate any collaborations with these end-users (i.e. procurement and building-owner stakeholders) or other industry partners. A second reviewer also quipped that there wasn't enough information about partnerships to make a sound judgement.

Moving forward, the reviewers had little to say about the project's future work, other than to restate their earlier concerns about working on a better value proposition and getting more specific information.

Weighted Average: 3.20 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.33 Accomplishments: 3.50 Project Collaboration: 2.67 Future Work: 2.67

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project aims to use innovative office lighting system with integrated spectrally adaptive control to improve building lighting use efficiency.

- The project addresses the challenge of Unrealized Design Potential by aligning with strategy #3 Advance SSL technology and increase market penetration and strategy #2 Improve networked lighting systems to reduce lighting energy consumption

- Application project in offices that demonstrates the energy saving potential of lighting without sacrificing comfort.
- Supports SSLs goal of extending applications of advanced lighting systems through demonstration projects.

B. Approach

This project was rated:

1) **3.33** for the degree to which it focuses on critical market barriers, and
2) **3.33** for the degree to which the approach addresses the market barriers identified.

- This project adopt a 3 level hierarchy which organizes the delivery of illumination and is capable of variable modulation of intensity, distribution and correlated color temperature.

- The approach was to use current SSL (LED) technologies and "stakeholder engagement" to develop better lighting systems. The objectives and the approach are stated in vague terms, and thus are difficult to judge. The project accounts not just for standard metrics related to efficiency and light intensity, but also circadian and psychological behavior (image forming and non-image forming); the project also deals with the development of open protocols for control and automation, although very little information was provided on the slides or during the presentation. No details on cost of implementation are provided.

- Project showed how a comprehensive energy savings and behavioral optimization system could be applied to an office environment utilizing best-in-class components, networking and intelligent control.
- Would have liked to have them call out specifically the major barriers to purchase and how these challenges could be overcome.
- Indicated that they completed value proposition development but did not report on it. Would like to have seen how persuasive the value prop is as it needs to combine energy savings (hard costs) with valuation of the comfort and behavioral components (soft costs). If relying on soft costs to justify the value prop, it could be challenging.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Completed value proposition development, design concept, wrote system architecture requirements, benchtop working demonstration including software component and integrated system testing.

- It is difficult to judge the project accomplishments from the slides or from the presentation because the one slide dedicated to them was written in generic terms, without quantifications. The project plan and schedule show that most tasks have been completed on time with the exception of the pilot installation.

- Excellent technical and design effort for the application. Supports the program intent to demonstrate integrated system capabilities for the office environment.
- No discussion of cost vs. performance, which is important to ultimate success to not only the interim goal but also long term implementations.
- If this effort is sufficiently supported with marketing and outreach, it will contribute to the program's goals.
- Hard to argue that it will have a significant contribution to interim goals, as cost/benefit is unknown and significant effort/demonstration will have to be expended for market education.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- This project involves a close collaboration between Philips and Pacific Northwest national Lab

- Very little information on integration and collaborations is provided; PNNL has provided consultative support; it is also stated that further collaboration is anticipated with "the labs" for pilot planning, although pilot installation was supposed to be done by now.

- Very good/excellent consideration of the end user environments and how they need to be optimized along with the energy savings from reduce illuminance.
- Purchasing/building owner stakeholders were not considered as prominent as would be expected. Again this is the focus on system performance over value proposition. From the slides it appeared value proposition was considered early in the project, yet as it probably is the most important market barrier for success, it should be carried through all elements and timeframes of the work. A Ferrari is fast and beautiful, but, for example, GM has a much more significant impact on the automotive market by focusing on the best value for the overall target market.
- Collaboration identified with PNNL.
- No indicated collaboration with targeted end user group or other industry partners. Hope is that the benefits of this work are not concentrated on just this one provider.

E. Proposed Future Work

This project was rated **2.67** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Good plan for future work was included.

- Proposed future work seems to list the very same items as in the current project, with different wording. It is recognized the need for quantification of the impact of the project.

- Good focus on further developing the soft value factors of the integrated system.
- Would like to see further exploration of value proposition with key purchase decision makers.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Energy saving and comfort provides high values to commercial office space.

- The target audience is the commercial office space lighting; the project delivers energy efficient solutions, reducing running cost while in the same time improving quality of life and productivity for the occupants of the space.
- Sophisticated technical solution that appears to deliver significant energy savings.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

The key research deployment activities for this project are directly relevant to the project's objectives.

- The oral presentation did not detail well the key research areas shown above, but the accomplished tasks listed in the project plan showed this information.

- Keen focus on overall system performance.
- Would like to see more focus on purchasing decision makers and their interpretation of the value proposition for their organizations.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- This project demonstrated good stakeholder engagement from concept design through validation, pilots and commercialization.

- The project uses the flexibility provided by current SSL systems to improve comfort and productivity. The objectives of the project are complex and challenging, especially considering the variety of cases encountered in reality.

- Great integrated design and applications of advanced lighting systems.
- Very good focus on end user needs while also optimizing energy savings.

2) **Project Weaknesses**

- It will be great to provide more quantitative data on energy saving.

- While the project is likely valuable and interesting, the presentation slides and the oral presentation were not well organized and did not clearly show the accomplishments achieved through this work. The

presenter talked on many issues and facts not shown on the slides, while many items included on the slides were not covered during the presentation.

- More work or transparent focus on system value proposition.
- Inclusion of other market players.

3) **Recommendations**

- N/A

- The impact of the project accomplishments should be quantified to demonstrate its value.

- See above comments.

Project # 33111g: Improved InGaN LED System Efficacy and Cost via Droop Reduction

Presenter: Isaac Wildeson, Philips
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both reviewers believed the project's work to improve performance and reduce costs via droop reduction holds significant potential to achieve multiple BTO goals. One reviewer believed the SSL subprogram's LED cost targets would be advanced if the reduced droop also increased low current performance, but was less sure if the project's withholding of proprietary results would help BTO achieve it short-term outcome of providing industry with the project's findings.

Both reviewers agreed that this project had made significant progress, but one reviewer said that the lower efficacy goal, the immaturity of the high-current LED market, and the single-manufacturer focus lowered the chance that the project would significantly contribute to the programs interim market goal. The reviewers seemed pleased with the project's collaborations, although one could not identify any key industry stakeholders or partners. As the project moved forward, both reviewers hoped for a better defect identification process, because without one, as one reviewer put it, "the process optimization to high current improvement may be less efficient due to poor targeting."

Weighted Average: 3.15 # of Reviewers: 2
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 3.50 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Improve InGaN LED system efficacy and cost via droop reduction is highly relevant to BTO mission.

- Significantly improving the efficiency droop would expand the market of LEDs in outdoor and other high current applications.
- If improving the efficiency droop also increases the low current performance, then achievement of SSL's LED cost targets will be positively impacted.
- This project is focused on improving the efficiency drop of a single manufacturer. The presentation had a limited disclosure of results, all presented in a "relative to baseline" basis, presumably due to proprietary concerns. It is not clear that this type of structure supports ETs SSL Subprogram Short Term Outcome "Private sector has access to validated solutions to develop or improve technologies & reduce cost".

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The approach of using predictive device modeling coupled with complementary advanced material characterization techniques and MOCVD growth development seems to be effective.

- Market barriers to high luminance LEDs related to performance at high current identified (high current efficiency and cost reduction).
- Market barrier related to reliability and lifetime of the improved high current performance over time not addressed. Project addressed the performance at high drive current barrier well.
- No explicit cost barrier elements in project plan.
- No reliability or lifetime directed tasks in the project plan.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Excellent progress has been made to demonstrate significant gain over production baseline EQE.

- Improved high drive current LEDs supports SSLs market/application expansion goals as well as the improved efficacy goals.
- SSL target metric for low current efficacy is ~20% improvement by 2020. No specific high current efficacy is stated, however it does not appear that the project goals are a 20% improvement (seems like 12-13%, hard to say since all graphs are relative to an internal baseline).
- Although certainly an improvement if the project meets its targets, the lower efficacy goal, the specific immature high current LED market at present, and the single manufacturer focus make it a lower probability that the project will significantly contribute to the programs interim market goal. This project would have a higher impact long term.

- The project has met its Year 1 EQE target and has narrowed down the cause of the efficiency droop to point defects.
- The defects cannot be seen by STEM and have not yet been identified. Consequently the process improvement tuning will rely in developing correlations between MOCVD process parameters and device results.
- Progress will continue on searching for the source of the specific defects.

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- This project includes close collaboration between Lumileds with Brookhaven National Laboratory, Sandia national Laboratories and MIT.

- Presenter very knowledgeable regarding key stakeholders, although they were not explicitly detailed or discussed in the presentation.
- The collaborators appeared to be national labs, academics and company internal development teams.
- No industry key stakeholders or partners were identified.
- Communication with other industry participants is through SSL presentations and academic publications.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Need to better understand microscopic identity of defects to guide further MOCVD process improvement.

- Going to make moderate and aggressive design and look for defect overlap with low Droop structures.
- Continuing to optimize MOCVD conditions.
- Continue to search for defect identities.
- Without defect identification, the process optimization to high current improvement may be less efficient due to poor targeting.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer

- The value of reducing droop and increase InGaN LED is critical for solid state lighting.

***Average*: 0** reviewers

- N/A

***Low*: 1** reviewer

- If project is successful the company could commercialize an improved product for high current applications.
- Can other manufacturers benefit from this research? This was not addressed.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers

- The research deployment activities that are relevant to the project's objectives have received ample emphasis.

- Sufficient focus on improving the IQE is evident.
- Lacking elements that will be important for commercialization reliability, lifetime, sustainability of the improvement I will presume will be addressed post-project by the company.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The approach of using predictive device modeling coupled with complementary advanced material characterization techniques and MOCVD growth development seems to be effective. Good collaboration between industry, national labs and university.

- Progress made on improving the performance of high current devices.
- Project converging on what might be the source of the defects limiting device performance.

2) **Project Weaknesses**

- Need to better understand the nature of point defects.

- Single company team yielding project benefits to a smaller subset of the market players.
- No reliability or lifetime components to the plan (i.e. are the gains in the IQE sustainable over the planned product lifetime?).

3) **Recommendations**

- N/A

- None.

Project # 33111h: Next-Generation 'Giant' Quantum Dots: Performance-Engineered for Lighting

Presenter: Jennifer Hollingsworth, Los Alamos National Laboratory
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both reviewers believed this project was relevant to the SSL subprogram's goal of improving LED performance. While one reviewer did not provide any relevant comments on the project's approach to illuminate their scoring logic, the other reviewer praised the project's excellently-detailed plan, the vast majority of which was devoted to overcoming cost and performance barriers. The reviewer noted, however, that "the known tradeoff of quantum yield and durability…would have been helpful," because without it the commercialization potential might be lower. Both reviewers were pleased with the project's collaboration, particularly the use of other national labs' expertise at no extra cost. While both reviewers agreed that the project's next steps were clear, one reviewer expressed concern that all activities might not be accomplished by the end of the project, five months away.

Weighted Average: 3.30 # of Reviewers: 2
Relevance: 3.50[1] Approach: 3.50 Accomplishments: 2.75 Project Collaboration: 4.00 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The use of giant quantum dots as narrowband-red down conversion phosphors is highly relevant for LED lighting.

- Giant quantum dots (gQDs) as a drop in replacement for red phosphors is consistent with SSLs goals of improving LED performance and improving down-conversion materials.

B. Approach

This project was rated:

1) **4.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The use of gQD could potentially lead to an improved narrowband red-emitters.

- Presenter called out the significant market barriers: better efficiency, low-cost. Recent work was dedicated to determining the mechanism for the suboptimal quantum yield (QY) and poor durability at higher temperatures. Project focus on better down converters and a drop in substitution with the giant QDs supports the performance and lower cost market barriers. The vast majority of the work is directed to overcoming these barriers. Excellent detailed project plan. Project plan milestone were typically focused on improving a single property. With the known tradeoff of QY and durability, a milestone directed to achieving x QY with y durability would have been helpful. A combined milestone would yield some important information as to the current overall status of the giant QD approach.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- gQDs with excellent quantum yields were achieved.

- The project strongly supports the SSL goal of core technology research directed to overcoming LED technical barriers. The single "stress test" development may have broader applications than gQD's, (e.g. phosphors). Significant progress in determining how and why gQDs have durability issues. It is not clear how to resolve the QY/durability tradeoff and if it will be a fundamental limiting factor with the approach. As the approach has some fundamental science questions and has not shown a high QY device that can pass curing or long term durability testing, the project is not expected to significantly contribute to SSL's interim market goals.

D. Project Integration and Collaborations

This project was rated:

1) **4.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **4.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- This project involves collaboration between several key partners include lighting manufacturer, university and national laboratories.

- Presenter has excellent understanding of key stakeholders and knows the issues well. Expanded use of other national labs who can add their expertise to the project (and at no cost!). Solid industrial partner who can do further characterization and device level durability testing.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Clear next steps and future plan were discussed.

- Project plan sets high performance goals and is being executed well. There is a significant risk that all activities may not be completed by the end of the project with only 5 months remaining. A large number of the current and future milestones are challenging with many involving partner work.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer

- Would have rated the value of deliverables High/Average if available. The science is excellent. The QY/durability trade off remains unresolved and could limit the commercialization potential of the work.

***Average*: 0** reviewers

- N/A

***Low*: 1** reviewer

- gQDs could lead to improved warn-white LEDs.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers

- The key research deployment activities relevant to the project's and program's objectives have received sufficient emphasis in this project.

- Only suggestion would be a more targeted effort on the QY/durability trade off

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The use of gQD as a narrowband red emitter seems to a novel approach.
- Solid team and project plan. If gQDs are successful in this application, it would have a significant impact on LED cost and performance.

2) **Project Weaknesses**

- The use of Cd is not ideal.
- Project plan may have been too ambitious. Would like to have seen the project plan have a greater emphasis to resolving the QY/durability trade-off as this appears to be the most challenging barrier to commercialization of the gQDs. Would like to have seen more combined property milestones to help evaluate overall gQD progress.

3) **Recommendations**

- N/A
- None.

Emerging Technologies
Building Energy Modeling

Project # 4302: Lucid (Small Business Voucher)

Presenter: Jessica Granderson, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers were mixed on this project's relevance to BTO's goals. One reviewer described the project as relevant because it furthered the adoption of DOE investments in OpenStudio, while another called the project a great example of how BTO's data and tools could be commercialized. A third reviewer felt that the project *might* support the goal of working with vendors to create end user applications using energy modeling, but was not convinced on this point for two reasons: (1) the project did not actually produce an end-user application using energy modeling, and (2) the features of core DOE modeling tools did not appear to have been expanded as a part of this project.

Reviewers were similarly mixed on the project's approach. Some reviewers felt that, because this was a small business voucher (SBV) project with a 1-year timeframe, the scope was clearly defined and focused on meeting the needs of Lucid, the SBV awardee. One reviewer felt the project was addressing critical market barriers, while another thought the project's approach was oriented toward solving real world challenges. One reviewer commented that the project's deliverables had not actually been implemented, however, and that efforts by LBNL to enhance the coverage of its Commercial Building Energy Saver (CBES) tool appeared to be sidelined until Lucid acquired additional funding. Another reviewer was not clear about what DOE was gaining from the relationship with Lucid, or whether Lucid was expected to share any information about future implementation successes with DOE.

When considering the project's progress and accomplishments, one reviewer felt that the project had delivered on its expected tasks, but that actual implementation of energy modeling into the Lucid platform had not occurred; consequently, this reviewer was uncertain about the project's ultimate impact because implementation was incomplete. Another reviewer recommended developing a plan for tracking use of its new, free benchmarking tool, to help evaluate the tool's impact on BTO's interim market goals. Regarding this free tool, one reviewer felt that a project weakness was the tool's possible misrepresentation of benchmarking, commenting that the tool appeared to present simple energy use and cost intensities as key comparison metrics for similar buildings, without clarifying that 'similar buildings' should by definition have similar operational characteristics.

In terms of collaboration, one reviewer commented that successfully executing the SBV project only involved LBNL and Lucid, and that further collaboration was not required. Another reviewer felt that Lucid's knowledge of its customer's needs and LBNL's scientists worked well together to commercialize a DOE tool, remarking that "[collaboration] cannot get any better than this." A different reviewer felt that collaborations should have been extended to include stakeholders from the architecture, engineering, and construction industry, to demonstrate the online system's capabilities and gain more market influence. A fourth reviewer, however, felt that it was not clear whether the work performed for Lucid by LBNL would ever be made available to other industry actors.

Some reviewers felt that the project's proposed future work was appropriate, noting that that project had accomplished its designated scope of work and that future work was logically aimed at securing other funding to finish integrating CBES into the Lucid platform. Similarly, another reviewer described future plans—to add a user interface for prioritizing energy efficiency measures for energy and cost savings—as the next logical step for the project's benchmarking foundation. In contrast, a different reviewer thought that no clear plan for the project's future had been presented, despite the project team's discussion of uses for the tool's data.

Weighted Average: 2.86 # of Reviewers: 4
Relevance: 2.50[1] Approach: 2.88 Accomplishments: 2.75 Project Collaboration: 3.13 Future Work: 2.75

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project is relevant to DOE's goals as is does further the adoption of DOE investments into OpenStudio. The project also did seem to spend much of the project funds on improving the core functionality of CBES - which is an LBNL 'product' layered on top of DOE's OpenStudio tools and EPA PM tool. In other words, the features of core DOE BEM tools do not appear to have been expanded as a part of this project.

- The project is a great example of how BTO's data and tools can be commercialized.

- The project could support the goal of working with vendors to create end user applications using energy modeling. While the LBNL project team has expanded CBES for implementation in Lucid's platform, the project deliverables did not actually produce an end user application using energy modeling.

- Most aspects of the project align with the BTO's goals. Provision of free building energy performance benchmarking (based on Energy Star, DOE Building Performance Database) as well as BEM-driven EEM feedback (using DOE's software platform) will certainly become impactful in the valuation of energy efficiency in real estate transactions. The proposed on-line benchmarking system can also be useful to serve for high-level decision makers who usually don't want to deal with complex and time consuming energy modeling procedures. It is not clear how the current platform differs from another free web-based tool; Asset Score (from PNNL) particularly about the planned feature of EEM prioritization of savings.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **2.75** for the degree to which the approach addresses the market barriers identified.

- The approach seems designed to very much fit the needs of the SBV awardee - providing them with a 3rd party source of trusted and validated information with which they can develop action-oriented visuals which drive customers into their SAS platform. Although presentation stated the portal "benchmarkmybuilding.com' was launched at the peer review on 3/16, this reviewer was unable to get the software to properly generate a benchmarking report on 3/19.

- Since this was a 1 year project, the scope was clearly defined and focused.
- The presenters did a great job of conveying the real world challenges of using a tool for building customers. They care about why a tool is needed more than they care about what the tool can do for them and how it does it. The collaboration and experience of working with Lucid is a plus.

- The project addresses the market barriers of implementing model-based retrofit analysis tools into a web-based platform. However, the deliverables have not actually been implemented. The efforts by LBNL to enhance the coverage of CBES appear to be on the sidelines contingent on Lucid acquiring funding in a subsequent project.

- Critical market barriers are identified, particularly the lack of well-grounded benchmarking to be used as reference points for further comparisons, underutilization of programs that are being developed by the national labs, as well as ignorance of analytical tools in energy retrofit projects. Benchmarks will help building owners and operators value their improvements from the point of energy performance. The proposed system (in the use of model-based retrofit EEM engine) could generate outputs based on (long term) life-cycle cost analyses in addition to initial investment costs. It is also seen that proposed benchmarking system by nature provides deterministic point answers to energy performance which isn't very effective for accounting for inherent uncertainties in valuation of energy efficient buildings. The

project contributes to overcoming most of the barriers identified. However, it is not clear how to support the building database (from Lucid side) improvement, updates and maintenance after the completion of the project.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Considering the program to be "SBV", this project has been successful in achieving the goals as stated. Much of the work accomplished under this SBV award has been in 'behind the scenes' improvements to infrastructure which will allow subsequent incremental improvements to be more easily made.
- On the subject of impact, this reviewer spent approximately 0.5 hours performing a web search which revealed no software tools offering the identical service of benchmarking a commercial building in the same manner as the approach taken by this SBV. The closest approximation discovered was a site hosted by a private sector company (http://www.buildingbenchmarks.com/) which provides a similar benchmarking service but queries the static CBECS dataset as opposed to the dynamic DOE BPD datasets.

- Since this project just completed and launched the tool at the time of review, detailed statistics on how many user have used the tool were not available at the time. Nonetheless, the tool development was completed as planned and that is a good accomplishment.

- The project team appears to have delivered most of the expected tasks, including the expansion of CBES and laying the groundwork for porting it to the BuildingOS web platform. However, it appears that the actual implementation of energy modeling into the platform has not occurred. The impact is uncertain because the ultimate implementation is incomplete.

- Strong qualitative and some quantitative supports are state. However, it is not clear from the application presentation slides how the proposed on-line system impact energy savings compared to 2010 baseline technologies. The project should provide a plan about how to track the use of the proposed system by the targeted audiences. On the other hand, integration of Energy Star and DOE BPD into a freely available reporting platform is a big leap forward from the point of leveraging underutilized DOE supported program functionalities. In the relatively short run, contributions to BTO program interim market goals will be likely small. The project needs to include additional collaborations to promote the use of the proposed system.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.25** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Successfully executing the SBV project seemed only to involve two organizations (LBNL and Lucid) so collaboration and integration with additional outside entities was not required.
- As a free benchmarking service, it does not appear that Lucid is wanting to use this portal to be used as a method for building owners to document mandatory benchmarking submissions, which are required by several cities, states and municipalities. Perhaps a future feature.

- The SBV program is a good setting to co-develop technologies for commercialization. Lucid knows about the customer need and worked well with national lab scientists to commercialize DOE tools. It cannot get any better than this.

- The project appears to enjoy good collaboration between LBNL and Lucid personnel. However, it is not clear whether the work performed for Lucid by LBNL will be available to be used by other vendors in the industry. I understand that this is a unique project through the SBV program involving only a single vendor, but I would hope that LBNL's efforts could be widely available. It is also not clear what DOE is gaining from the relationship with Lucid or whether Lucid is expected to share any information about future implementation successes with DOE.

- Collaborations should be extended to include some stakeholders from AEC industry (market leaders) and even to some commercial BEM-tool vendors. Demonstration of some impactful capabilities of the on-line system is key to gain a more profound market influence. Communications with the PNNL could be helpful to gain insight into some possible overlapping functionalities with Asset Score tool.

E. Proposed Future Work

This project was rated **2.75** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The SBV has accomplished the designated scope of work, and future work appears to be aimed at leveraging a Technology Commercialization Fund (TCF) proposal to more fully integrate the CBES tool (via the API) into the Lucid SAS platform. Work under the TCF which leads to a CRADA or more formal licensing agreement seems a logical next step for supporting further integration between the CBES API and the Lucid SAS platform.

- Discussions about how the data can be put to better use or how the data analytics can be used for retrofit recommendations and analysis were done but no clear plan was presented. Also looks like the project has needed so who will carry out the future work, if any?

- The work is basically complete.

- The future work plans include some effective items for overcoming the current market barriers. The outstanding future plan items are adding a user interface for EEM prioritization for energy and cost savings which is the next logical step after setting up a benchmarking foundation. Particularly, so as to deal with the measured performance vs. modeled performance disagreements automated model calibration functionality plan is very significant. Such a feature will attract more users (e.g., ESCOs) to the platform. From this perspective, it will be crucial to make a distinction between component-level retrofit analysis (and related model calibrations) vs. building-level retrofit analysis (and related model calibrations) based on the availability of sub-metered performance data resources.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer
- All deliverables met.

***Average*: 3** reviewers
- As mentioned previously, the SBV project takes a 'minimalist' approach to acquiring information without providing users pathways for improving the quality or quantity of that information as desired. In addition, the approach of querying the DOE BPD carries some interpretive risk, as, unlike CBECS, the DOE BPD is a biased dataset whose queried results must be recognized as such.

- The project produced a simple and elegant web platform for benchmarking, but only laid the groundwork for actual use of energy modeling in an end user application.

- Benchmarking on its own would result in a limited traction from the key target audiences. Full potentials could be surfaced with the integration of EEM prioritizations and functions dealing with operational data

(e.g., automated model calibrations). Collaborations should be extended to reach out and to track the usability.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- The key research areas/ deployment activities of this project are receiving sufficient emphasis.
- The project successfully performed all key activities.
- Energy Star and DOE BPD integrations were already managed. CBES is already expanded to a wider range of building typologies and U.S. climates. Such activities exhibit potentials to receive adequate emphasis for the BTO's program objectives.

***No*: 1** reviewer
- The fundamental challenge of using energy modeling to improve the performance of existing buildings is not currently part of the overall goals of the BEM program. It should be.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project demonstrates well the strengths of what can be accomplished when the public and private sectors collaborate to take foundational information generated by trusted and validated DOE funded tools and link them together within a visual environment focused on action oriented outcomes developed by sector experts who are focused on providing solutions to their specific use-case and end customers.
- Great example of the success of small business vouchers program.
- Successfully transferred multiple DOE tools/databases to market.
- The lucid tool is available for free for anyone to use and benchmark their building.
- The project seeks to address an important industry challenge. Many municipalities are enacting BERDO ordinances that require benchmarking and Portfolio Manager has been used on something like 40% of the US commercial building stock. To go beyond simple benchmarking and actually improve building energy performance, users need tools to evaluate energy efficiency measures that could be implemented. The work to improve CBES and implement it in a benchmarking web platform could contribute to addressing this challenge.
- The project shows strengths in tackling with informational barriers against getting the use of commonly accepted and highly sophisticated building performance databases in an integrative manner for the purpose of performance assessments and comparisons of high-performance buildings.
- Incorporation of federally-funded, supported EnergyPlus and OS platforms to derive model-driven outputs for this publicly available/free web-based program is totally in line with BTO's BEM strategies.
- Expansion of covered building types and U.S. climate zones will definitely widen the size the of the use base to gain enough traction from the targeted audience.
- Planning for EEM prioritization and automated model calibration functionalities are perfectly matching with the expected (logical) progression of the proposed project.

2) **Project Weaknesses**

- The projects weaknesses include a possible misrepresentation of benchmarking and how it should be used, when using the EPA PM tool - which may lead to downstream confusion when users attempt to benchmark their buildings using the EPA PM tool and underlying infrastructure. The SBV project implementation asks a minimal amount of questions, choosing not to ask the key operational questions such as number of employees, number of weekly hours, etc. These operational attributes are used by the EPA PM tool to provide a normalized metric (the EPA PM Score) for equitably comparing your building to other buildings having different operational attributes. The Lucid SAS tool appears to ignore these normalizations and simply present EUI and ECI outcomes as key comparison metrics for similar buildings, while making no effort to distinguish that 'similar buildings' should by definition have similar operational characteristics.

- Not necessarily a weakness but the tool can be evolved into more than a benchmarking tool.

- While the problem statement and project objectives, the project did not result in any energy modeling implemented in an end user application. It could happen in the future, but it did not occur through this project.

- Emphasis could be given to AEC, architectural design companies as an extension of collaborations to reach market leaders.
- There should be some tracking system with solid metrics about how to evaluate the adoption and usability of the proposed on-line platform.
- Possible overlapping functions with the PNNL's Asset Score Tool should be carefully and critically evaluated.
- Some further clarifications should be made about which metrics are being used to assess Indoor Environmental Quality (IEQ) impacts mentioned in Commercial Building Energy Saver (CBES) program. Are those metrics also reflected in the proposed platform?

3) **Recommendations**

- Consider expanding the Benchmarking Tool interface to expose the key operational parameters, perhaps providing default values for them as necessary to prevent users from being blocked from using the full EPA PM feature set. The resulting EPA PM score of 0 - 100 is such an easy metric to relate to that it should also be exposed, in this reviewer's opinion.

- Possibility of how data from Lucid can be used to improve the BPD or CBES should be explored.

- The project is finished.

- None.

Project # 32488: Validation and Uncertainty Quantification

Presenter: Philip Haves, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed that this project's efforts to improve and validate the accuracy of energy modeling was addressing BTO's Building Energy Modeling (BEM) goal of improving the credibility of simulation tools. The reviewers disagreed sharply, however, on whether the project's approach sufficiently addressed market barriers. One reviewer believed that every critical market barrier had been adequately identified and effectively addressed, while another reviewer limited their approval of the project's approach to the "key barrier" identified: disagreement among BEM engines and the lack of experimental measurements to provide ground truths. A third reviewer believed that this market barrier was "probably the least significant contributor to user mistrust," suggesting that the project's very large budget was therefore not justified by the approach. Multiple reviewers concurred, with two similarly questioning the significance of algorithmic approximation to the overall discrepancy between simulated and measured data, and another reviewer predicting that BEM market acceptance would not occur until two more significant hurdles were also overcome—uncertainty in key model inputs and variance among modelers.

While one reviewer believed that the project had made significant progress towards its goals, the remaining reviewers were unconvinced. One reviewer expressed concern that the project plan and schedule did not match the project's accomplishments. Other reviewers felt that the presented accomplishments were unclear or somewhat nebulous—commenting that information on the uncertainty framework lacked depth—while another reviewer remarked that insights from the FLEXLAB experiments were not shared. One reviewer believed that the project's research would not appreciably advance BTO's goals by improving the accuracy of BEM. According to this reviewer, "while validating simulation algorithms with real test results has academic merit, it seems a bit like rearranging deck chairs on the Titanic."

Most reviewers were pleased with the project team's integration and collaborations, commenting that the technical advisory group (TAG)—and the relationship with ASHRAE Standard 140, in particular—was an outstanding, clever, and wise idea that would deliver value to industry. One reviewer expressed a desire for greater industry involvement in the project itself, while another noted that the frequency of communications with TAG or ASHRAE could not be discerned from the presentation.

Reviewers were generally in agreement that the project's future work followed naturally on prior achievements in support of BTO's goals. One reviewer was not clear on what "implementing the extended uncertainty framework" implied, however. Moving forward, one reviewer suggested adding HVAC performance testing labs to the TAG, so that solutions to the project's measurement and equipment setup issues could be accelerated. A different reviewer encouraged the project team to work with simulators other than EnergyPlus.

Weighted Average: 2.91 # of Reviewers: 4
Relevance: 3.25[1] Approach: 2.88 Accomplishments: 2.63 Project Collaboration: 3.38 Future Work: 3.25

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The 2016 BTO MYPP specifically references a goal of improving the confidence of BEM tools. This project, when completed, has the potential to lead to improved confidence of the underlying algorithms which form critical underpinnings of many BEM tools.

- The project should lead to improving the accuracy and credibility of energy simulation tools which is in alignment with BTO's goals and MYPP (p104). The project demonstrated that they have the facilities to make empirical testing possible and generate sets of measured data for simulation and model validation.

- The project is well aligned with BTOs efforts to remove barriers to acceptance and use of building energy modeling.

- The project successfully deals with problems/issues of insufficient characterization of modeling engine accuracy as well as much needed empirically-based model validation techniques (in addition to analytical solutions) for ASHRAE 140 procedures. Improving model accuracy is key to tackle with the impression that energy modeling doesn't have a firm footing in reality due to inconsistent results across simulation tools and deviations of predicted building performance from measured levels.

B. Approach

This project was rated:
1) **2.75** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project does not address other key sources of variance between actual (measured) and predicted performance - specifically the uncertainty associated with input parameters or modeler decisions/workflows. It is hoped by this reviewer that follow-on BTO research can be conducted to explore these areas. Market acceptance of BEM tools will not make significant progress until breakthrough have been achieved in all (3) of these areas.

- The project describes the key barrier being the disagreement amongst different simulators and the lack of experimental measurements to provide ground truths. During the presentation, not much was said to how critical is this lack of agreement amongst simulators and what are the lost opportunities due to that?

- One barrier which was not completely addressed in the presentation was how significant is the role of BEM engine and algorithmic uncertainty in the overall discrepancy between the simulation and real world data.

- For the key barrier identified, the approach presented is effective and should help resolve the disagreement between simulators and the issue of the lack of empirical data for validation.

- The project purports to address that barrier that users do not trust BEM results, especially given well-known discrepancies between modeled and actual building energy performance, with the objective of enhancing the credibility of BEM tools. However, algorithm uncertainty is probably the least significant contributor to user mistrust. It is, furthermore, a very large budget to address a problem with little impact on the credibility of energy modeling.

- All critical barriers about dealing with the lack of confidence about BEM models are adequately identified. Such barriers are effectively addressed. Some additional studies could be incorporated about generating and disseminating useful data for building systems that could be used for the development of empirical (data-driven) models in addition to physically-based law-driven models.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is well over halfway through the three year performance period, and yet has very little actual progress to share. The project plan/schedule shared during the peer review did not match up with the presented accomplishments or descriptions of planned work. For example, as of the peer review, HVAC equipment testing at NREL has yet to begin.

- It does seem like the original project goals were over optimistic and aggressive, and the plans for a follow up project to be conducted during FY 2018 - 2020 will be needed.

- Nevertheless, it is anticipated that the results from this project, and the project's integration with ASHRAE Standard 140 as a delivery method for disseminating results, will form a strong basis for characterizing trust in the underlying algorithms behind BEM tools.

- This project is in year 2 of its 3 year duration and significant progress has been made and demonstrated in the presentation. Key accomplishments include:
    - FLEXLAB experimental facility has been created.
    - HVAC test facility at NREL
    - Flexible research platform ORNL

- The focus thus far has been on getting the test-bed facilities correct since a high degree of measurement accuracy is indeed required.

- The presentation did not go deep into the uncertainty framework which is also part of the project. The novelty of the uncertainty ratio (slide 12) is unclear.

- Preliminary results were presented for load comparison in FLEXLAB but insights from this early experimentation were not shared.

- The ORNL calibrated BEM results look impressive.

- While validating simulation algorithms with real test results has academic merit, it seems a bit like rearranging deck chairs on the Titanic. Energy modeling tools will likely be slightly more accurate as a result of the project, but it is not clear that the impact will be worth the effort.

- In addition to qualitative ones, some quantitative supports should be mentioned about the contributions of the current study to reach program performance goals including interim market goals. How to increase BEM accuracy? It is not clear how to integrate the validated models into BEM programs (through source code updates?). Some of the research activities could be extended to be aligned with SOEP-based research work. Generating Modelica-based external models and a new way of coupling with EnergyPlus engine (via Open Studio SDKs) would be beneficial.

D. Project Integration and Collaborations

This project was rated:

1) **3.25** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- This reviewer believes the Technical Advisory Group that is supporting the project is a key component to ensuring the project delivers value to a broad set of industry actors by aiming resources and performance tests in areas which are actually of interest to the BEM community at large.

- More broadly speaking, the integration with ASHRAE Standard 140 community is a clever and wise idea. Leveraging the institutional prestige of the ASHRAE Standard 140 community makes a great deal of sense. Having the project results integrated into the ASHRAE/ANSI process is also a clever strategy for long-term project.

- The primary collaboration and integration is with a technical advisory group (TAG) with a diverse set of key stakeholders as members of the group.

- The project also coordinates with the AHRAE Standard 140 committee. The frequency of communications with the TAG or ASHRAE 140 committee was not specified. The progress did indicate that initial results from the FLEXLAB and FRP were presented to the ASHRAE 140 committee earlier this year which is a good sign.

- The project demonstrates good collaboration within the energy modeling and validation community. Multiple DOE labs are coordinating testing in diverse laboratories and the project includes good coordination with ASHRAE Standard 140. Their technical advisory group is outstanding.

- Collaborations could be extended to include some industry stakeholders (mechanical system, HVAC system manufacturers) in order to support decisions about which type of low-energy HVAC systems and components to test and measure.

E. Proposed Future Work

This project was rated **3.25** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The project as a whole represents 'foundational' research that it is very unlikely any individual commercial or private sector organization would undertake. As such, it seems to be a suitable role to be served by federal research dollars. As described by the presenter, this type of foundational research is difficult to accomplish, as during the ground breaking research, undoubtedly unexpected issues will arise and need to be solved before continuing further.

- It seems much of the work to date on this project has been in putting in place the necessary framework so that not the real research can begin - for example the Technical Advisory Group has helped the project set priorities, the facilities have been configured and arranged to be able to be adequately exercised to test these priorities, and the first sets of data have now been generated - leading to the stage of "analysis of data"

- Future work is recommended to leverage the investments in strategy and infrastructure made as part of this project.

- A future plan describing immediate and medium next steps was presented.

- The proposed plans include starting and finishing the testing at all the sites. This is in alignment with the proposal's goals.

- Medium term goals of preparing and submitting measured data to ASHARE 140 is also good.

- The uncertainty is around 'implementing extended uncertainty framework'. It is not clear what this implies, will an uncertainty tool be created or else how will the results of the uncertainty be used enable change in the simulation engines. The ANL uncertainty framework and its role was unclear in the presentation.

- Given the specific objectives of the project, the project seems well positioned to deliver the proposed future work. I am confident that they will achieve their project goal.

- Future work plan items are based on past progress and also focusing on overcoming the related barriers. Project didn't mention about how to tackle with possible risks and providing alternative pathways to mitigate them.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The outcomes and results from this project will be information that will lead to improvements in the actual algorithms of popular energy BEM engines.

- Because this outcome is valuable to the entire community (and not just to an individual software vendor), this work would very likely not have been undertaken by other individuals or communities.

- Project deliverables have significant potentials to impact the key target markets of the program. Modeling engine accuracy concerns and dependable rigorous protocols to improve the accuracy will affect a wide range of end users who have preconceptions and concerns about the use of BEM due to the lack of accuracy and uncertainty characterizations.

***Average*: 1** reviewer

- As was adequately bought up during the presentation, algorithmic uncertainty is only one piece of the bigger picture on why discrepancies exist between ground truth and simulation. While the scope of the project is well defined and is on validating the simulator while eliminating as many confounding factors as possible, a quantitative measure of the impact of the project is difficult to gauge.

***Low*: 1** reviewer

- In my opinion, there is little demand for greater experimental validation of energy modeling algorithms.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- This reviewer does believe that the key research areas of this project are receiving sufficient emphasis.

- The key research areas and deployment activates are centered on continued testing at LBNL and ORNL as well as the NREL facilities.
- These are in line with the program's objectives and are receiving sufficient emphasis.

- Deployment activities in key research areas are relevant due to the fact that model accuracy improvement and enhancing ASHRAE 140 validation procedures have fundamental impacts on the acceptance and usability of the building energy modeling programs.

***No*: 1** reviewer

- The credibility of energy modeling tools to predict actual building energy use is a critical issue that deserves significant additional effort. However, the main sources of the discrepancy between modeled and actual performance are more likely related to model inputs that describe its operation, including the behavior of occupants and the actions of building operators.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project strengths include the tight coupling with the ASHRAE Standard 140 community and process, as well as the diverse group of stakeholders that has been formed.

- Top strengths include:
  - 1. Hi-fidelity test-beds are a plus.
  - 2. Close working relationship with ASHRAE 140 and TAG is a plus.
  - 3. Project is addressing a problem which should influence benchmarking for different building energy simulation engines today.

- The project team comprises an all-star team of energy modeling experts and experimental facilities, and their collaboration with others in the energy modeling community is exemplary. The uncertainty quantification will make a significant contribution to the understanding of energy modeling accuracy.

- The project exhibits strengths in dealing with improving modeling accuracy through empirical evaluations (not just depending on analytical and inter-model validations) as well as focusing in quantifying the inherent uncertainties in model responses.

- More realistic experimental testbeds are prepared for acquiring empirical data about building systems.

- The project focuses on a wide range of system tests and measurements (conventional and low-energy HVAC systems, components and control mechanisms).

- Get the use of multiple (well-developed) test beds located at different national lab sites.

- Direct contributions to related industry standards (ASHRAE 140) procedures.

2) **Project Weaknesses**

- The project's weaknesses appear to be the inability to manage the project to execute to the original schedule, given unforeseen conditions. Much of the projects budget and accomplishments to date have been spent on setting foundations for future work, which now can be leveraged.

  1. Unclear how the results from the comparison of simulation vs ground truth will be fed back into the simulators.
  2. The uncertainty framework was not discussed during the presentation to a good extent, and it is unclear what novel insight is expected to result from the work or how it will be incorporated into simulators.
  3. More collaborations with other simulation teams outside of EnergyPlus will benefit the project.

- The fundamental premise that this project will improve the credibility of energy modeling tools is flawed. The agreed main barrier to widespread acceptance of energy modeling is the discrepancy between modeled and actual building energy performance. This project may allow DOE to boast that the models in EnergyPlus are, indeed, very accurate, but that self-fulfilling assertion will not move the barrier.

- Possible connections could be established to support SOEP research activities.

- Feedback from industry could be obtained for the prioritization of systems to be tested so as to better respond to the needs of the targeted market audiences.

3) **Recommendations**

- The project technical advisory group should consider expanding membership to include representation from HVAC performance testing labs, such as ETL Intertek and others. The expertise provided by these members may expedite solving some of the measurement and equipment setup issues that have manifested during the test facility setups.

- Work with more simulators besides E+.

- Share what has been learned from the initial results and how any lessons learned have been incorporated into future plans.

- How are the outcomes on uncertainty and disagreement between simulators expected to be incorporated into the simulators themselves to improve their agreement. Is it event possible to have agreement?

- The uncertainty quantification is a very interesting element of the project that deserves highlighting.

Project # 35511: Modelica - Spawn of EnergyPlus

Presenter: Michael Wetter, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers strongly expressed their confidence in this project's alignment with BTO's Building Energy Modeling (BEM) goals, characterizing this project's research as critical and foundational. One reviewer said that this project would not only maintain, but also "future-proof," EnergyPlus, by leveraging open standards Modelica for equation-based modeling and Functional Mockup Interface for co-simulation and model-exchange. Another reviewer concluded that this project was "the most far-reaching BEM project in this peer review."

Reviewers were equally fond of the project's "state-of-the-art" approach to simplifying EnergyPlus' "monolith of modeling algorithms and solution techniques in a spaghetti of daunting code;" reviewers believed that this approach would address multiple market barriers and reduce technology lags. Several reviewers also felt that the streamlined code would let equation-based models be more easily repurposed and integrated better with other design-oriented tools. Another reviewer concurred, commenting that the project could revolutionize the delivery of BEM tools, significantly advancing BTO goals.

Nearly every reviewer was convinced that the project's accomplishments advanced BTO's goals. Only one reviewer disagreed, expressing their belief that the project's excellent progress and achievements were not entirely aligned with the BEM subprogram's goals. One reviewer commended the project's approach as an accomplishment in itself, expressing that leveraging the OpenStudio "middleware layer" to create a transition from EnergyPlus to its successor was innovative and creative. One reviewer thought that the project's performance didn't adequately test the "stochastic behavior of occupants" in actual operational conditions, and suggested that LBNL could undertake such work moving forward.

Reviewers were generally pleased with the project's collaborations and integration. One reviewer contended that the project team was perfectly positioned at the interface of existing and future BEM tools, while another said every relevant stakeholder had been brought to the table. One reviewer, however, made a lengthy plea for developing a relationship with existing tool users, who could sing BEM's praises to other industry non-users.

Reviewers were encouraged by the project team's identification of future barriers and risks, and appeared mostly satisfied with the team's plans to overcome them. One reviewer, however, thought that the project's goals for fiscal years 18 and 19 might be too ambitious, warning that widespread market adoption would not occur unless the performance of Spawn of Energy Plus at least matched that of its predecessor. Two reviewers expressed concern that steep learning curves would need to be overcome as well.

Weighted Average: 3.75 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.75 Accomplishments: 3.75 Project Collaboration: 3.75 Future Work: 3.75

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This reviewer sees BEM initiatives as 'enabling' technologies that help BTO predict pathways for achieving BTO goal, as well as to develop proxies for representing measurement towards those goals. As such, continued DOE funding of (appropriate) BEM initiatives remain in this reviewer's mind a critical and necessary foundational piece of DOE BTO infrastructure.

- This is a critical project for building the next generation of EnergyPlus that leverages open standards for equation-based modeling (Modelica) and co-simulation. It is critical to BTO's goal of maintaining and future proofing EnergyPlus and connect energy simulation with control design, optimization, and real world implementation.

- The overarching program goal, as stated in the MYPP, is to increase the use of BEM tools in design and improve accuracy. While it is not clear that this project directly serves this goal, I consider it the most far-reaching BEM project in this peer review. BTO should consider improving its goals.

- Spawn of EnergyPlus (SOEP) through Modelica and FMI open standards is critical to the BTO goals and fully supporting the overarching goals in ET BEM sub-program topic. This is due to the reason that this application not only focuses on improvement of the current monolithic-inflexible and restrictive program architecture of the computationally powerful EnergyPlus program but also pays attention to merging multiple-domains of energy simulation (for design, optimization and control implementation) into a unified framework. Proposed computational abilities of modeling unconventional, manufacturer-specific building technologies in an integrative (EnergyPlus-based) platform will surely increase the use of EnergyPlus (as a currently market-viable but relatively underutilized software product) that can cost effectively save energy to reach that stated BTO goals. Reducing program maintenance efforts is also another powerful aspect of the application apart from reducing technology lags between industry and modeling capabilities.

B. Approach

This project was rated:
1) **3.75** for the degree to which it focuses on critical market barriers, and
2) **3.75** for the degree to which the approach addresses the market barriers identified.

- The project represents a 'state of the art' approach to maintaining the superiority of DOE BEM funded tools. The project has key identified goals, specifically reduced maintenance effort and reduced technology lags, which provide pathways for BEM tools to enter new, previously restricted markets and applications.

- An excellent and clear overview of the approach was presented at the review. Equations are more compact than solvers and easier to write and maintain and therefore, equation-based models are easy to repurpose. The following market barriers were identified:
    - scalable, future-proof infrastructure
    - reduced maintenance effort
    - reduced technology lag
    - better integration with control workflows.
- The only aspect not covered which might be a barrier is the learning curve associated with using Modelica and how that may affect the adoption of the new BEMS engine.

- The project represents the future of building energy modeling tools and the approach taken is outstanding. While the market barrier it addresses may not be critical to meeting BTO BEM goals, the effect of the project could revolutionize the delivery of BEM tools. Current tools (i.e., EnergyPlus and OpenStudio) are a monolith of modeling algorithms and solution techniques in a spaghetti of daunting code. The approach proposed here will separate energy modeling algorithms from the solution techniques. In this future world,

engineers develop energy models while leveraging the experience of mathematicians, computer scientists, and other larger industries (e.g., automotive) for solution methods.

- With the introduction of SOEP, this application attempts to improve the integration of BEM tools with control design, numerical optimization and verification workflows. Co-simulation functionality with externalized compilers-solvers-simulators also support the tackle with the critical market barrier of insufficient energy model and controls integration. Open studio SDK integration (over apps and measures) could be instrumental for dealing with other market barrier of insufficient integration with existing design-oriented tools. The project effectively addresses the market barriers that are identified in the application presentation. However, not enough details are given about any planned empirical validation of JModelica in addition to already mentioned inter-model validations against Dymola. The project also misses the point of how to support BEM within the proposed SOEP for buildings under actual operational conditions such as taking into account the stochastic behavior of occupants. A connectivity could be established with occupant behavior modeling activities within LBNL.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.75** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- For this reviewer, it has become clear over the last 12 - 18 months, that the underlying EnergyPlus code/infrastructure is becoming ever more obsolete and will, at some point in time, need to be refactored into a modern environment. This reviewer has a background in software development and has personal experience with the difficult choice of determining the 'optimal' time to invest in complex code refactoring or simply 'start all over again'.
- This project chooses a path forward for EnergyPlus which is neither, The innovative solution of using the OpenStudio framework as a middleware layer to bridge both what will become 'legacy' EnergyPlus while also providing a pathway to access "Spawn of EnergyPlus" features is an innovative and creative solution which can be used to solve several simultaneous problems that inevitably occur during software platform transitions of this magnitude..

- The progress and accomplishments were covered in comprehensive detail in the presentation. The accomplishments in the past year on OpenStudio integration, Modelica buildings component library, jModelica, and quantized state system were clearly highlighted and presented. Based on the progress presented, the contribution of the project to the market goals is quite likely. The project is expected to have a favorable impact on use of OpenStudio and EnergyPlus by the controls/SCADA community.

- This project is making excellent progress and has accomplished much toward achieving its internal goals. My scores are lower because the project's goals are not necessarily aligned with, and do not substantially contribute to, the program goals. In my opinion, the program goals are lacking.

- The project provides strong qualitative and quantitative support to the program performance goals. ET program goals will be supported with increased adaptability and extensibility of EnergyPlus program with enhanced co-simulation functionalities to support virtual prototyping of unconventional-innovative building mechanical systems (which can be listed within HITs). Particularly SOEP features are needed to be able to establish a foundation of equation-based modeling of advanced technologies while using the powerful simulation engine of EnergyPlus. This can result in considerable effects on accelerated technology development. BEM can catch up with the fast-phased R&D and technology development in HVAC industry by being compatible for coupling with external solvers with HVAC and control models coming from manufacturer supported libraries. However, current project accomplishments could also include ways to integrate/handle data-driven (empirical) external model generation functionalities. Such models could also be superior to physically-based/law-driven models in terms of computational flexibilities and response time when utilized within model predictive control (MPC) algorithms.

D. Project Integration and Collaborations

This project was rated:

1) **3.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- While the project is engaging with several influential partners, the list of key partners involved in the project seems to be missing representation from the current 'practical' user base, i.e. a representative who are currently using the EnergyPlus platform for scalable production type of BEM work, today. While the research and lab community seems well represented, it is this reviewer's concern that project plan as shared during the review lacks an appreciation of how difficult it is can be to convince commercial end-users of BEM tools to adopt changes in existing workflows. Considering DOE's MYPP for Energy Modeling, this project may, if not carefully executed, create another market barrier to the commercial adoption of physics engines. In short, this reviewer strongly recommends that the 'voice of the existing tool user' be added to the conversations, if for nothing else to provide the project team with an engaged ally who can assist in communicating to their peers reasons for technical adoption of the improved SOEP workflows.

- The SOEP team collaborates directly with the OpenStudio ecosystem and also with other projects like Open Building Control and data center toolkit.

- Several training workshops are planned and have been conducted to communicate the projects accomplishments till date. Possibility of a collaborative relationship with the industry (ABB) was also mentioned and should be a good direction for the project, but it appears to industry partnerships exist at the moment.

- Project personnel are perfectly positioned at the interface of existing and future BEM tools. They are integral parts of both the EnergyPlus and Modelica communities, working effectively with all partners.

- The project has collaborations with all the key stakeholders related with the topic. Particularly, extending the collaborations with 41 institutions via IEA EBC Annex 60 is a big advantage. Apart from such interactions, collaborations could also be established between web-based BEM communities and some dominant industry vendors. Fairly well-coordinated collaborations are existing particularly including training workshops at certain international conferences. Such efforts can be enhanced with studies about how to educate modelers in SOEP through on-line training and support systems.

E. Proposed Future Work

This project was rated **3.75** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The projects FY 2017 goals of an end-to-end MVP seem achievable. The projects goals for FY 2018 and 2019 seem ambitious. From this reviewers perspective, the market adoption and acceptance (by a large number of users) will not occur if the performance of SOEP does not at a minimum meet or exceed equivalent traditional EnergyPlus computational burden (run times). To further qualify this, EnergyPlus model runs of reasonably complex buildings using small (1 or 5 minute model timesteps) and using EnergyPlus EMS features can currently require well over an hour to execute on a 2017 benchmark laptop. While SOEP must certainly be able to match this benchmark, it will it be able to match the EnergyPlus model runs of single family home using an hourly model timestep (and not using EnergyPlus EMS features) which currently takes less than 45 seconds? For practical reasons related to tool adoption purposes under large scale use-cases, it is this reviewer's hope that the project team views minimizing run-time optimization of SOEP as a mission critical performance metric.

- The future plan for the project in the next year involves completing the end to end tool chain verification. The long term goal is to complete the integration with Openstudio.
- Some key barriers to accomplish these goals are:
    - (1) Quantify the disagreements between the Modelica based simulation engine and the traditional E+ solver.
    - (2) Address any learning curves associated with using the new simulation setup, especially for regular users of E+.

- The project personnel have a clear vision of the main barriers and risks and have planned their future work to effectively address these barriers. In my opinion, the main risks are that the compilers and solvers on which the platform depends are either too expensive or inadequately supported in the future.

- The project successfully identified a diverse set of some key decision points as items of future project development. Possible risks in meeting the stated performance targets are not mentioned together with strategies about how to mitigate them. Steep learning curves, expert level modeling knowledge requirements inherent to SOEP could pose some risks of successful market penetrations.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- The key target market for the new framework seems to be advanced E+ and OS users, for example ones who would want to conduct detailed predictive controllers for buildings and need to simulate such controllers. The high rating is due to the fact that the reviewer thinks this is a good direction for building energy simulation and will have a high impact on the target audience.

- The deliverables from this project could fundamentally change the way energy modeling software is developed. On the other hand, if successful, it would be transparent to the ultimately users of BEM tools.

- The key deliverables of increased adaptability, modularity and scalability of SOEP (with Open Studio integration) will be positively accepted by the target market since all of these features improve interactivity of the core EnergyPlus engine. Communicating with IEA Annex 40 and IBPSA Project 1 2017-22 will be significant to keep track of the user needs and keeping up with the most recent technologies and operational trends for better target audience influence.

***Average*: 1** reviewer

- This reviewer has concerns that the project, even when successfully executed, will require significant market/education efforts to convert users of the existing 'traditional' EnergyPlus BEM to the SOEP platform. This will be a market disruption (by design), and market confusion within the existing user-base of the EnergyPlus BEM engine will, without a doubt, occur. The project does not seem to have identified any concrete actions, steps or a plan for managing or minimizing this confusion.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The project appears to have a very well thought out and sound plan to execute the technical risks of this project, but does not seem to have (or has not shared) a deployment plan that addresses the adoption risk.

- The project has very well thought out and refined objectives and the progress thus far are in alignment with these objectives. Key activities were laid down in comprehensive detail during the presentation and showcase that sufficient emphasis is being devoted to key activities.

- Project Activities are in-line with the ET program objective of increasing the use of BEM in design and building operations. Accomplished and proposed activities have significant potentials to attract more

industry vendors focusing on EnergyPlus design tool integration that could potentially result in a deeper impact for the use of high-efficiency technologies to achieve substantial gains on energy savings.

***No*: 1** reviewer

- Current BTO efforts on building energy modeling are focused on supporting and marketing existing tools. Greater effort should be placed on emerging issues.

H. Additional Comments and Recommendations

1) **Project Strengths**

- This reviewer considered the project's strength to be the ability to leverage the vast institutional memories contained with the group of industry experts who have been involved in defining the proposed technology stack. In other words, the technical implementation team is 'top-notch'. The proposed solution represents several improvement in the core functionality of the EnergyPlus BEM engine. Users will, over time, benefit from these improved functions and feature sets as they become aware of them and chose to adapt/adopt them into their workflows.

- Project's goals are critical to BTO's modeling goals.
- Excellent progress and accomplishments have been demonstrated and there is little to no doubt that the project will meet all its desired objectives.

- In my opinion, this project is the only energy modeling project that qualifies as an emerging technology. It is far-sighted in recognizing that the current trajectory of EnergyPlus - a large, unwieldy, one-size-fits-all energy modeling tool - is unsustainable. It is the future of energy modeling.

- The project proposes enhancing EnergyPlus development that will impactful in tackling with multiple market barriers for BTOs ET sub-program of energy modeling.
- The project has strength in reaching an extended audience (and corresponding impacts) from architects to ESCOs, manufacturers and building operators (with hardware and software in the loop processes).
- Future plans are carefully determined and have potentials to serve the objectives of ET that requires accelerated improvements to implement high-efficiency technologies to building design for substantial energy cost savings.
- The project framework is dependent on well-known and commonly accepted modeling standards; such as Modelica and FMI.
- The project’s approach includes enhanced modularity and inter-operability via Open Studio integration.

2) **Project Weaknesses**

- This reviewer has concerns that the project, even when successfully executed, will require significant market/education efforts to convert users of the existing 'traditional' EnergyPlus BEM to the SOEP platform. This will be a market disruption (by design), and market confusion within the existing user-base of the EnergyPlus BEM engine will, without a doubt, occur. The project does not seem to have identified any concrete actions, steps or a plan for managing or minimizing this confusion.

- Quantitative evidence of the size of the expected users or feedback from expected users from missing.
- Any associated learning curves with the new tool should be discussed.

- The main weakness is also its biggest asset. In relying on more sophisticated compilers and solvers from outside the BEM community, it opens itself to a reliance on tools out of its control. Oh, and BTO’s goals do not include sufficient recognition that the current tools are ultimately unsustainable.

- New generation of EnergyPlus development (SOEP) features are excluding some significant research potentials that can be exploited with:

- Taking into account stochastic modeling of occupancy presence and behavior (actions) instead of relying on commonly-used pre-determined and fixed schedules (particularly in MPC studies).
- The new EnergyPlus generation could also include automated-advanced model calibration and validation models coupled with core simulation engine in a similar fashion to Modelica and FMI models.
- Supporting BEM and EnergyPlus SOEP education to existing or new modelers through on-line training and support modules (particularly on the proposed transformative SOEP features and open-studio ecosystem integrations).

3) **Recommendations**

- This reviewer would encourage broader participation of membership from additional stakeholder groups, or perhaps the formation of a separate group representing the existing BEM user base, who could be leveraged for project feedback and dissemination of information into the broader BEM community at large. As mentioned previously, the reviewer feels the existing BEM user not well represented in this projects plans for integration and collaboration.

- The only recommendation I have is that while it is justified to complete the end to end tool chain verification using a simple toy example model. The project should present more results and insights about cases where the new Modelica based simulation engine is easier, faster, better for the new user. What is that the OS and E+ user of tomorrow be able to do with the new simulation engine which they cannot do today? A quantitative answer to this question is required.

Project # 35515a: Fenestration Modeling Tools: WINDOW, THERM, EP-Calc

Presenter: Charlie Curcija, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed that this project's development of a more accurate and functional suite of freely-available, detailed, window energy performance modeling tools was central to BTO's goals. One reviewer also commended the project's efforts to improve the public's interaction with the tool suite by improving its usability with newly improved source code releases and by developing a cloud-based home for the International Glazing Database and the Complex Glazing Database. In this reviewer's opinion, cloud-based databases would be instrumental to effectively communicating standardized performance data to multiple stakeholders.

Reviewers generally approved of the project's approach, commenting that the team identified and aligned the project well with the four market barriers identified. One reviewer felt that the project team's assessment of market barriers should also have accounted for the current lack of standardized testing and measurement protocols for identifying product characteristics that can be used as inputs for simulation models.

While several reviewers believed the project's accomplishments were satisfactory and in line with the team's stated goals, other reviewers were more muted. While acknowledging that the team's accomplishments had been completed on schedule, one reviewer felt that—despite its importance—this "largely maintenance project" did not have a fundamental impact on the Building Energy Modeling (BEM) program's overall goals. Another reviewer commented that's the project's accomplishments lacked quantifiable benchmarks. One reviewer, however, remarked that the adoption of this project's tool suite by "ALL major fenestration manufacturers" was evidence enough that the manufacturing community valued these tools strongly.

Reviewers were in agreement about the project's strong collaborations and integration. Every reviewer applauded the project's outreach, with multiple reviewers commenting that the team had identified and engaged all potential stakeholders on a frequent and effective basis. One reviewer expressed a desire to see closer collaborations with assembly manufacturers, however, in order to capture these stakeholders' thoughts on the issue of standardized testing and measurement protocols.

Reviewers were satisfied with the project's proposed future plans, with most feeling that these plans were reasonable in scope and timing. Two reviewers wished to see a more expedited and concerted focus on transitioning the tools to an open-source platform, a subject which both reviewers highlighted frequently throughout their remarks.

Weighted Average: 3.55 # of Reviewers: 4
Relevance: 3.00[1] Approach: 3.50 Accomplishments: 3.38 Project Collaboration: 3.88 Future Work: 3.75

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Given the prevalence of windows in the built environment and the importance of their selection during the building design process, the project is relevant in the way that it links together manufacturers and designers/specifiers/users through accurate and independently verified tools and associated measurement facilities. The national product performance rating program that this project support are also very important and relevant.

- The project is relevant to BTO's long term energy savings objectives due to increased potential of energy savings through better window technologies, thermal, and daylighting modeling and simulation tools.

- While the project did not nominally start until 2015, BTO has supported window modeling tools for decades. This project is another in a long line of such efforts. They have been, and continue to be, critical to the delivery of energy modeling tools to the industry. These tools, in particular, are used by window and window covering manufacturers and as pre-processors for EnergyPlus.

- The project has a comprehensive approach of fenestration modeling (prime fenestration, integrated shading devices, window attachments and coverings) by improving functionality and accuracy of a suite of interconnected tools. Such an approach adequately aligns with the BTO's ET goals for improving modeling capabilities for window systems and related design tools. Cloud-based and unified IGDB & CGDB proposal is also instrumental for effective communications of standardized performance data across multiple stakeholders. The project also shows a good relevance to BTO's ET goals by addressing the need for open source (publicly available) source code releases so as to extend the ground of algorithm usability. Performance evaluations are crucial not just at element level (e.g., glass panes) but also at assembly level (e.g., fenestration system with frames and dividers and integrated shading devices) and integration to whole-building level. The project's demonstrating research items aiming to handle such multi-levels modeling approach is significant.

B. Approach

This project was rated:
1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.50** for the degree to which the approach addresses the market barriers identified.

- The project's approach of integration and collaboration with key technical partners and industry stakeholders makes it likely to succeed. The movement to transition to open-source analytical models mirrors trends seen in related fields. This transition will likely lead to unexpected, and positive net results. some

- The presentation clearly identified four key issues with making better models: enabling rapid development of new technologies, enabling cost effective certifications, providing wider access to tools, and moving to an open source model.
- The project's approach of developing a suite of credible modeling tools for fenestration systems, shading systems, windows attachments and coverings is focused on overcoming the key barriers.

- In general, the project is an extension of the support efforts of previous projects. As in the past, the project incorporates new features that reflect the continuing development of window technologies. This project is taking a welcome approach to enable cloud-computing support for the tools. Curiously, the EP-Calculate tools does not account for the impact of daylighting.

- Most of the critical market barriers are identified as key issued by the project. The need for rapid virtual prototyping, cost-effective certification of windows (with shading devices), reaching to a wider audience of

simulation tool users and the importance of open source models for improved 3rd party contributions. The project also needs to identify the barrier of a lack of or inadequacy of standardized testing and measurement protocols to identify product characteristics/properties to be used as inputs to newly introduced and existing simulation models. Some sort of close collaborations with assembly manufacturers are needed to understand their perspectives and concerns or needs regarding this aspect. Target audiences should also include façade engineers and designers who are utilizing the suite of tools as design decision support systems. The project successfully addresses the identified market barriers. Some additional clarifications should be provided about how the enhanced algorithms (modeling air flow around the shading devices) are validated and whether the updated algorithms require more input parameters about the systems being modeled (such inputs may not be readily available for different actual products on the market).

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.25** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The tools resulting from this project have been adopted by ALL major fenestration manufacturers, which is a clear sign that the manufacturing community sees value in these tools. In addition, a strong (and growing) user base indicates the community of specifiers and designers are also accepting the project's tools as useful and valuable.

- Primary accomplishments in the last year have been:
  - releasing new versions of WINDOW and THERM
  - releasing new and updated CGDB and IGDB content every few months
  - Planning an open source tool to integrate with EnergyPlus.
- Good progress has been demonstrated the WinCalc and EP calculator are good directions which are likely to result in even a higher market impact.

- The accomplishments and progress of the project are as expected and according to schedule. However, this project is largely a maintenance project in support of existing tools. As important as the project is, it does not have fundamental impact on overall program goals.

- Strong qualitative support to the stated performance goals is provided. However, details of quantitative support to these goals are not sufficient. Relevant information could be collected from the existing stakeholders about some quantitative metrics revealing the improved adoption of the suite of modeling tools with the impact of the pursued project. Current accomplishments are in line with project's ultimate goals, more details should be given about the framework of populating performance data for updates of IGDB and particularly CGDB databases. Market impact could be further enhanced to a wider audience including designers with special focus on how to integrate simulation elements into typical design and simulation workflows. It will be crucial to search for integration capabilities to link EP calculator to the Open Studio ecosystem.

D. Project Integration and Collaborations

This project was rated:

1) **3.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **4.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project exhibits a very large and diverse set of partners, subcontractors and collaborators. As such, this project has done a very good job of outreach to all key stakeholders within the community.

- In collaborative and integrative aspect of the projects really came across well in the presentation.
- The integrations with relevant stakeholders and the frequency of communication/feedback from them is quite impressive.

- The project is a model of collaboration with industry and community partners and integration within that community. The project has close collaborations with both window and window covering companies and industry organizations. It is also integrated into both energy modeling and product ratings and standards.

- No key stakeholders are omitted from the application. Collaborations are established with rating organizations, trade associations, manufacturers and AEC market leaders. Furthermore, well stated and open and collaborative approach to open source developers and partners renders the project with superior quality from the point of stakeholder coordination.

E. Proposed Future Work

This project was rated **3.75** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The project's future plans for FY 2017 and beyond are reasonable in scope and timing. This reviewer would prefer to see a prioritization of the transition to open-source software, as they believe this is create market based opportunities for other software developers to incorporate the project's work.

- The next steps and plans for FY17 and out years are well thought out and offer enough confidence to the reviewer that the team is fully capable of meeting their project objectives and will have a positive impact on the target market/audience.

- The future work reflects the progress to date and the needs of the industry, especially the efforts to publish APIs for the programs and enable cloud computing support.

- The proposed works are strategically based on the development of current suite of fenestration modeling tools. More focus could be given to open source transition activities. So as to mitigate possible risks of unsuccessful market adoption of the tools some alternative paths could be mentioned. More detailed future plan information should be provided about how to promote EP Calculator 1.0 within the user community.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- The project is delivering powerful and interconnected and credible tools to the marketplace. Without these tools available to provide information to the marketplace, adoption of new and innovative window technologies would be slowed.

- The use of the tools by the industry and manufacturers leaves little to no doubt that the project is likely to meet its deliverables.

- The deliverables of this project are widely used by, and provide a vital service to, the industry and the energy modeling community.

- The value of project deliverables is high from the point of target audiences. Algorithm improvements will provide a wider window/shading device technology coverage. Open source plan is an indication that this aspect will be addressed within the project and updates of IGDB/CGDB is directly related to the targeted market.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- This reviewer believes that the key research areas relevant to the project's objectives are receiving sufficient emphasis.

- BTO and LBNL provide strong support for these efforts and should continue to support them. There are not compelling challenges that suggest significantly greater effort.

- All the constituent parts are in place to result in a sufficient emphasis. A more profound impact could be achieved by; (1) putting open source transition to high priority list, (2) generating some connectivity of the suite of fenestration modeling tools with the open studio ecosystem as well as testing the potentials of algorithm coupling with SOEP framework.

***No*: 1** reviewer
- The emphasis seemed to be more on developing better models and better algorithms and releasing more versions of these tools but not much on integrating the existing tools into E+ and OpenStudio, although these directions were briefly mentioned.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project's strength include involving a diverse group of partners, subcontractors and collaborators, who are actively engaged and contributing towards the project's goals.

- Good accomplishments till date.
- Outstanding project integration and industry collaboration.
- Likely to have a positive impact on the market/audience.

- Projects like this will continue to be a critical part of the BTO energy modeling portfolio and continued support is required. It may not be sexy or even an "emerging technology," but the building community relies on these tools for standards, ratings, and energy modeling.

- The project has a comprehensive approach in dealing with simulation models, calculation engines applicable to different performance evaluation levels (component-based, assembly-based) with inherent potentials to be linked with whole-building energy models.
- The project demonstrates activities dedicated to improvements of modeling functionality to better represent the effects of integrated shading devices on indoor thermal performance (including air flow around – through different shading elements).
- Focusing on open source model transition to create better interactions with 3rd party interface-oriented developers. This is in line with the BTO ET's stated strategies.

2) **Project Weaknesses**

- The project's weaknesses may be risk / exposure to how to achieve beyond FY2017 goals given concerns of budgetary / funding sources being reduced in FY 2018. This reviewer feels strongly that providing the projects software outcomes as open-source tools can alleviate this risk, to a degree.

- Tying it all back to energy savings should not be sidelined, the EP calculator is a good direction.

- The project came across as very well established technology making incremental improvements rather than an emerging new technology.

- The only significant criticism of this project is that these efforts could just as easily be performed by an industry organization.

- Integration of individual fenestration modeling tools (e.g., EP Calculator) with open studio platform is needed to widen the audience/user base.
- Transition to open source structure should have a higher priority level in the overall progress of the research project.
- The project fails to identify how the updates and maintenance of the cloud-based IGDB and CGDB will be achieved after the completion of the project term.
- The project doesn't provide adequate details about how the improved algorithms (of air flow around shading devices) will be extended into EnergyPlus program (a new version release with source code updates?). Possibilities of external model coupling within SOEP from LBNL is missed.

3) **Recommendations**

- This reviewer recommends the project re-prioritize the task of completing the transition of the software tools to open-source to a higher level.

- This appeared to be a very mature project with a well-established market which is already using the tools being developed. Emphasis should be increased on what parts of the project count as emerging technologies.

- It may be useful to incorporate the impacts of daylighting into EP-Calculator.

- None.

Project # 35515b: (Complex) Fenestration Modeling Tools: Radiance

Presenter: Eleanor Lee, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed on this project's alignment with BTO's goal of increasing the ability to simulate windows in high-performance building envelopes. Reviewers also agreed with this project's approach, describing it as robust and well thought out, and commenting that the project team had successfully identified a majority of the critical barriers related to windows and building envelope technologies. One reviewer noted, however, that the modeling tool's new 5-phase method required more extensive testing, and this reviewer was not clear on how well third-party users would embrace the new method. Another reviewer recommended that any additional computational and informational needs that were imposed by the new 5-phase method should be clearly stated.

When considering the project's progress and accomplishments, reviewers commented that the project's tool had demonstrated significant improvements in modeling accuracy, and that the impact of this increased accuracy could be observed by the increased number of times that the tool had been downloaded recently—described by one reviewer as an "order of magnitude increase." Despite this increase in the number of downloads, one reviewer warned that complex modeling workflows, such as those required by this project—might not be readily accepted by the modeling community even if the proposed models are superior in their predictive capacities. This reviewer also expressed uncertainty about whether the project time remaining would be sufficient to construct standardized testing protocols to generate certified Complex Fenestration System (CFS) product databases, describing the development such databases as crucial work that would drive market awareness and acceptance of CFS products.

Reviewers soundly approved of the project team's integration and collaboration, describing the project's impressive list of collaborators and referring to the project team's engagement with AERC, codes and standards bodies, industry, and others as quite remarkable. One reviewer thought that the project team should increase its stakeholder interactions, however, specifically citing ASHRAE Technical Committees, commercial program developers, and members of open source communities as targets for additional outreach.

Reviewers generally approved of the project's proposed future work, describing it as logical, flowing naturally from past accomplishments, and well thought out. Reviewers did flag some potentials risks, however, including that the project's impact on energy savings would not be measured, and that additional testing requirements could impact adoption of the tool by third-party users. One reviewer encouraged the project team to indicate how current work would be sustained after the current project was completed, while another strongly recommended that the project team document its software algorithm methods.

Weighted Average: 3.45 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.25 Accomplishments: 3.50 Project Collaboration: 3.75 Future Work: 3.25

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project provides necessary credibility for simulation tools that will be used for emerging technology, R&D, design and engineering, and rating and certification programs for complex fenestration products. This project enables and supports incremental improvements in both Codes and Standards and Emerging Technologies programs.

- Part of achieving BTO's energy savings goals by 2030 is developing modeling and simulation capabilities for innovative facade systems. This project addresses the lack of computationally efficient tools to evaluate complex fenestration systems and therefore, aligns with BTO's goals.

- The project supports the continual development and improvement of Radiance, which is a critical component of the BTO energy modeling portfolio. While it officially began in 2015, it is the most recent of a long line of projects in support of the tool. This particular project addresses complex fenestration systems with efforts to significantly improve model accuracy.

- The project with the objective of developing validated simulation models for Complex Fenestration Systems (CFS) and implementing them in software tools aligns with BTO's goal in increasing the current abilities to simulate windows of high-performance building envelopes. Updating Radiance computational capabilities also aligns with BTO ET window strategies in improving window design tools. The project can make direct and measurable contributions to the realization of the full potential of energy and cost saving impacts of optically complex fenestration systems. The project's plans for supporting incorporation of Open Studio models in related software tools (compatible with EnergyPlus) is also in line with the stated BTO ET's strategies related to window assemblies. To be able to meet the projected performance levels, the project should better indicate possible plans for developing certified product databases together with challenges or constraints that might arise from measurement costs and productive interactions with the manufacturers of various CFSs.

B. Approach

This project was rated:
1) **3.25** for the degree to which it focuses on critical market barriers, and
2) **3.25** for the degree to which the approach addresses the market barriers identified.

- The project approach taken by this project for developing validated algorithms and product databases includes engaging with key partners such as the CFS manufacturing community, academic institutions, organizations such as ASHRAE/CIBSE, and other international research institutions. The approach, following steps for development, testing, debugging and final validation, is robust and represents a well thought out approach.

- The approach is focused on developing standard models for assessing complex fenestration systems. Key issues with direct solar components, and high resolution BSDF data have ben identified. The score by the reviewer is just short of outstanding since the target market for this project is descriptive rather than quantitative. It would be preferred to breakdown the market/audience empirically into manufacturers, owners, architects, code officials, utilities etc.
- Other than this minor ommittance, the approach presented and being used is outstanding.

- The project approach for complex fenestration systems draws on established methods of analysis and expands to a new 5-phase approach for improved accuracy. The models address the need for greater accuracy. Unfortunately, the new methods require more extensive testing and it is not clear how well the third-party users will embrace the new methods.

- The project has successfully identified majority of the critical barriers related to windows and building envelope technologies. It not only focuses on the challenge of the lack of performance metrics-measurement techniques for building envelopes but also tackling with the lack of ability to simulate windows in building envelopes. The project also successfully addresses the significance of establishing an equitable basis for CFS products via development of standard measurement protocols. One of the most critical aspects is the research effort to integrate Open Source models into software tools. However, current plans for product characterizations (and related testing-measurement procedures) are not clear/detailed enough to be able to cope with possible technical risks. Improved accuracy that comes along with 5-phase method could possibly come with additional modeling requirements on the modeler side as compared to commonly used 3-phase method. The project should clearly state any additional computational and informational needs imposed by the newly introduced 5-phase method.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project (to date) has examine both 5-phase and 6-phase solutions, and has determined that an improved 5-phase method is significantly more accurate than the traditional 3-phase approach. It does not appear that the 6-phase method adds enough worthwhile incremental accuracy to recommend implementing in software code. The impact of the project can be inferred by the increased number of download of the Radiance software which has implemented 5-phase methods into the source code.

- This project is more than half way into its duration and the accomplishments reflect the same. Detailed quantitative results were presented on validation using full scale measured data, 5 phase methods accuracy results, and BSDF input data comparisons. The radiance model was validated from monitored data from FLEXLAB. The 5 phase approach has been shown to be more accurate than the three phase approach. This project has directly resulted in an order of magnitude increase in number of downloads for Radiance. (A year by year breakdown should be included, if available).

- The project team has demonstrated significant improvements in accuracy. The impact of this improved accuracy will depend on the adoption by third-party users, which has dramatically increased in recent years.

- The project can provide qualitative and some quantitative support to ET program performance goals. Significant increases in the use of Radiance open source simulation engine is reported on a global scale. Some further evaluations need to be conducted whether the newly introduced BSDF models would further increase the use of Radiance engine or not. Equal if not more emphasis should be given to the integration of new models to current modeling workflows (model-based) as it is given to the development of more accurate models. Complex modeling workflows (Radiance to EnergyPlus with EMS routines) may not be readily accepted by the modeling community even if the proposed models are superior in their predictive capacities. It is also not clear whether the remaining project time (03/2017 to 09/2018) would be enough to construct standardized testing protocols to generate certified product databases to get the full potential of the new modeling approaches. Substantial evidence about meaningful contributions to the ET's interim market is likely to happen provided that the industry recognizes the missed energy saving-cost saving opportunities by the missed utilization of the 5-phase, high fidelity approach proposed by the project.

D. Project Integration and Collaborations

This project was rated:

1) **3.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project includes an impressive list of collaborators and project integrators, and the reviewer made a strong case describing the roles of multiple partners, subcontractors and collaborators involved in the project. It is clear to this reviewer that the CFS product manufacturing community considers this to be a valuable research project and provide support as needed.

- The projects integration and collaboration with AERS, codes/standards bodies, and industry is quite remarkable. It's great to see that the models, data, and the softwares are being used to a great degree of extent by practitioners and engineers.

- The project team has a long history of collaborating with both industry and the user community. This particular project involves collaboration with industrial partners and their trade associations, code and standard bodies, third-party integrators, and international researchers.

- The project has demonstrated an insightful understanding of the key stakeholders. Particularly collaborations with AERC and NFRC are crucial so as to advocate the use of innovative window products that can be better evaluated in virtual environment. In addition to this, the project can increase stakeholder interactions with ASHRAE Technical Committees (TCs) are with some commercial program developers and members of open source communities who are adopting Radiance engine in their workflows as well as standardized material libraries for CFC products. Existing collaborations on the other hand are fairly well coordinated.

E. Proposed Future Work

This project was rated **3.25** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The presenting reviewer discussed that validation efforts will continue, after which the final algorithms will be made available under open-source licensing arrangements. The open-source licensing will encourage other CFS product evaluation tools (in addition to Radiance) will have easy access to the validated algorithms and implemented code.
- From this reviewer's perspective, the more impactful future work product will be the development of certified product databases for CFS products. This is a task that can only be tackled once validation efforts are completed, but is a very important task which will drive market awareness and acceptance of CFS products.

- The next steps and future plans for the project have been well thought out. They involved identifying key error sources and improving models and algorithms, more validation of the models, and integrating the project work into software tools. Future plans also involve developing model and standardizing products with high res BSDF data.
- The minor risk is that the coupling of this work with impact on energy savings should not be omitted and the impact must be measured.

- The proposed future work flows naturally from past accomplishments. The additional testing requirements and the adoption by third-party users pose the main risks.

- The project plans for future work are organized in a logical manner in terms of continuation based on the previous progress. The outstanding future plan items are incorporation of open source models into software platforms and development of certified product databases. The only risk existing (that could prevent the achievement of the project objectives) is the availability of the remaining project time to establish certified product databases (time extension could be crucial). The project should indicate how current work could be sustained after the project completion. Without continuous maintenance and update of standardized-structured product databases the usability of the advanced CFS models will be severely diminished. Future plan items could also include how collaborations will be constructed to introduce the new approach to rating-certification programs, codes and standards.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- The project represents means and methods for allowing a broader community (beyond the research and development community) to evaluate the cost-effectiveness of CFS product systems. This is not something that can be accomplished today, thus as an enabling technology it represents new cost-effective pathways for CFS technologies to be evaluated and eventually adopted.

- The models and software being produced as a part of this project are certainly expected to address the market needs for better simulation and standardizations of complex fenestration systems.

- Fenestration systems are becoming more complex and users are expecting greater visual accuracy. The project deliverables directly address these needs.

***Average*: 1** reviewer

- The key target audiences could be specified in a more integrative manner. The project should increase time and efforts to model implementation, automated workflow development and certified product database generation aspects.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- This reviewer considers the key research relevant to the project's objectives as receiving sufficient emphasis.

- The focus thus far has been on validating the models and integrating them into simulation tools. The key activities accomplished as well as planned demonstrate that project's goals are receiving enough attention.
- Although it can be challenging to measure the direct energy impact of this work but doing so will improve the relevance of this work to the program's objectives.

- The Radiance program, and fenestration systems in general, have received strong BTO support for many years. With growing adoption of Radiance, such support should continue. However, it is not clear that current support is inadequate.

- Key research areas (including the future research plan items) are relevant to achieve sufficient emphasis for project as well as program's objectives. Given enough amount of time, physically-based model development and full scale field data validations and implementation of open source models into software tools (preferably EnergyPlus compatible) and development of standardized testing protocols and development of certified product databases are all of the required steps of achieving some profound impacts to the current state of energy efficient window design and characterization in the current building industry.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- This reviewer considers a project's strength to be the remarkably strong and diverse integration and collaboration community.

- Mature project with great technological achievements so far.
- Outstanding tight integration with key stakeholders and industry.
- Tools are being widely used in the real world is a plus.

- This project is the latest in a long line of projects in support of Radiance, which is a critical component of the BTO energy modeling suite. The use of Radiance has dramatically increased in recent years, adding greater importance to its continued strong support. The current project reflects the achievements of this highly successful LBNL team.

- The project's objectives-outcomes are perfectly in line with BTO-ET window topics (improving testing and modeling capabilities, including window design tools).
- The proposed method is proven to be superior to the existing 3-phase method (validation using full scale field measurement data).
- The project addresses the need for developing open source models and further integration to software platforms (utilizing DOE supported Radiance synthetic imaging system).
- The project addresses the significance of developing standardized measurement and testing protocols for characterizing innovative CFS products for virtual prototyping.
- The project addresses the significance of developing commonly accepted and certified CFS product databases.

2) **Project Weaknesses**

- This reviewer notes no significant project weaknesses.

- Attempts should be made to better measure the impact and close the loop with energy savings resulting from this work.

- The enhanced modeling required of complex fenestration systems could challenge the testing protocols and some of the most recent third-party users. The impact will only be realized with widespread adoption.

- Additional modeling complexities (in terms of additional input data requirements) that may arise from adoption of 5-phase method were not evaluated.
- The project doesn't reveal plans about how the certified CFS product database system maintenance and necessary updates will be accomplished after the project completion.
- The project doesn't show enough focus in proposing automated-easy to use modeling workflows to reduce modeling burdens on the prospective users of the proposed simulation methods.
- Collaborations should be extended to ASHRAE TCs, commercial vendors and open source modeling communities as well.

3) **Recommendations**

- The only comment this reviewer has for this project is to strongly recommend that documentation of the implemented software algorithm methods be ensured. Often, software documentation tasks are one of the last deliverables to be completed and are lacking in sufficient detail for users and others to adequately use the software without careful inspection of the source code, which is not ideal.

- Present breakdown of users rather than just a list.
- Tie it back to impact on energy savings.

- I was surprised to learn that the tools do not account for spectral variations, but expect that these factors will become more important with increasingly complex fenestration systems.

- None.

Project # 99125: AIA 2030 Commitment

Presenter: Kevin Settlemyre, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's central building energy modeling (BEM) goal of increasing the use of energy modeling in design. One reviewer commented that developing a consistent reporting metric in DDx 2016 would advance this goal, with another remarking that the project's cost and return-on-investment features would build a business case for BEM that could unlock further industry adoption.

Reviewer's also felt that the project's approach of using an application program interface for external vendors to access the DDx reporting database would address the current lack of performance-based feedback on buildings designed with BEM. However, while one reviewer agreed that this approach would address data integrity and reporting consistency problems, they wished for a carbon footprinting mechanism as well, which was seen as an omitted market barrier. Another reviewer thought that the project's approach of incrementally adding features to the core DDx was wise, as it allowed users to provide feedback to AIA as the feature set increased.

Reviewers were mostly pleased with the project's accomplishments, with two reviewers commenting that the project had accomplished its planned tasks. Several reviewers were impressed with the tool's development and the 60% growth in GSF reported, with another reviewer commenting the project's "exceptional insights…[would] have an unprecedented impact on our understanding of role of energy modeling in building design."

Reviewer were impressed by the project's collaboration with stakeholders, commenting that the project team "had deep understanding of key stakeholders for the acceleration of market penetration." Multiple reviewers applauded the team's frequent meetings with AIA, which one reviewer thought would ensure the adoption of the AIA DDx platform. One reviewer wished that the team had collaborated with other modeling software developers, while another reviewer wanted greater interactions with engineering consultancy firms and governmental institutions.

Nearly every reviewer felt that the team's remaining tasks were appropriate and relevant for overcoming the project's stated market barriers. However, a few reviewers felt that the team had not developed a sufficient risk management plan for addressing problems if they emerged. One reviewer was left wondering when the AIA DDx would be complete and no longer needing DOE's support, while another reviewer thought that it was critical for AIA and DOE to develop a formal data sharing agreement upon project completion.

Weighted Average: 3.31 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.38 Accomplishments: 3.25 Project Collaboration: 3.38 Future Work: 3.25

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- DOE currently is lacking critical infrastructure to provide feedback to how 'effective' energy DOE influenced modeling workflows are, with respect to driving value throughout a building's entire life cycle. This tool has the potential to collect this type of information from the design community, and if properly marketed and adopted, will provide invaluable performance metrics and feedback to DOE as to the effectiveness of supporting infrastructure.

- The project aims to support the AIA 2030 commitment challenge by enabling and providing a consistent reporting metric to help firms evaluate the impact of design decisions on energy use intensities and energy performance.
- The online database is being built using the DOE Standard Energy Efficiency Data (SEED) platform. The project is aligned to BTO's goal of tracking building energy modeling use cases in the market.

- The overarching goal of the energy modeling program is to increase the use of energy modeling tools in design. However, you can't manage what you don't measure. This project offers the first (to my knowledge) opportunity to obtain concrete data on the use of energy modeling tools in building design.

- AIA 2030 DDx online design data exchange platform is critical to the BTO and supporting the overarching goals in ET BEM sub-program. This is due to the fact that through collaborations with AIA, the use of BEM tools in the design of energy efficient buildings will be better understood, the building performance data is shared and modeling activities will be promoted among the building industry. AIA 2030 DDx is also instrumental to track not only the use of BEM tools but also the building energy performance levels that are targeted by BTO. DDx 2016 features that are aimed at BEM cost and related ROIs can be very effective in promoting high-performance and BEM-driven design making approached that are not fully embraced by some industry members due to lack of convincing financial metrics pertaining to the BEM operations. DDx platform could be further enhanced to identify specific high-performance building technologies (also supported by the BTO ET) in reaching to 2030 targets.

B. Approach

This project was rated:
1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.25** for the degree to which the approach addresses the market barriers identified.

- The project's strategy of providing an API through which external vendors can link their tools and platforms to the DDx reporting database is a very wise approach. Having major (market dominating) software vendors such as AutoDesk actively involved and engaged in the project sends a powerful message to other software vendors to include the DDx interconnects in their tools as well.

- While some key market barriers have been identified, such as data integrity and reporting consistency, discussion about the following barriers was omitted: How to establish reliable baselines? How is the impact of CO2 emissions measured? The uncertainty around carbon based regulations can also affect this project outcome and its impact.

- Well-designed approach with DDx. The work to automatically import data from large firm databases and from energy modeling tools is particularly helpful. Issues of data integrity and consistency are still issues.

- The proposed DDx platform successfully addresses the informational barrier which prevents designers having adequate performance-based feedback about buildings designed with BEM-driven decisions. DDx could be in practical use to track the adoption/use of EnergyPlus-based BEM platforms. However, expansion beyond AIA should also be planned (this will be beneficial to DOE). DDx could provide some

connections to Open Studio ecosystem of programs using similar API-based connectivity as demonstrated in AutoDesk's Insight 360. High-impact-techs (HIT) are instrumental in achieving significant building performance improvements to reach BTO's overall savings goals. They also become more critical in design, construction and operation of net-zero energy buildings. The application could offer some data collection, analysis and visualization functions focused on identification and prioritization of HITs for the purposes of NZEB design. This could also serve the aim of faster adoption of market ready HITs. The application's plans to overcome its identified barriers are sharply focused, added features of BEM cost and ROI, bulk import and design software APIs could significantly improve the adoption of the proposed platform.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.25** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is accomplishing the project's stated goals by carefully and incrementally adding features to the core DDx offering, in a manner of "minimal viable product" release strategy. This software deployment strategy is a wise strategy, as the community gains awareness of the DDx system and the feature set increases, the community can provide valuable feedback to AIA via the DDx.

- Results presented were quantitative and showed clearly showed the progress in tool development and adoption.
- A 60% increase in GSF reported since 2030 is a good sign. Interesting results about the time for return on investment for building energy modeling were presented. The work on developing an API for submitting DDx project data directly from BEM software is promising as well.

- The project is nearing completion and seems to be accomplishing its planned tasks. The results seem to provide exceptional insights to the use of energy modeling in meeting the AIA 2030 challenge. The data available from this project will have an unprecedented impact on our understanding of role of energy modeling in building design.

- The project didn't demonstrate a strong qualitative support to ET program performance goals. It is not clear how the DDx platform will serve for supporting substantial improvements to the use of techniques available to reduce energy use in buildings. The use of BEM modeled and actual building performance data can be shared and visualized informatively but the project doesn't reveal approaches and subsequent predictions of expected increases in the use of EnergyPlus, Open-Studio-based design decision support systems and how such increases could result in primary EUI savings (current and projected to 2020-2030). Due to volunteer participation method followed in DDx, there may exists a possibility of bias in the reported energy performance data such that participating firms/companies tend to report high-performing project results (and become reluctant to report mediocre – poorly performing ones). The application should provide some measures about how tackle with possible deviation of reported levels from the actual performance (to prevent some misleading conclusions or projections for targets to reach).

D. Project Integration and Collaborations

This project was rated:

1) **3.25** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project's active engagement with the LFRT and other key stakeholders indicated the project has identified feedback methods to ensure the eventual use and adoption of the AIA DDx platform. This is, in

this reviewer's opinion, a critical item, as the AIA DDx platform will, in the future, reach a stage of maturity that will no longer require DOE support, and will be developed, maintained, hosted and operated by AIA and other non-DOE stakeholders.

- The presenter demonstrated a good understanding of the market and the key players. It is clear that the project involves a high degree of collaboration with key stakeholders. Weekly meetings with AIA staff and monthly meetings with AIA working group is a good sign. Perhaps, the presentation could have also covered some key/interesting/or even surprising insights they learned from these meetings which otherwise would not have been possible.
- The interest from industry (Autodesk and LFRT) was also discussed in the presentation.

- The project involves a large collection of partners, including AIA, AutoDesk, LFRT, and a host of design firms. The partners appear to have worked together very well in this nearly-completed project. The one missing stakeholder seems to be the many other energy modeling software developers. To the extent that EnergyPlus is only the fifth most widely used tool, there are opportunities to engage other tool developers.

- AIA 2030 DDx project demonstrates a deep understanding of key stakeholders for the acceleration of market penetration. Focusing on market leaders is key to the ET's program objectives and AIA 2030 DDx project accomplishes that aspect. Additionally, the project can increase stakeholder interactions with engineering consultancy firms (utilizing BEM for system design improvements – code compliance, LEED certification). Some connections with governmental institutions (e.g., GSA) could be established to widen the project base. Existing collaborations are fairly well coordinated.

E. Proposed Future Work

This project was rated **3.25** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- It was not entirely clear from the reviewer's presentation as to when it is expected the AIA DDx platform would be sufficiently built out to no longer require DOE support and funding. It would be, in this reviewer's opinion, valuable for DOE to fund further integration of DOE developed tools such as the BPD or links to OpenStudio/EnergyPlus into this platform in creative ways that can result in more data capture. This reviewer also feels that it is critical that AIA and DOE develop a more formal agreement as to data sharing, such that DOE is ensured the ability to extract performance data (aggregated, anonymized, etc.) from the DDx platform after DOE completes funding of DDx feature set buildouts.

- A good next steps and future plan was presented which covers:
    - providing insight into EUI and its drivers.
    - linking design to EUI
    - adding measured data import capability
    - tracking energy efficiency measures across different building types and locations.
- The future directions are interesting and relevant.
- The discussion of any alternate plans in case of a problem was omitted. For instance, what happens if firms do not participate/provide data to the expected extent?

- The project is almost complete. The remaining tasks seem appropriate.

- The presented future plan items are effective for overcoming the stated market barriers. The outstanding future works are integration with DOE tools and program (some more clarifications needed) as well as importing and linking design data with actual EUI levels. On the other hand, the application doesn't indicate possible technical risks and some strategic decision points about how to mitigate them effectively. There may be risk of reduced participant involvement upon comparisons of measured vs. predicted building performance data (inherent deviations).

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- The project has the potential to provide a feedback loop to DOE relating to the actual usage and impact of energy modeling tools (including those primarily influenced by previous DOE investments). The information acquired via this feedback loop is invaluable, as it represents an actual measurement system of investment impact.

- The assessment here is related to the recommendation. The deliverables, in principle, should allow the building designers to close the loop with energy usage but this needs to be validated through empirical evidence.

- DDx will provide unprecedented insights to all the key market sectors.

- The value of AIA 2030 DDx project deliverables to key markets of the ET program is high. This is due to the fact that DDx online platform features are in line with the current needs of the market which are; (1) low, or no-cost applications, (2) enhanced visualizations for quick information gains, (3) ease of use with reduced number of program inputs, (4) connectivity with regularly used software platforms and local databases, (5) basis of standardized and easy to comprehend performance metrics.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The key deployment activities relevant to this project's objectives are receiving sufficient emphasis.

- The key task is to make it easier and low touch for firms/designers to provide their data during different development phases and the development activities being undertaken are relevant to this key objective. Sufficient emphasis is being given on collaborating with key stakeholders and industry to develop the tool and promote its use.

- Deployment activities are relevant to receive sufficient emphasis. It is apparent that DDx platform forms a common foundation to track the performance levels in relation to commonly accepted 2030 goals. Adding energy end use breakdown functionality will be critical to inform users about specific performance areas to focus on. Functionality will be further enhanced with EEMs tracking so that awareness about design improvement measures that can foster current performance levels could be provided within the same online platform.

***No*: 1** reviewer

- Efforts like these deserve far greater emphasis and funding. We need more data, especially on how these models are used. The big question is, "What's next?" How will the database continue to be populated? How can you engage other firms? How much detailed data on modeling assumptions and techniques can you collect without encountering privacy concerns? And biggest of all, can you connect the DDx to Portfolio Manager to compare modeled versus actual performance?

H. Additional Comments and Recommendations

1) **Project Strengths**

- The strengths of this project include the close coupling of key industry stakeholders who have a vested interest in the long term success of this DDx project after DOE support and funding is exhausted. The ability for these stakeholders to use the DDx to drive value from within their own firms represents an creative method of market transformation, enabled by prior DOE investments.

- Relevant to BTO's goal of tracking building energy use.
- Remarkable progress and project execution so far.
- Quantitative progress results.
- Close collaboration with key stakeholders and industry.
- Relevant future plan and future direction.
- Presenter demonstrated a good understanding of the key problems and the market impact.

- One of the greatest frustrations in the energy modeling community is the lack of data on the use of modeling tools. The project will offer insights that could finally provide BTO program planners and software developers with these insights. This project could be a game changer!

- The project shows strengths in dealing with the information-based barriers which prevent key stakeholders (architects, building owners, BEM community, ESCOs, etc.) to utilize high efficiency building technologies due to lack of collective/actual information to assess and compare building energy performance. This is provided by no cost, easy-to-use DDx which can generate comparable, standardized metrics for a range of building types and use cases.
- DDx offers some scalable and flexible data visualization techniques for the ease of knowledge extraction from collections of numeric performance data.
- DDx is very useful in tracking BTO ET performance goals, the use of EnergyPlus-based BEM platforms and to identify current states to detect potential areas of future focus.
- Collaborations with commercial BEM market leaders (via design software APIs) reveal significant potentials to widen the data collection base (both quantity and diversity).
- Reporting feature of cost of BEM and related ROIs (e.g., payback of modeling fees in moths) is a strong approach to deal with another market barrier of avoiding BEM in building delivery processes which is regarded as an extra cost (a burden on the project budget).

2) **Project Weaknesses**

- A project weakness may be described as unclear 'exit strategy' - a vision and description of when subsequent DOE support will not be needed and a clear timeline and project plan for getting there. The 'future work' presented by the reviewer did not lay out a clear understanding of when and how the project could be considered complete and ready to be closed out.

- While risks and barriers were correctly identified, not much was said about how to overcome those barriers.
- The success of the tool depends completely on its adoption by the design firms and the market. Not enough evidence was presented that the firms want this tool. It was not clearly demonstrated what a firm can do with this tool that it could not have done without the DDx tool.
- The URL of the DDX tool didn’t work at the time of the review, although that’s just a minor weakness, and the fidelity of the tool is not in question.

- My only criticism of the project is that it may not go far enough. I am not familiar with the exact set of data collected in DDx, but the implication from the presenter is that it does not collect details of the modeling assumptions.

- Project is not clear about what type of benchmark/baseline performance level is assumed to make possible cross sectional/comparative performance analyses.

- Project is missing some useful integrations to open-studio platforms via dedicated APIs (similar to Design Software APIs for Autodesk's Insight 360).
- Some collaboration opportunities with engineering consultancy firms, governmental institutions are not considered.
- Tracking EEMs and identifying HITs and integration with DOE's tools and programs should be taken at the highest priority level.
- DDx only provide some deterministic point performance levels instead of revealing a range of variance for a specific building model set up to reveal uncertainties and to evaluate possible risks associated with the reported building case.
- Inherent biases arising from reluctance in sharing poorly-performing projects should be addressed.

3) **Recommendations**

- This reviewer recommends the project develop a more concrete project plan for next steps and future plans, along with metrics that can be clearly measured to represent DDx success and adoption/acceptance.

- The project's biggest hypothesis is that the data solicited via the DDx portal will be put to good use by the firms to reduce their EUI (if this is not the hypothesis, then that didn't come across well in the presentation). This hypothesis has to be validated and both success stories and failures of using the DDex tool must be analyzed to better assess the impact of the portal. Going back to the reviewer's earlier comment 'what is it that the target users/firms of the portal are doing different today, which they could not have done without the portal? Is the answer, better reporting or better design?

- There is little time for much additional input, but I am especially interested in the opportunity to gather detailed data from the energy modeling software.

- None.

Project # 99303: NRGSim - Enhanced Envelope Phase Change Material Simulations in EnergyPlus (Small Business Voucher)

Presenter: Edwin Lee, National Renewable Energy Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers were mixed on this project's relevance to BTO's goals. One reviewer noted that, through this project's improvement of algorithms and modeling methods, EnergyPlus could be used by a broader set of users to easily evaluate the cost-effectiveness of phase change material (PCM) strategies. Another reviewer agreed that this project would improve the accuracy of building energy modeling (BEM), but noted that the improvement would only affect a small and non-critical sector of the BEM market. A third reviewer highlighted that the project had not yet revealed or indicated any potential for substantial energy savings from improved BEM accuracy of PCMs.

Reviewers were similarly mixed on the project's approach. One reviewer commented that the small business voucher (SBV) project was taking a logical approach to implementing improved PCM analysis methods in EnergyPlus. Another reviewer highlighted that the project had defined two key barriers, and that both were being addressed. One reviewer, however, felt that the project's target audience and market description were too general, and that quantitative measures of the target market should have been presented. Another reviewer highlighted numerous issues that the project was *not* addressing, including how the new PCM models could be integrated into EnergyPlus and how these models would be maintained after completion of the current project.

When considering the project's progress, one reviewer noted that the project would likely deliver on project goals while also remaining under budget. However, this reviewer strongly encouraged the project team to ensure that sufficient time was spent documenting the PCM solution, warning that documentation budgets were sometime cut to stretch the implementation and testing budgets for many code implementation efforts. Another reviewer similarly highlighted that the project was accomplishing its goals according to the project plan, but commented that these goals were not expected to have much impact on BTO's overall objectives, noting that the project did not demonstrate qualitative or quantitative support for BTO's performance goals.

In terms of collaborations, one reviewer observed that there was only one stakeholder under the SBV program and that the NREL team was coordinating well with them. Another reviewer remarked that the project team was engaging with well-known PCM modeling experts as well as key EnergyPlus developers; as such, this reviewer did not identify any gaps in the project's integration or collaboration. A third reviewer, however, felt that the project had demonstrated only a basic understanding of key stakeholder, highlighting some other possible stakeholders had been omitted, including PCM manufacturers and other national lab experts.

Looking forward, one reviewer said that the project was expected to be completed as planned, while another felt that future plans were reasonable but that more details could have been presented. A third reviewer felt that presentation of future plans failed to address key technical risks and possible risk mitigation strategies. The final reviewer felt that a model validation step would be prudent, thought they acknowledged that the project team had indicated that underlying algorithms had been field validated by 'other researchers.' One reviewer noted that it would be helpful to add PCM enhancements to EnergyPlus' combined heat and moisture transfer (HAMT) models as well.

Weighted Average: 2.74 # of Reviewers: 4
Relevance: 2.25[1] Approach: 2.88 Accomplishments: 2.50 Project Collaboration: 2.88 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Phase Change Materials (PCM) form the basis for creative and unique applications of thermal (mass) storage, providing innovative solutions for shifting the peak cooling demand of a building - thus relieving cooling loads from a strained electrical grid. There are, to this reviewer's knowledge, few open- source analytical tools available for evaluating the effectiveness of PCM system designs. The current DOE BEM engine, EnergyPlus, provides limited and overly complex methods for representing the performance of PCM. By improving the algorithms and modeling methods, users of EnergyPlus will be able to be used by a broader set of users to more easily evaluate the cost-effectiveness of PCM strategies.

- This is a new project trying to incorporate PCM models into EnergyPlus

- The project should improve the accuracy of building energy modeling for a narrow market.

- The project's support for BTO's goals is "fair" with potentials of improving the current computational capacity of EnergyPlus in the field of Phase Change Material (PCM) evaluations. Such an approach would help tackling with the Building Energy Modeling (BEM) challenge of the lag of technical coverage in simulation engines as well as problems of engine accuracy. The project's suggestion of providing a more industry-oriented PCM modeling input parameters (compatibility with manufacturer's specification data with PCM model input parameters) would also be effective from the point of increased energy saving technology adoption and evaluation by the current market. However, the main goal of BTO's ET program is to support R&D activities that can provide substantial reductions in building's primary energy consumption in comparison to high-efficiency technologies but not relative to standard commercial buildings. From this perspective, the project doesn't reveal/indicate potentials for substantial energy savings through improved modeling accuracy of PCMs to be used as demand shift-energy saving measures. The project impact and relevance to BTO's goals is also not evaluated whether PCM modeling functionalities could still result in increased building technology adoption which also requires relatively lost cost manufacturing and ease of installation (aspects of building constructional systems integration).

B. Approach

This project was rated:
1) **2.75** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- This SBV project is taking a logical approach to implementing improved PCM analysis methods into EnergyPlus/OpenStudio by working with a nationally recognized technical experts on PCM technologies, whom also have practical experience, as well as experience with modifying EnergyPlus to accomplish their needs.

- Two key barriers defined - current model inputs are difficult to obtain from manufacturer's data, and current model does not capture physical hysteresis.
- Both the barriers are being addressed in the project. The target audience and market description is too general, a quantitative measure of the target market should be presented if available.

- Phase change materials represent a very small and non-critical sector of the energy modeling market. The project should improve modeling accuracy and input needs.

- The project has identified some of the market barriers that are relevant such as difficulty of translating PCM manufacturer's specs data to BEM models as input parameters as well as limits in the predictive capacity of current PCM models within EnergyPlus program. The project also identified the current hurdles in maintaining customized versions of EnergyPlus (with high-fidelity PCM models) as opposed to merging

these models with DOE's mainline EnergyPlus releases. However, the project doesn't mention about how the new PCM models could be integrated into EnergyPlus program structure (source code updates & maintenance issues versus possibility of utilizing Spawn-of-EnergyPlus (SOEP)-based integrations). It is also not clear how to maintain further releases/updates of PCM models after the completion of the current project. It is also omitted from the application whether the proposed PCM models could cover a substantial range of manufacturer's specs existing in the market (or applicable to a certain segment/niche in the same market). The project doesn't provide adequate details related to the methods for evaluating/quantifying the increased accuracy of the proposed PCM models. Without focusing on the state-of-the-art BEM model integration and usability platforms, it could be challenging to identify the level of impact that improved PCM models could have on the current market.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.25** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- At the time of the peer review, the project had only expended ~ 25 percent of the allotted budget, and the subsequent tasks of implementing and testing the proposed solution within the EnergyPlus / OpenStudio codebase had yet to be undertaken. It is expected that if carefully managed, the project will accomplish this implementation and testing, delivering on the project goals while also remaining under budget. As with many code implementation improvements, the task of documentation often remains one of the last deliverables, and sometimes documentation budgets are cut to stretch the implementation and testing budgets. This reviewer strongly encourages the EnergyPlus/OpenStudio developers to ensure sufficient time is spent documenting the code, creating example files for including in EnergyPlus distributions, etc. to ease the burden for new users who will want to exercise the improved PCM modeling features.

- Although this is early into the project, the bulk of the work of integrating the better PCM models remains to be done.

- The project is accomplishing its goals according to the project plan. However, they are expected to have little impact on the overall BTO program goals. They are doing a good job, but it's just not that important and serves a very limited user base.

- The project doesn't demonstrate qualitative or quantitative support for the achievement of the program performance goals. The project doesn't clarify potentials of the reduction of building energy use intensity relative to the 2010 high-efficiency technologies as stated in the ET program performance goals. Contributions to the ET interim market goals will likely be only marginal. The project needs to identify what type of standardized and BTO-advised model validation protocols will be utilized to identify uncertainties in the proposed PCM models. Possible performance contributions could be severely diminished due to a number of constructional limitations and/or unidentified building integration techniques related to PCM technologies. The project fails to identify whether there exists a standard format of manufacturer's specs data that could be regulated to provide seamless integration to computational PCM models to be upgraded for improved modeling accuracy.

D. Project Integration and Collaborations

This project was rated:

1) **2.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The SBV project is engaging with both well-known industry experts in modeling PCM as well as key EnergyPlus development team members. As such, this reviewer has not identified any gaps in project integration and collaboration.

- It came across during the presentation that the tool integration was just being performed for one individual at NRGsim.

- There is only one stakeholder under the SBV program and the NREL team is coordinating well with them.

- Through its collaboration with NRGMSim+ with cost sharing, the project has demonstrated a basic understanding of the key stakeholder. However, some other possible stakeholders such as PCM manufacturers who can be helpful for characterizing PCM data for models are omitted. Possible inter-lab collaborations are also currently missing in this application. Collaborations could be extended to some other national labs (LBNL) to come up with fruitful interactions that can foster the integration of the proposed PCM models with EnergyPlus simulation engine (via SOEP as well as open-studio ecosystem).

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- As this is a very short project in length (less than one year), the proposed future work related to this project is somewhat irrelevant. No significant future work was identified during the peer review. The issue of code validation was raised during the peer review Q/A session, and the reviewer commented that the underlying algorithms had been field validated by 'other researchers' so the project team did not feel like a software validation test (measured data vs the results of the improved simulation predictions) was warranted, given the high cost of the validation effort, the existence of previous algorithm validation studies, and the limited budget available to grantees for SBV projects. Nevertheless, this reviewer feels a validation step would be prudent, if not a part of this SBV project then perhaps a part of the Modeling and Uncertainty work occurring at the LBNL FLEXLAB, at a later date.

- More details could have been presented rather than just saying Go/No decisions will be made.
- The team seemed capable of delivering all the project outcomes and the efforts will be directed at completing the model implementation in E+

- The project is expected to be completed as planned. Future work plans are reasonable.

- The proposed future work plan is mostly focusing on EnergyPlus program implementation. Some strategically located decision points seem to be missing. The application failed to address the identification of key technical risks and quality management and possible risk mitigation strategies. Future work should be extended with the inclusion of how the high-fidelity PCM models could be incorporated into more flexible (easy to maintain) workflows. No alternative pathways to mitigate possible risks preventing the project's objectives are given in the application.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The project is certainly relevant to practitioners and researchers who need/want better tools for evaluating the performance of PCM solutions. Over time, it is likely that PCM solutions will play a larger role in demand side management solutions, and that the investments in these improved algorithms will have significant paybacks.

- Very specific scope has been defined. Meeting those deliverables should have the expected impact on the market.

***Average*: 0** reviewers
- N/A

***Low*: 2** reviewers
- The deliverables are minor improvements to a model with little use in the broad energy modeling community.

- The applicability potential and constructional (architectural) integration potentials are not identified. The cost of design, installation and maintenance of the studied building technology are not evaluated. Sole improvement of current PCM models may not necessarily relate to the key target audiences of the ET program.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- This reviewer believes that the key research and deployment activities relevant to this project is receiving sufficient emphasis.

- The key activity should be integrating the model into E+ and that indeed seems to be the case.

- The models for phase change materials appear adequate.

- Project activities are in line with the ET program objectives of advancing current technologies in BEM to a higher level by dealing with one of the fundamental market barrier of lack of computational flexibility in the representation of physical characteristics and operations. The project can be further enhanced by focusing on the integration of PCM models with EnergyPlus engine.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The projects strengths include the ability to quickly bring together a comprehensive and robust team to integrate state of the art analysis methods into a very complex existing code base. This can only be achieved by engaging the correct stakeholders in the process, which this project has done. SBV projects appear to be designed to provide a way for DOE to, using the agility and talents of the our national lab staff having specific subject matter expertise, quickly create real value through projects that synergistically provide both benefits to both the private and public sector. This reviewer feels that this project is capable of accomplishing this.

- Demonstrates how feedback from the industry can be used to improve E+ and building sim tools.

- The project address the stated goal of improving model accuracy. The project team is clearly capable and will deliver the results expected.

- Offering improved predictive capacity for PCM technologies that have proven potentials to save energy (with dynamic thermal storage for demand shifting)
- Offering solutions to data interoperability issues between product manufacturer's specs and computational model input parameters which is one of the most significant barriers against improved utilization of BEM for characterization of innovative building technologies that could possibly offer substantial primary energy savings.

- Unified custom versions of EnergyPlus (with improved PCM models) into the mainline DOE EnergyPlus releases

2) **Project Weaknesses**

- This reviewer was unable to identify any reasonable project weaknesses aside from the lack of a task (explained in previous answers) covering specific software validation once the codebase has been improved.

- The fact that the development is being done for just one individual is a red flag.
- Unable to assess market impact or direct benefit to BTO.

- This is a small project for a single user within a small community. The presenter seemed uninspired by the work.

- The application shows a weakness to state applicable metrics (for projections or) evaluations of the impact of the proposed PCM models on substantially reducing the energy use of typical buildings compared to the high efficiency technologies in 2010 baseline.
- The application didn't propose (accomplished or planned) for the integration of the new PCM models with Open Studio ecosystem.
- Possible inter-lab collaborations are ignored.
- The application doesn't provide adequate details about how to NRGSim's PCM models are tested for validation (analytical or empirical validations).
- The application should evaluate the real impact of the project to be able to answer the first EERE question (Is this a high-impact problem?).

3) **Recommendations**

- This reviewer finds no additional recommendations for the project.

- Explain specifics of what Go/No go milestones have been done/will be done.
- It came across as one guy is trying to integrate a tool into E+ in his spare time. Although, they get the benefit of doubt of being an early stage project.

- It would be helpful to add these enhancements to the HAMT models as well.

- None.

Emerging Technologies
Sensors & Controls

Project # 312117: VOLTTRON Compatible Whole Building Root-Fault Detection & Diagnosis

Presenter: Jin Wen, Drexel University
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed that the project is directly relevant to BTO's goals, as it could lead to direct energy savings and increased grid reliability. One reviewer noted that, in addition to providing tools to the industry, the project is also training students for future impacts. Overall, the reviewers found the project to be progressing well, despite some delayed deliverables and a lack of clarity on the status of the commercialization plan. Reviewer opinions on the campus building implementation and testing case study were mixed.

All reviewers liked the project team's collaboration with university undergraduate and graduate students, as well as with the small business partner. Two reviewers, however, suggested additional industry involvement in order run the algorithm in their buildings as a test-case for ease of setup and translation into new buildings. One reviewer also warned that, as a potential competitor, the existing partnership with a building diagnostic and performance management software company could complicate commercialization.

In general, reviewers agreed that the project addresses key technical barriers that will make fault detection and building control algorithms easier to install and overcome limitations previously identified in the field. Reviewers found the project to be appropriate for its target audience, by offering particular value to building owners who would benefit from its ease-of-use and implementation in the market. One reviewer commented that improving fault detection algorithms for buildings, and making them easier to deploy, will help building owners "actually use them" when they do not have the staff for a complex setup procedure. Another reviewer, however, expressed doubts about the methodology of the project and its lack of detailed documentation.

Overall, reviewers saw strength in the project's aim to simplify deployment complexity while using big data analytics and machine learning for whole building diagnostics. As such, most reviewers noted that the project is addressing key issues and deployment concerns, though one noted that advances in data analytics outside the BTO community will be more likely to affect market penetration. Reviewers also questioned if the approach developed will be applicable to a broad range of buildings.

While most reviewers found the future work well planned, there were concerns about scope, particularly around the achievement of certain milestones. One reviewer noted that the project needs to focus on being competitive in the market, and not just on being an undergraduate teaching and research project. As the project continues, reviewers recommended exploring additional applications, including automatic fault detection and diagnosis for building subsystems like central plants and air handlers. One reviewer also suggested testing against many different scenarios.

Weighted Average: 3.07 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.10 Accomplishments: 2.90 Project Collaboration: 3.40 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project supports the BTO goal of delivering automated fault detection techniques and tools to the industry. In this case, it is also training undergraduate students in the topic for future impacts.
- This project is clearly a great fit for BTO's goals as it could lead to direct energy savings in buildings.
- Building fault detection is important to improve the efficiency of the US building stock thus this is relevant to BTO's goals.
- Building level fault detection has been addressed by other research entities and industry for at least 5 - 10 years, while this project's methodology is relatively fresh and novel.
- Project addresses BTO goals of increasing building energy efficiency, reducing emissions and increasing grid reliability by addressing FDD from a whole building perspective. Project team points out the difficulty in achieving the aforementioned goals via traditional component FDD processes.

B. Approach

This project was rated:

1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project is exploring novel techniques in data analytics to identify whole-building operating faults. Their approach is addressing and expanding on limitations that have been identified over the past two decades of work in automated fault detection. It is not clear that they have overcome the challenges, since this is a small project with limited scope, but they are continuing to make progress.
- Making fault detection and building control algorithms easier to install and use directly addresses a huge market barrier. Many buildings do not have the staff or expertise to add these types of algorithms themselves, and making it easier could really help this technology to market. My comment on approach comes from how this is pitched to building owners and managers. Often energy reduction isn't very motivating, particularly when the building owner doesn't pay for the energy bills. However, happier occupants might be more compelling for why they should add this technology. I think that ensuring the surveys help answer this question is important.
- Market barriers not stated in significant detail but yes working towards lower cost solution, addressing lack of consumer training, addressing false alarm rates.
- Although this research has the potential to be applied in mass scale, lots still to be figured out, such as a scalable baseline determination method, which still can be time consuming, messy and even eventually infertile.
- Team recognizes that it's a subset of the data collected from various sensors that is required to help identify patterns and anomalies. It's not clear if approach will require building owners to retrofit buildings to ensure the correct data is collected and processed. Approach is using proven machine learning/AI methods.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and

2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project team has involved students in the entrepreneurship program to address market issues and are making progress. The project is demonstrating the viability of their methods through implementation on campus buildings.

- It's not clear to me what the status of the commercialization plan is. That was milestone Q3 and I didn't get the sense that a plan was complete. The technology seems to be progressing successfully.

- Making progress; some deliverables a few months behind the originally planned dates

- From my years of experience and practice in this field, the accomplishment achieved and case study demonstrated are unimpressive and limited.

- Very good progress in the first year. Results indicate good performance of the technology....in test conditions.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project team is collaborating with colleagues at other universities, at national laboratories, with industry partners, and with the HVAC smart building community at large. The PI is very active in the AFDD research community.

- The partners described in the presentation and the slides seem like great partners for developing the algorithm. However, it might be helpful to have a partner that actually wants to run the algorithm in their building. This would be a good test-case of how easy it was to setup the system and how well it translates to a new building. Also, having a partner in the same space (KGS Buildings) is useful, but may also complicate the commercialization story by essentially being a competitor.

- Coordination with both academia and industry.

- Love the fact that undergraduate students and student workers are engaged!

- Appears to be good collaboration between the university team members. It's not clear how much involvement industry is playing in the project.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- While it is a small project, the team has demonstrated good planning and coordination, including its work with students from engineering and business, facilities management, and industry partners. They now at a point where they are implementing the fruits of their labor and evaluating the impacts. The future work plan is logical and appropriate.

- The future work seems well aligned with the project goals.

- I am a little concerned about milestone Q7. Developing a GUI seems like a task that could easily take more time than the next nine months. I think the project PI should be careful to properly scope that goal.

- Accomplishments are discussed as well as future work in the slides and presentation - including next steps and future plans.

- Need to focus on how to make the research project competitive, instead of a fun teaching research project with many possibilities, but in real world hard to get anywhere.

- Builds on past research. Project will be the basis for future course curriculum. Would be nice to see tests undertaken in multiple building sites, but understand that budget is not there.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers
- There are many players getting into the field of building data analytics. Since the work was implemented in the open-source VOLTTRON platform, they should be readily implementable in the market. The success of the field demonstrations will further enhance their value.

- Improving fault detection algorithms for buildings and making them easier to deploy will help building owners/managers actually use them, particularly when they do not have the staff for a complex setup procedure. The value, if this works, is quite high.

- Thus far the deliverables appear to make sense and be appropriate for the targeted market.

- Deliverables will be of great value to the building owner. The students will also value the experience.

***Average*: 1** reviewer
- Shows some promising potential, but unconvincing, with doubt that the whole methodology hasn't been thoroughly thought through and documented in detail with a clear logic.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Building fault detection and diagnostics have received significant DOE funding for almost two decades. It is not clear that additional research funding with enhance its implementation. In my opinion, advances in data analytics outside the BTO community are more likely to affect market penetration.

- They are testing in an actual building and generating faults as well as trying to detect naturally occurring faults. They are also analyzing what happens for misdetected faults. These are key issues and deployment concerns.

- Key research areas are receiving emphasis and focus.

- Project adequately addresses program objectives. I like this project.

***No*: 1** reviewer
- It gave me the impression that the project is just started and hasn't got into a full scale of attention to be able to explore and address all key aspects.

H. Additional Comments and Recommendations

1) **Project Strengths**

- In my opinion, there are two main strengths of this relatively small project. First, the project is well integrated across a wide range of stakeholders, including students from engineering and business, building owners, industry partners, and well-respected researchers. Second, It is applying promising strategies in data analytics to the issue of whole building diagnostics, which has languished for most of two decades.

- Simplifying deployment complexity addresses a key market barrier. They have a real building they are testing on. Commercialization is a core goal from the beginning. Undergraduates are involved. This should increase awareness about this industry and its importance.

- Whole building fault detection, if achieved can be a lower costs way to determine problems with less data; they are using real data and real faults to help improve models.

- Relatively fresh introduction of pattern match into data processing for scaling.

- Looking a FDD from a whole building perspective. Utilizing big data analytics and machine learning and existing sensor equipment. Nice teaching project.

2) **Project Weaknesses**

- In my opinion, this is a solid project at a small scale and well-aligned with BTO goals. BTO will get good value for its investment, but it is not clear whether the techniques will be broadly extensible. The team also limits its scope to detection, without considering diagnostics. This limited scope is very reasonable within the budget, but it obviously limits the impact of its results.

- Difficult to tell if the technology and approach will scale to a variety of buildings. Not clear how easy this will be to implement in practice.

- Project generally on schedule but appears to be a few months behind goals set from slide 20 but generally good progress, goals.

- The overall method of whole building fault detection is unattractive and left behind.

- How long will it take to train the system to recognize a normal operating pattern? What if there isn't sufficient data to analyze? Is there a fall back solution? Will the system detect multiple faults in a building?

3) **Recommendations**

- Many of the techniques being explored by the research team could have broader applications of data analytics in buildings. The team might consider exploring such applications, including AFDD on building subsystems like central plants and air handlers.

- These have been covered in my previous responses.

- None at this time

- Breakthrough is desperately needed to develop cutting-edge technology (AFDD) to be able to demonstrate competitive end results and prove the complete advantage of the introduction of pattern match. It cannot just stop at showing some potentials. On the other hand, the DOE BTO funding contribution is relatively very small, and it's a good trial to stimulate research and education in higher ED in this direction.

- Test against many different scenarios.

Project # 32438: NorthWrite (Small Buisness Voucher)

Presenter: Michael Brambley, Pacific Northwest National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

All reviewers agreed that this project directly supported BTO's goal of improving the energy efficiency of HVAC systems by commercializing building fault detection and diagnostics (FDD) for widespread use. Reviewers were positive about the project's approach, including identifying and addressing market barriers. One reviewer commented that the project is clearly trying to overcome the difficulty of successfully implementing existing building control and efficiency algorithms.

Reviewers agreed that the project's FDD technology addresses an underserved segment of the building market, and also that the technology's market viability stems not just from potential energy savings, but also from the opportunity FDD affords for more effective building management. However, one reviewer felt that the project placed too much emphasis on the validation of a previously-developed algorithms in the PNNL lab and not enough emphasis on field testing.

In terms of impact, reviewers were both supportive of, and cautious about, accomplishments to date. One reviewer commented that while progress had been made, it had not been extensive yet, due to the fact that the project was still fairly new. Another reviewer expressed concern about the project's future impact now that small business voucher (SBV) partner, NorthWrite, is being acquired.

Reviewers were positive about the collaboration between NorthWrite and PNNL, though some reviewers suggested further collaboration with others in the FDD community, including larger vendors. Another reviewer stressed the importance of field evaluations of the algorithms for FDD deployment, as well as making field test data available to DOE and the FDD community for the long-term success of the effort.

Reviewers identified potential risks with the future trajectory of the project due to NorthWrite's upcoming acquisition. Despite this uncertainty, reviewers suggested enumerating a plan and the timeline for making the algorithm documentation publically available, as well as increasing the number of field tests and the variety of RTUs tested against, including non-PNNL-developed equipment. One reviewer recommended that PNNL work with NorthWrite to obtain access to the field testing algorithm data and results and make them publically available. Another reviewer suggested conducting an assessment of minimum meter needs for the FDD technology, as well as an evaluation of how well the algorithms perform in the face of changing meter capabilities.

Weighted Average: 3.05 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.10 Accomplishments: 3.10 Project Collaboration: 2.90 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project is relevant to BTOs goal to commercialize building fault detection and diagnostics for widespread use in commercial buildings. PNNL has been developing FDD strategies for many years; this work will push their algorithms further toward deployment.

- This project can lead to long-term energy savings of rooftop HVAC units in existing buildings. This is clearly aligned with BTO goals.

- One of BTO's main goals is to improve the energy efficiency of HVAC systems - fault detection represents a significant possible improvement in commercial HVAC systems.

- It's great DOE and BTO to identify and fund such projects of key industry needs and focuses, and establish a starting point with resources to help the industry jump start.

- Providing fault detection technology to improve equipment operations will improve building energy efficiency, reduce emissions and increase grid resiliency.

B. Approach

This project was rated:
1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project is seeking to validate and demonstrate the effectiveness of FDD algorithms for packaged rooftop equipment previously developed by PNNL and LBNL. Similar algorithms have also been developed and tested by other researchers and commercial enterprises. The approach here is to validate the algorithms at PNNL's laboratory and assist NorthWrite with deployment in existing buildings. It is implied that two decades of work on FDD algorithms for rooftop units have not been tested. While the PNNL testing may indeed demonstrate that their algorithms are valid, it is my opinion that the greater barriers to deployment are in the field evaluation of these algorithms. At this point, it is not even clear that NorthWrite will make the data from their field tests available to DOE or the FDD community.

- This project takes a clear approach on overcoming one key market barrier: published building control and efficiency algorithms are difficult to implement successfully in practice. For this size of the project, this scope seems appropriate. Other market barriers that came up include releasing actual real-world input and output data so that new algorithm implementations can test on a variety of virtual buildings in a variety of areas, and better support for handling sensor variety between differing buildings.

- Adoption of fault detection algorithms is significantly limited by how easy it is to implement, thus this project seeks to help improve ease of use to improve adoption rates

- It concerns me the fact that NorthWrite is bought right now and if all the research, data, and information will still be available to the public and the rest of the industry.

- The project team proposes to provide pseudo-code, documentation, test data, and other operational information for 18 algorithms that provide fault detection and diagnostics. I do believe (and see recommendations), that a method that confirms that the software developed by the end-user truly implements the algorithm. There is a risk that the software developed by the vendor will produce the correct test results, but still not operate as intended in an operational environment.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.80** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Slides discuss some accomplishments and progress, however since this is a fairly new project the list is not extensive yet.

- Need to understand the clauses that what will happen when the Small Business Voucher receiving company is bought.

- Sensor algorithms and fault detection and diagnostics have been fully documented and the next step is testing against PNNL equipment.

D. Project Integration and Collaborations

This project was rated:

1) **2.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.20** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Many other researchers, including many funded by DOE, have worked on FDD topics since the 1990s. There are also other testing labs that have evaluated FDD algorithms for rooftop units. There appear to be significant opportunities for collaborations with others in the FDD community.

- Given this is a SBV program, the integration with the main partner (NorthWrite) is strong. The level of collaboration and partnership matches the size of the project. One question that comes up is to what extent is NorthWrite willing to contribute to the long-term success of this project? Are they willing to open-source data from their algorithm testing?

- They collaborate mostly with NorthWrite, a small business partner.

- Don't know when NorthWrite and its acquirer started the negotiations.

- The team includes a vendor and national lab. There appears to be good collaboration and integration between the two entities. It might be interesting to include another vendor...say a larger vendor would be helpful.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- There is potential risk that the new owner of NorthWrite will not share NorthWrite's commitment to the project and the technology. It is not clear how the field test data - arguably the most valuable outcome of the project - will be collected, analyzed, and made available.

- The future work seems very well aligned with project goals and the trajectory of the project. There are many clear milestones related to having the algorithms implemented by NorthWrite, and if that relationship changes with NorthWrite's acquisition it should be clear. One thing that could be better enumerated is the plan and timeline for making the algorithm documentation and testing publically available.

- Good progress; since this is fairly new, there are still many unknowns.
- Uncertainty of the acquirement.
- Future plan includes implementing and testing the algorithms against PNNL equipment. What about testing against other equipment in the field?

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- Open sourced pseudocode of the algorithms and real-world benchmarks of their performance is a very fitting deliverable of this project.
- The challenge of faulty and inefficiently running systems is an area that could significantly reduce energy use in this building sector.
- It will be a great help to provide all the project outcomes and documentation to the public and industry and will tremendously stimulate the industry in RTU's AFDD applications.
- I believe the deliverables will be highly valued by the targeted vendors and end-users

***Average*: 1** reviewer
- It is not obvious that further algorithm lab testing is the most valuable information for the market.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Fault detection and diagnostics have received significant funding from DOE for almost two decades. It is not clear that significant further research funding will significantly accelerate market adoptions.
- Given the size and scope of this project, the key areas of this project are being sufficiently emphasized.
- They appear to be; the focus currently is on algorithm development - deployment and adoption are still in the future work stages.
- It answers what the market and industry ask for. Right on.
- With the exception of addressing software engineering issues, I believe the project team is adequately addressing the program's objectives.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project builds on many years of research on FDD for packaged rooftop equipment, with an effort to validate algorithms in the laboratory and demonstrate deployment in existing buildings in the field. It is well-aligned with program goals.

- Clear goal with obvious market opportunity. Very well on track towards meeting the project goals. Clear and interested partner. Addresses an underserved segment of buildings. The market viability for the end user (building owner) is stronger than just energy savings. It also includes the opportunity for a more effectively managed building.

- Strong collaboration with key partner to make successful, and strong potential impact as well as a significant need in the industry.

- Great identification of the industry and market needs, and professional execution.

- Great idea of having a set of algorithms to choose from depending on available sensors. I also believe the idea of having a package that defines the pseudo code, documentation, test data/results, and other documentation to help vendors create their FDD technology is a strength.

2) **Project Weaknesses**

- The project seems to place excess emphasis on the validation of the previously-developed algorithms in the PNNL laboratory with little emphasis on the testing of the algorithms in the field. At this point in the overall development of FDD algorithms, it is my opinion that demonstrated field results are most important for large scale acceptance and implementation.

- Not clear if documented algorithms will be enough to encourage additional sensor installation to provide the inputs for the algorithms. Also not clear how well the algorithms might be able to adapt to a slightly mismatched set of input data streams. Not clear if documented algorithms and lab scale test data will be enough for others not involved with this project to successfully implement the algorithms. Related, not clear if NorthWrite will provide real-world data.

- This project is still in the early stages of completion, thus no significant publications/findings/impact as of yet.

- Uncertainty brought in by a small business voucher receiver being bought by a much bigger entity.

- The lack of control over the actual software development and deployment is a concern. As noted during the review, algorithms can be implemented in many different ways. They can even reproduced test data/outcomes, but still behave differently. How do you validate and verify the developed source code?

3) **Recommendations**

- It is highly recommended that PNNL work with NorthWrite to obtain access to the data and results of the field testing of the algorithms.

- Since power meters at the RTU level can be very helpful for some of the algorithms, it would be useful to have a minimum feature definition for meters that would meet this need. Many existing options are too expensive today, but often lower cost comes with reduced performance. So an assessment of minimum meter needs (perhaps in contrast to the requirements outlined by DOE's Wireless Metering Challenge), as well as an evaluation of how well the algorithms perform in the face of changing meter capabilities (update rate and accuracy) would be useful.

- None at this time.

- Looking back, still a super initiative carried out by DOE to address market needs timely and creatively.

- To address the weakness just described, you might increase the number of test/outcomes. Also, I would increase the number of different RTUs to test against.

Project # 32612: Building Energy Management Open-Source Software Development (BEMOSS)

Presenter: Saifur Rahman, Virginia Tech
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed that this project addressed BTO's goals of developing cost-effective, energy efficient technologies to improve HVAC, lighting, and plug load control. One reviewer applauded the projects' low cost and the BEMOSS system's ability to recognize multiple devices, though another reviewer questioned how the BEMOSS product would be delivered to the market.

Nearly all reviewers expressed concern on the project's approach. One reviewer highlighted that there was no apparent strategy to deliver the product to the market. Similarly, another reviewer questioned how this system can actually support a viable business, because of the conflict between the low-cost needs for management systems in small buildings and the need for generating enough revenue to enable sustainable development and support. In addition, it wasn't clear who will support the open-source software or who will install BEMOSS in a building. On a positive note, some reviewers found the approach to be well implemented and sound, addressing market barriers through its interoperable functionality.

Reviewers were mixed on the value of the project to its target audience. Those who saw high value commented that this open-source, highly-flexible platform will help overcome interoperability issues in commercial and residential buildings, particularly smaller buildings. One reviewer noted, however, that a lot of money had been spent on deliverables that might not have an actual impact without a company to commercialize it.

Reviewers were also mixed on the project's progress and accomplishments, though most reviewers agreed that the project had met its milestones according to schedule. One reviewer highlighted that the project helped to draw attention and resources to this topic, enticing private entities to enter the market. Another reviewer, however, felt that it was unclear whether the project would have an impact in the market because it only addresses the interoperability aspect of the challenge for low-cost building automation in small buildings.

Overall, reviewers identified a number of strengths, particularly the project team's ability to develop a prototype that addressed the underserved small and medium commercial building sector. Reviewers also highlighted the project's collaboration with a number of partners, as well as BEMOSS's ability to scale to a number of devices, offering flexibility in the market. Reviewers also highlighted weaknesses, including questioning the project's ability to commercialize the product without a clearly identified pathway. Furthermore, reviewers believed that the automated fault detection and diagnostic (AFDD) applications and case studies selected to demonstrate utility of the platform were not competitive, occupant preferences did not appear to be considered, and updating API and protocols would be necessary to remain relevant as technology evolves.

Given the advanced stage of the project, reviewers did not offer many recommendations for future work, other than suggesting pathways for commercialization and noting that it was an appropriate time to sunset DOE funding due to market developments since the start of this project. In addition, one reviewer recommended that additional effort be placed on the development of modern supervisory control algorithms, while others suggested exploring Internet of Things device integration into the system, as well as adding another pilot study using several buildings in different regions.

Weighted Average: 3.03 # of Reviewers: 5
Relevance: 3.80[1] Approach: 2.90 Accomplishments: 3.10 Project Collaboration: 3.10 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- On paper, the project supports the goal to improve building energy management through development of low-cost control systems. However, it is not clear how the project products will be delivered to the market.

- A building management system with an open architecture is clearly aligned with BTO's goals.

- This project aligns with BTO's goals of developing cost-effective, energy efficient technologies that can help improve HVAC, lighting and plug loads. Small and medium sized commercial buildings represent a significant portion of the building energy use in the US and thus are important to focus on. This project helps improve interoperability to enable better energy management systems of these buildings

- This project is about the future "norm" of building energy management, and that future is now!

- Very relevant technology - addressed BTO goals of increasing energy efficiency, reduce emissions and increase grid reliability. A bolt-on system that manages HVAC, Lighting and plug loads to maximize energy efficiency. Low cost and recognizes multiple devices. A nice project.

B. Approach

This project was rated:
1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **2.60** for the degree to which the approach addresses the market barriers identified.

- While the work to develop an open-source building automation system for small and medium commercial buildings is a noble and potentially valuable objective, there is no apparent strategy to deliver the product to the market. Open source software is only one piece of the puzzle. The project developed some hardware in the BEMOSS Core to implement the software in the demonstration buildings, but the presenter suggested that this Core was only used for demonstration and that there was no expectation for the future of this hardware. With the project nearly completed, there appears to be no hardware platform on which to implement the software and no obvious commercial enterprise ready to embrace and deliver control systems to the market.

- I think this is the weakest part of the project. Many market barriers are addressed, including cost, interoperability, and ease-of-use. What is missing is how this system can actually support a viable business. Directly at odds are the need for the management system to be low cost (and BEMOSS is open source) in order to get adoption in smaller buildings, while also generating enough revenue to sustain development and support. Determining how this project is used going forward I think is probably the most critical aspect of the future work.
  Issues:
  - Who supports the open source software?
  - Who installs BEMOSS in buildings?
  - Who transitions the code from research project quality to product stable?

- Addresses market barriers such as the need for plug and play sensors and interoperability, specifically focusing on HVAC, lighting and plug loads. There are other loads possible but this specifically focuses on these.

- It helped a kick start through lead-by-example, but to sustain an open source system with tax payers' money is hard to stay competitive or logical, seeing this field of emerging technologies is forming an industry.

- Project is in the final phase, however, approach is very sound. Start with software, undertake lab tests and then pilot studies in the field. Relies on VOLTTRON to maximize open-source opportunities. Nicely implemented. I do have one concerned (and also raised later in the evaluation)—it doesn't appear that the team takes building occupant preferences into consideration.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- This project is a gamble because it is only one step in addressing the overall problem. The project appears to have met its objectives by delivering and testing the product. However, it is unclear whether this project will have any impact in achieving the goal to deliver low-cost building automation to the underserved small and medium building market. Ultimate success rests on the adoption by a start-up company to commercialize the product, which is one of the stated intermediate (1-3 years) outcomes of the project.

- Given the three deployments, this project is clearly making progress and having clear impact. The one aspect that caused my scores of 3 and not 4 is the energy reduction aspect. While BEMOSS does enable setting thermostat set points from a central location, it's not clear to me that simply raising or lowering the temperature of a room or dimming lights is a strong enough argument that BEMOSS can help buildings reduce energy. Showing that the actual software platform was critical and that components interacted in real-time to reduce energy would be much more compelling.

- Has met milestones according to project plan/schedule, has published significantly in conferences in the US and abroad; appears to be on schedule for completion

- It's DOE and BTO's vision to fund such a project and infuse what the industry needed the most from the very beginning, to kick start a then emerging technology in the market. Since then, the project really helped stirring up the market, drawing attentions and resources, and promoting private entities into this market and technology front.

- Project is on schedule with testing underway in three different buildings. It would have been nice to see some additional pilot studies undertaken on buildings in other parts of the country.

D. Project Integration and Collaborations

This project was rated:

1) **2.80** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project has a very impressive industry advisory committee, which comprises 22 major companies in the building control community. Curiously, the project team does not appear to include expertise in actual building and HVAC control algorithms. The application layer of the software architecture houses the algorithms for saving energy though control. The presenter made very little mention of these algorithms and, during his presentation, displayed a surprising lack of knowledge of building performance. The touted market impacts of significant energy savings were due to simple scheduling of thermostat set points and lighting dimming, which can be readily and inexpensively achieved with existing products.

- I think a formal partnership with a company that could help install BEMOSS at scale and provide support is missing. The other partnerships, industry affiliates, and deployment locations are great and seem to be going very well.
- Lots of collaborators for project integration, interoperability functionalities, etc.

- There are just too many parties out there in this field and it's hard for the researchers to engage them all, also due to the competition concerns it's impossible to integrate or collaborate in some cases.

- Project team consists of academic and government agencies. Also includes an industry advisory board. It appears that there was very good collaboration and integration among team members as the technology was successfully developed and pilot tested. One area that apparently wasn't addressed was installation and operational costs...are there any. Did industry members on advisory board provide information on marketability of the technology?

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The project is nearly completed and there is little future work remaining.

- The future work related to electricity saving and fault detection seems right on track for this project.
- Upgrading to VOLTTRON 3.5 is reasonable. I think a missing milestone is the path to commercialization or post June 2017 plan for the project.

- Project is nearly complete, thus there is not much left in terms of additional items to cover in future work.

- It should be the sunset stage of a once inspiring and very successful (from stimulating the market stand-point) project since it is not competitive anymore.

- Project is in the final phase and on schedule

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- A platform for managing existing buildings with a variety of installed equipment is very important for the targeted markets. Small buildings in particular can really benefit from this.

- Interoperability is a big issue in not only commercial but residential as well. It's great to see an open source highly flexible platform being developed and becoming available for non-high end commercial buildings.

- I have no doubt that the deliverables from this project will be highly valued by building operators.

***Average*: 2** reviewers
- The product appears well-developed. However, a lot of money has been spent on deliverables that may not have an impact on the market.

- It was once high, but not too much these days anymore.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- With the development of VOLTTRON and BEMOSS, DOE is inserting itself into the building controls and energy management market that is generally well-served by a mature industry. In my opinion, it is now time to wait and see if these products get any traction.

- Clearly the deployments demonstrate that the deployment aspect is getting enough attention.
- The aspects related to energy reduction and peak demand management could be better addressed and should be a priority for the next six months.

- Yes I think they received sufficient emphasis.

- The project is well thought out and executed. Key objectives were achieved.

***No*: 1** reviewer

- Sunset stage of a great initiative, while being uncompetitive anymore.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project has a noble goal of developing an open-source platform for building energy management, specifically addressing the underserved small and medium commercial building sector.

- Supports many protocols and can scale to many devices. This also allows it to be very flexible given the heterogeneity of the market/industry. Three real-world deployments. Some energy savings demonstrated. Open source.

- Appears to be on time and on schedule, lots of collaborators, implementation in multiple buildings as test beds, demonstration of energy savings.

- The capacity to break barriers and build a functional prototype.

- Ability to discover existing equipment within building. Open source and appears to require little retrofitting of an existing building. Nice project

2) **Project Weaknesses**

- The project is a risky bet that "if you build it, he will come." It is argued that the small and medium commercial building market is underserved because the controls industry lacks an open source platform for building energy management. In my opinion, this argument is flawed. Without a future company to commercialize the product, the project could be a waste of $2 million. It is simply not clear that there is a market for this product.

- Not clear what the plan is for the technology once the project ends. Not enough applications targeting energy savings.

- Challenges with making the project relevant in terms of APIs and protocols as things change and develop over time. This is inevitable unfortunately thus the challenge is to make sure it can be updated and remain useful and relevant.

- AFDD applications and case studies are not competitive or convincing at all, and pretty much left behind. The project developed a platform successfully, then stalled without making too much further progress in making or demonstrating good uses of the platform.

- What happens if a critical component (e.g., AHU) starts to fail? Does the system detect this and adjust? Does the system raise a flag? The system doesn't appear to take occupant preferences into consideration.

3) **Recommendations**

- Additional effort should be placed on the development, or the ability to develop, modern supervisory control algorithms.

- I think it would be interesting to explore if newer IoT/connected devices can be integrated into the system and if there is any building management reasons to do so. Even if there isn't, having a platform for controlling, managing, and connecting IoT devices would be very useful.

- No significant recommendations.

- None.

- If possible, add another pilot study using several buildings located in other parts of the country.

Project # 32631: Home Battery System

Presenter: Dane Christensen, National Renewable Energy Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers all strongly agreed that this project is relevant to BTO's goals, addressing opportunities from emerging technologies to advance energy management in the residential sector. All of the reviewers agreed that the project is addressing major technical barriers, from the control of HVAC equipment and appliances to electrical storage and demand response. One reviewer succinctly noted that the project touches on the key issues of equipment integration, increasing energy efficiency while maintaining occupant comfort, and the use of existing sensors and controls. Critically, one reviewer questioned the project's cybersecurity elements, particularly around data storage.

Reviewers were impressed with the project's progress despite its relatively early stage, having remained on schedule and achieving its go/no-go milestone for Year 1. One reviewer, however, found the metric for success poorly defined. All reviewers agreed that the project demonstrated strong partnerships among national labs, utilities, universities, and private industry, noting in particular the project team's ability to engage with the market and align partnerships to the projects' goals.

All reviewers found that the project is targeting the appropriate audiences and markets, particularly utilities that have little insight into shiftable and demand response loads in homes as well as home owners that have sensors, equipment, and alternative energy sources installed, but who need help integrating them. One reviewer positively remarked that "the project appears…to demonstrate the potential for residential participation in grid integration with novel methodologies and real-world application." Another reviewer characterized the project as a high-return-on-investment project.

Reviewers highlighted particular strengths of the project, noting its ability to address building-to-grid integration in the residential sector, its use of partner resources, and its outreach to users. They also discussed weaknesses of the project, namely the project plan's lack of clarity around how cybersecurity will be addressed. Another reviewer felt that it was not clear what kinds of testing will be completed in the future, specifically the use cases that will be explored through the proposed testing.

Reviewers found that the project's future work was well organized, progressing accordingly, and appropriate for the project's maturity. Two reviewers reiterated concerns over cybersecurity, noting the need to further clarify cybersecurity's role in the project. Reviewers also recommended exploring thermal storage as a demand control strategy, as well as clarifying how occupant comfort will be evaluated and accounted for.

Weighted Average: 3.62 # of Reviewers: 5
Relevance: 4.00[1] Approach: 3.80 Accomplishments: 3.40 Project Collaboration: 3.80 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- While DOE is not the main driver of this project, it is an excellent opportunity to leverage their support to further its goals for energy management in the residential sector. The project involves many novel strategies to engage the residential sector in grid integration.

- This project is very relevant to the DOE/BTO goals. Between finding ways to have technology effectively work with people, developing techniques for security, and automatically generating energy savings, the core concepts in this project are very important for the BTO to meet their goals.

- The project is relevant to BTO's goals and meets needs in the field in general. It contributes directly to particularly residential opportunities in the emerging technologies office, for example building to grid integration

- The research topic is of key interest of US and the whole world's today and future. Homes as a whole demand cutting-edge solutions like this one, and US and DOE/BTO responded actively to the contemporary pulse.

- The statement "Effectively meet homeowner comfort/budget and power-sector demand response needs with a low-cost, simple-to-use, cyber-secure, and interoperable solution" says it all. This project is very relevant to BTO goals of increasing building (in this case residential) energy efficiency, reduce emissions (less power used) and increase grid reliability

B. Approach

This project was rated:

1) **3.80** for the degree to which it focuses on critical market barriers, and
2) **3.80** for the degree to which the approach addresses the market barriers identified.

- This project recognizes the complete range of residential grid integration issues, from control of HVAC and appliances to electrical storage. Curiously, while the project is entitled "Home Battery System," the battery appears to play a minor role in the approach for the project. In my opinion, this is a good thing, because the more interesting challenges are in the demand response rather than simple storage. The project also takes the approach of fully automating home operations after input from the homeowner - there may be opportunity to engage the homeowner more during operation.

- I believe this project is addressing two of the primary market barriers: understanding what people actually want and managing the diversity in loads, IoT products, and connected devices. Comprehensively addressing these will be very beneficial for this technology to actually get adopted. What I found less clear was the aspects related to security. I see this as an important but not fundamental barrier, but from the presentation I am not sure how exactly security is being addressed by this project. Some of my questions:
    - Who is driving the security requirements? The homeowner? The project leads? Do the requirements change based on the building?
    - Where is the control algorithm for the project running? Is there a local option where all the data stays in the house?
    - Does this project aim to upgrade the security of the devices/appliances?

  A better description of what is currently lacking in the market and how this project will address those concerns would better frame the security aspect of this work.

- Degree to which market barriers identified – the team spent all of slide 3 identifying the market barriers in this field and what they are doing/can be done to overcome them.

- Along the way, I could see the researchers dynamically adapted the "live" study and innovative work to the ever-changing market needs, evolutions and new happenings. From home battery to home IOTs, this project remains on the leading edge to address one of the biggest potentials in savings energy, building greener communities, engaging the public and improving national energy security.

- The project is addressing all the key issues: integrate different pieces of equipment, increase energy efficiency without sacrificing occupant comfort, use existing sensors and controls, minimize capital costs and address cyber-security issues.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is still relatively young, but results indicate good progress. It is not clear how the results of this project will be delivered to the market or the impact that can be achieved. The metric for success is not well-defined.

- This project is making very good progress and has clear accomplishments. It seems well on track for the June 20, 2017 milestone.

- According to the current work and progress discusses in the presentation and slides, it appears that they are making progress towards their goals and the goals of the program – they achieved their go/no-go milestone in Year 1 even though they were delayed.

- Lots of "homework" has already been done by the researchers to secure the true end results.

- Project is on schedule and successfully passed go/no-go milestone. Have undertaken experiments using two different residential houses. Publications and have attracted interest from industry. All good results.

D. Project Integration and Collaborations

This project was rated:
1) **3.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **4.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project seems to be an exemplary partnership among the national lab, utility, university, and private industry. There seems to be strong integration among the partners and meaningful contributions in the areas of partner strengths. While Bosch seems to be an engaged and critical partner, I expected more involvement from more traditional (HVAC, lighting) industry representatives.

- The collaborations are very strong for what this project is aiming to do. Working with the BPA in the electric utility space, Bosch in connected device and hardware space, and CSU in the human behavior space are all clear partnerships towards this project's goals.

- They collaborate with Bonneville Power Administration, Bosch, Colorado State University, each of which plays a different role in the success of the project, providing strategic direction, cybersecurity/hardware, and behavioral advice and knowledge.

- Great vision and efforts have been made to reach out and engage the market, industry and other key players, as I could conclude.

- Good collaboration between academia (CSU), national lab, industry (Bosch), and a utility (BPA). In fact, representative from Bosch was at the review...clearly a well-integrated team. I have high confidence in this project.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Much work awaits the project team, but they seem to be well organized and making good progress. The future work seems reasonable.

- The future work seems focused on demonstrating the system in a real-world setting and testing the simulation analyses with actual devices. Having a "no-go" option if the tests are not successful also fits with BTO goals. The cybersecurity aspect of the future work could be clarified, however. Does Task 6 intend to make a research or substantial contribution, or is it more of a due diligence task before this system can be market ready?

- The answer to this question was not discussed in significant detail, however they appear to be on budget and on time and meeting decision points.

- The research and development presents great potential to be integrated into homes and utility programs, including as big as smart grid and as "little" as Americans' everyday life in modern times.

- Project builds on past performance and next steps call for laboratory testing to confirm performance...including cyber-security testing. These steps seem appropriate at this stage of the project.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- The project appears on track to demonstrate the potential for residential participation in grid integration with novel methodologies and real-world application.

- Utility companies have very little insight into shiftable or DR loads in homes, and it is expensive for them to retrofit the existing technology on to homes. They see a clear benefit if a mutually beneficial solution that engages the homeowner can be added to existing buildings. Homeowners typically have no interface or the wrong interface to manage the energy/comfort tradeoff in their homes, and by including them in the design this can be dramatically improved.

- Significant number of papers published, awards won, reached out to get opinions from potential users on their preferences

- Based on the importance of the topic, outcome, potentials and funding diversity, it's a high ROI project.

- Deliverables target the home owner that has multiple sensors, equipment and possible alternative energy sources and needs help in integrating all of this.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- The project seems on track to move from simulation to real-world tests of the technology, which is critical in a project like this.
- Yes there is significant focus, specifically on building to grid integration and controls
- Homes and utility companies are the audience and market, and the project have been staying close and integrated right on to that key audience.
- It appears that the project is addressing the key objectives of the program.

***No*: 1** reviewer

- Residential buildings comprise over half of the energy use in buildings in the U.S. Effective integration of residential buildings in grid management is critical to future management of this vital infrastructure and deserves greater DOE attention.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project addresses one of the greatest opportunities for building grid integration - the residential sector. The project employs novel methodologies for model predictive control and multi-criteria decision making. It employs both demand control of building end-uses and battery storage and provides guidance to future research.
- The project intersects three very important areas: improving the technology that utility companies have to better manage the grid, providing essentially a building management system for homes, and enabling energy reductions. These are all very important and interesting areas. The project incorporates learning that can help address the appliance/device diversity problem and changing user preferences. The project incorporates a home battery opportunistically. The project considers how to best engage users.
- Takes advantage of significant resources and strengths of partners to accomplish a larger goal that requires these partners to work together; included an assessment of user preferences; Good speaker with strong knowledge of topic and ability to answer questions; significant cost share. Takes advantage of significant resources and strengths of partners to accomplish a larger goal that requires these partners to work together; included an assessment of user preferences; Good speaker with strong knowledge of topic and ability to answer questions; significant cost share; has won awards and published significant number of papers
- In-depth study with a concrete plan, but also stayed agile and adaptive, demonstrating great potential for integration and market place deployment.
- Multi-disciplinary team, addresses confusing situation where home-owners are overwhelmed with so many devices that communicate via different protocols. Focuses on a whole-home solution. Addresses cyber-security concerns.

2) **Project Weaknesses**

- At this point, the project is exploring methodologies and technologies for residential building-grid integration. However, it is not clear how ultimate success will be measured.

- The cybersecurity plan is, at this point, unclear. I could not understand exactly what the specific challenges are and what the proposed solutions are. I'm not clear on what happens in homes that do not have any smart/connected devices, or only have one or two.

- No significant weaknesses.

- The vast speed of battery technology development presents some challenge for the researchers to stay alert and remain ready to be adaptive - a fluid process.

- Not clear what kind of testing will be undertaken. What use/test cases will be explored? Also not clear how occupant preferences are accounted for in the technology.

3) **Recommendations**

- It might be worthwhile to explore thermal storage as a demand control strategy.

- I'm curious how the comfort evaluation will work. As determining user preferences is wrought with pitfalls, I would expect that determining comfort would be too.

- None.

- DOE funding contribution is very reasonable for such a crucial cause, and good to see the cost share ratio is so "big" and attractive. Well done.

- Ensure adequate test cases are included in the testing. Test in homes in different climate/environmental conditions.
-

Emerging Technologies
Buildings-to-Grid

Project # 32739: Northwest Connected Buildings Innovator

Presenter: Nora Wang, Pacific Northwest National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Reviewers believed that this project's development of system-level strategies to enable transactive energy in connected neighborhoods was a central and necessary endeavor to BTO's goals. One reviewer even went on to enumerate the variety of non-energy-efficiency benefits that BTO's buildings-to-grid work could unlock—including increased energy productivity, as well as reduced consumer costs and environmental impact—commenting that the project would do well to aspire to and monitor these impacts.

Several reviewers believed that the project's approach—the Connected Buildings Challenge—adequately recognized and addressed market barriers. However, one reviewer could not identify a clear value proposition for the consumer, nor did this reviewer feel that enough data was collected to verify whether software developers were satisfied with VOLTTRON's capabilities.

Despite assigning generally high marks on the project's accomplishments, which the reviewers identified as simply convening a range of potential industry partners, reviewers scored the project's collaborations poorly, with one reviewer saying that Microsoft, Amazon, and the Smart Buildings Center seemed "to have played no useful role so far." Several other reviewers wished for more utility involvement, noting that only PG&E attended the Connected Buildings Challenge and underscoring their belief in the importance of utilities to the success of transactive energy.

Moving forward, reviewers were supportive of the project's future work plans, though a few offered the caveat that additional focus group meetings should be pursued to refine further the value proposition to the consumer and the utility, while one reviewer suggested including water heater manufacturers in addition to considering water heating's importance to home power use.

Weighted Average: 3.38 # of Reviewers: 4
Relevance: 4.00[1] Approach: 3.50 Accomplishments: 3.63 Project Collaboration: 2.75 Future Work: 3.25

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The proposed approach of developing system-level technical strategies for connected neighborhoods is indeed a necessary endeavor for enabling energy savings in the building sector.
- Project addressed social aspects of automated homes, which is crucial for their acceptance by the end customer.
- The project derives its motivation from "System-level research strategies that enable a full integration of fragmentally developed connected devices is important to enable a truly transactive utility network for residential buildings (the attributes of which are also shared with small commercial buildings). Such research is truly relevant to BTO's overall goal.
- This project is developing a suite of key underlying use cases and capabilities related to transactive control, and as such, seems to be central to much of DOE's B2G effort. It's good to see intensive outreach with manufacturers and facility operators, although it would also seem that more outreach to utilities would be useful.
- One item to note regarding BTO's objective (which is generic to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., 'virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).
- This project's discussion generally recognizes that broader opportunity, but it would be useful to work to broaden program objectives and metrics to explicitly incorporate these other aspects, and ensure that the focus within BTO (and in projects such as this) is not unduly restricted to/focused on increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:

1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.50** for the degree to which the approach addresses the market barriers identified.

- The proposed approach does take into account the realities and challenges when implementing and fomenting a transactive utility network.
- Involvement of a large range of companies
- The Connected Building Challenge was an excellent idea. If they can do more of such things, they should. However, I don't see a path to follow up on the market barriers identified, such as lack of a clear value proposition for the consumer. Also, there seems to be have been little data collected during the project whether the basic approach is unsuitable for market. For instance, it is assumed that all developers will love to develop on VOLTTRON. What if its design is fundamentally flawed? Such a finding might be inconvenient, but developers who took part in the challenge would be well placed to provide such input.

- Great to see the development of transactive control capabilities and use cases, and outreach to key manufacturing and building owner stakeholders who will be essential to adoption.

- It would seem valuable to more fully involve utilities, as well, given their central role in consumer contact, rate design, and program design. Doing so sooner rather than later would help ensure that the transactive control capabilities are addressing the most practical and complete set of issues that will make their way through the utility space.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.75** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- So far, the team has been able to accomplish several important things including networking with other potential partners including realtors.

- Involvement of a large range of companies, but no water heater companies at this point.

- *No Comment*

- Great set of use cases and outreach activities. It would be great to see CEE and some CEE members become deeply involved sooner rather than later.

D. Project Integration and Collaborations

This project was rated:

1) **2.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project integration appears to proceed smoothly. The team has reached out to Microsoft, Amazon and other potential partners to enable better adoption of the proposed scheme.

- See previous comments.

- Microsoft, Amazon, and Smart Buildings Center seems to have played no useful role so far.

- It appears that there has been great outreach to manufacturers, and some outreach to utilities. Notably, it appears that only one utility (PG&E) attended the Connected Buildings Challenge meeting.

- It is certainly the case that utilities and/or other service providers will have a vital, even dominant role if B2G is to effectively deliver on the enormous potential. In light of that, it would be good to see more intensive effort to involve utilities at the earliest opportunity. Early and ongoing input could be a real plus both for inbound (i.e., tapping utility insights and expertise), and outbound (i.e., communicating the opportunities and facilitating adoption).

E. Proposed Future Work

This project was rated **3.25** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The proposed future work consists of both leadership and technical activities to enable better adoption of the proposed scheme.
- Development of a prototype demonstrative home is a good idea.
- *No Comment*
- The plan looks good, with the caveat that more outreach to and involvement of utilities would almost certainly be useful.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- Involvement of a wide range of companies is a good strategy for success.
- The focus group findings and lessons learned from the Challenge will be extremely useful in overcoming market barriers.
- Looks like great early efforts.

***Average*: 1** reviewer
- The success of the project will depend on a large measure how the focus groups and other entities decide to adopt or promote the proposed scheme.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- It appears that the proposed activities would enable better adoption of the proposed scheme.
- See previous comments.
- *No Comment*
- Yes, but with a caveat regarding increased involvement of utilities and industry, as noted in previous comments.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Being able to bring big players such as Microsoft and Amazon does give the project considerable leverage in potential future activities across the industry.

- Involvement of a large range of companies and inclusion of their comments in a demonstration home is an excellent idea.

- The main strength of the project is the kind of real world test of its ideas that was done by the connected building challenge, and the focus group meeting.

- Please see previous comments.

2) **Project Weaknesses**

- More information about the proposed transactive-base home management system should be reported.

- Water heaters are currently not considered bit are critical for low load homes.

- The stated motivation is "System-level research strategies that enable a full integration of fragmentally developed connected devices is important.

- To enable a truly transactive utility network for residential buildings (the attributes of which are also shared with small commercial buildings)." However, apart from the CB Challenge, the rest of the activities - such as field demos - can hardly be called "system level research". Field demos are useful, but perhaps for a project with such an important goal, the time and effort needed for field demos can be better (re) directed to actual system-level research to figure out how to overcome the identified barriers?

- Please see previous comments.

3) **Recommendations**

- Additional focus group meetings should be pursued in the future.

- Include a water heater manufacturer into the project.

- Overall, good project.

- Great work - go Go GO

Project # 32740a: Connected Homes

Presenter: Ed Vineyard, Oak Ridge National Laboratory.
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Reviewers agreed that this project's development of a home energy management system (HEMS) on the VOLTTRON platform was directly aligned with the BTO's Buildings-to-Grid (B2G) objectives. Several reviewers further affirmed that HEMS, along with the applications that software engineers would develop on VOLTTRON, were essential to enabling home-based transactive energy across the grid, with this project providing a valuable early use case. One reviewer expounded on the numerous benefits that B2G technologies could unlock in addition to energy savings.

Several reviewers strongly believed that this project's approach thoroughly considered and assessed the foreseeable market barriers to the adoption of the project's open-source HEMS. Two reviewers also praised the project's intensive collaborations with utilities and manufacturers, while one reviewer was particularly pleased that water heater manufacturers were included. Another reviewer stressed the importance of considering state and federal energy utility regulators like FERC, because these actors would be critical to the creation of effective market signals and incentives that utilities, B2G technology suppliers, & homeowners would be responding to. This reviewer did acknowledge, however, that questions of market signals and incentives were distant B2G challenges, and did not offer any guidance on how this project could specifically address them.

Reviewers were pleased with the project's progress, with two reviewers noting their approval of the project's exhaustive literature review—including that some academic publications had produced as a result. Developing the capacity to control home thermostats on VOLTTRON's platform, as well as the project's joint efforts with Emerson and Southern Companies to build and demonstrate this technology, also impressed a few reviewers. In general, reviewers were pleased with the project's collaborations and integration efforts, although one reviewer expressed disappointment that the presentation did not outline enough information about what each of the partners were actually doing.

Reviewers believed that the project's plan for future work was appropriate to achieve its stated objectives. One reviewer noted, however, that project success "would largely depend how well the integration of all key home systems is managed."

Weighted Average: 3.49 # of Reviewers: 4
Relevance: 4.00[1] Approach: 3.63 Accomplishments: 3.25 Project Collaboration: 3.50 Future Work: 4.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Development and adoption of an open-source Home Energy Management System (HEMS) based on VOLTTRON technology is indeed important for the energy sector. Specifically, the residential market is in need of HEMS to facilitate and enable energy savings in that market.

- Project team included both HVAC systems as well as water heater manufacturers. Good communication with project partners, including PNNL for VOLTRON questions

- An open source HEMS will be an excellent platform for many startups to provide Apps for home energy management. This is a project that is highly relevant to DOE/BTO's roadmap.

- This comprehensive residential B2G project is completely aligned with BTO's B2G objectives, and will make a great use case for transactive control and VOLTTRON. As I see it, the Southern Company project builds directly on this, too.

- One item to note regarding BTO's objective (which is relevant to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., 'virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).

- The project discussion generally recognizes that broader B2G opportunity, but it may be useful to work within BTO to broaden program objectives and metrics to explicitly incorporate the full suite of opportunities and capabilities, and ensure that the focus within BTO (and in projects such as this) is not unduly restricted to increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:
1) **3.75** for the degree to which it focuses on critical market barriers, and
2) **3.50** for the degree to which the approach addresses the market barriers identified.

- The team members have clearly identified the key issues to enable complete adoption of the proposed open-source HEMS.

- See previous comment.

- The fact that the project starts with a literature review and assessment of market barriers is a very strong point for its approach.

- This all looks very well thought out.

- Very good to see the early and intensive collaboration with manufacturers and utilities. That will surely both enhance the project's ongoing work and results, and also facilitate communication with utilities and other manufacturers, accelerating adoption and development where appropriate.

- One area that deserves more consideration is with respect to the eventual key role that will be played by state and federal energy utility regulators. E.g., working with utilities, consumers and other stakeholders, PSCs and FERC will develop or approve utility rate design and B2G programs/incentives, and they will also establish wholesale and DSO-level electric market design. All of these will be critical in creating effective market signals and incentives under which the utilities, B2G technology suppliers, & homeowners will operate. These regulatory issues are a somewhat more distant challenge for B2G, but there is considerable relevant discussion ongoing in a host of regulatory venues. Prompter, fuller inclusion of regulatory perspectives could be helpful both to the project directly and to BTO's broader B2G effort overall.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.25** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- So far, the team has been able to perform a literature review of existing HEMS, and developed means for controlling thermostat using VOLTTRON technology. The team has also been able to work closely with Emerson to facilitate adoption of the proposed HEMS.

- Project includes water heaters which are a critical component for smart homes.

- A good amount of work has been done. The fact that some of the work has been published is noteworthy.

- It appears that this project is already delivering, including by facilitating the Southern Company homes project - excellent!

D. Project Integration and Collaborations

This project was rated:
1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- So far, the team has been able to reach out to a large number of partners and subcontractors to expedite the adoption of the proposed approach.

- Excellent job in including industrial partners.

- I didn't see much of what the collaborators have done in the presentation.

- Outstanding - inclusion of manufacturing and utility input from the outset looks like a real plus.

E. Proposed Future Work

This project was rated **4.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The proposed future activities are in line with the rest of the project. In the end, the success of the project would largely depend how well the integration of all key home systems is managed.

- Future plans not only include a field demonstration, but also additional technical aspects (e.g. FDD and demand response control algorithms) and development of the necessary partnerships for wider deployment.

- *No Comment*

- Looks very well thought out and comprehensive.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- PI talks in language and in terms of examples that are directly addressing homeowners.

- *No Comment*

- Initial discussions look excellent.

***Average*: 0** reviewers
- N/A

***Low*: 1** reviewer
- The team has laid out a good plan to develop a robust HEMS.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- The team has identified all the key research challenges for successful implementation of the proposed HEMS.

- See previous comments.

- *No Comment*

- Looks GREAT.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project's strengths include integration of home systems components to enable energy saving through HEMS technology.

- See previous comments.

- N/A

- Please see previous comments.

2) **Project Weaknesses**

- Nothing major to report; however, team members should make an effort and reach out to other companies that serve the residential market.

- None identifiable.
- N/A
- I see no weaknesses. Looks outstanding.

3) **Recommendations**

- Dissemination of the project achievements to the public should be encouraged and pursued.
- N/A - excellent progress and excellent plans for future work!
- N/A
- Looks brilliant - go Go GO!

Project # 32740b: Connected Neighborhood

Presenter: Roderick Jackson, Oak Ridge National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Most reviewers believed that this project's outcomes were extremely relevant to BTO's Buildings-to-Grid (B2G) goals, such that several reviewers alternatively characterized the project as phenomenal, amazing, and a potential game-changer. One reviewer commented further that this residential project was building on other PNNL and ORNL work to create an excellent use case for transactive control via VOLTTRON, while another reviewer said that the results "should get a great deal of positive mileage." One reviewer expounded on the numerous benefits that B2G technologies could unlock in addition to energy savings.

While one reviewer called the project's approach sound—commenting that it could be replicated in other regions—another reviewer appeared to disagree. A third reviewer felt that the project's metrics suffered from scope-creep, suggesting that the researchers should pick a single, easily-measured performance metric in order to make a stronger business case.

Since this project was still in its early stages, reviewers commented little on the project's progress except to say that the team's early milestone achievements gave two reviewers confidence that the remaining tasks would be achieved. Reviewers were generally pleased with the project's integration and collaborations, which included utilities, original equipment manufacturers, and neighborhood developers. Moving forward, several reviewers appeared content with the project's future plans, with one reviewer commenting that the remaining tasks were straightforward, and another remarking that planned tasks would help the project team identify potential implementation and adoption issues.

Weighted Average: 3.46 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.38 Accomplishments: 3.38 Project Collaboration: 3.75 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The scope of the project is quite pertinent, which involves demonstration of the proposed scheme in 50 to 60 homes per neighborhood. Also, the whole approach is encompassing since it involves integration of several system interfaces.

- Multiple field demonstration sites equipped with smart water heater and HVAC systems. Chosen approach is to communicate to manufacturer API's rather than retrofit hardware.

- *No Comment*

- This is an amazing project.

- This comprehensive residential B2G project is completely aligned with BTO's B2G objectives, builds on other PNNL and ORNL work, and will make a great use case for transactive control and VOLTTRON.

- If you can make a success of this phenomenal project, it will be a game-changer for B2G and BTO's work, I expect. It will be a readily communicated with lay and professional audiences, and should get a great deal of positive mileage.

- One item to note regarding BTO's objective (which is relevant to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., 'virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).

- The project discussion generally recognizes that broader B2G opportunity, but it may be useful to work within BTO to broaden program objectives and metrics to explicitly incorporate the full suite of opportunities and capabilities, and ensure that the focus within BTO (and in projects such as this) is not unduly focused on/restricted to increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:
1) **3.25** for the degree to which it focuses on critical market barriers, and
2) **3.50** for the degree to which the approach addresses the market barriers identified.

- The proposed approach is sound and could definitely lead to a new energy model for neighborhoods. The proposed approach could lead to further implementation in other regions, if proven successful.

- See previous comment.

- My criticism here is similar to my criticism of another large-scale demo project: I don't believe these projects provide much value because of the way they are designed. How is this significantly different, say, from the Olympic Peninsula project?
- The bullets provided under "Approach" show that the scope is too broad: "Based on weather, solar irradiance, and load forecasts coupled with time of use pricing, the neighborhood master controller will

optimize battery storage, generation, and “virtual storage” to minimize overall system cost". Just defining (and measuring) "overall system cost" itself is a real problem! Since the goal is ultimately market adoption, why not pick a performance measure that can be measured more easily and can help in making a business case?

- This all looks very well thought out.

- Great to see the early and intensive collaboration with manufacturers and utilities, which of course this project couldn't do without.

- One area that deserves more consideration is with respect to the eventual key role that will be played by state and federal energy utility regulators. E.g., working with utilities, consumers and other stakeholders, PSCs and FERC will develop or approve utility rate design and B2G programs/incentives, and they will also establish wholesale and DSO-level electric market design. All of these will be critical in creating effective market signals and incentives under which the utilities, B2G technology suppliers, & homeowners will operate. These regulatory issues are a somewhat more distant challenge for B2G, but there is considerable relevant discussion ongoing in a host of regulatory venues. Prompter, fuller inclusion of regulatory perspectives could be helpful both to the project directly and to BTO's broader B2G effort overall.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The achieved accomplishments have demonstrated the team's ability to fulfill the remaining tasks. The team has also teamed up with HVAC manufacturers to enable better adoption of the proposed scheme.

- See previous comment.

- Project is in early stages; not much to see.

- Sounds like this project is moving apace, and the framing and approach are brilliant.

D. Project Integration and Collaborations

This project was rated:
1) **3.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team has been able to reach out to different companies and utilities to enable faster adoption of the proposed scheme.

- Including utilities, OEMs, and neighborhood developers.

- *No Comment*

- This is clearly going very well, as the project is soon to break ground.

- Huge congrats. Amazing work, team.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The proposed future work should help the team members identify potential implementation and adoption issues in the near future.
- Looking forward to the outcome of the field test sites.
- *No Comment*
- As with the rest of this project, the plans (which are appropriately skinny in your description) are straight-forward, and look great.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- Better understanding of constraints posed by end users.
- Please see previous comments.

***Average*: 2** reviewers
- Once the reported challenges have been overcome, the proposed scheme could make a difference in neighborhoods across the country in terms of energy consumption.
- *No Comment*

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- The team has clearly identified the key challenges to enable complete adoption of the proposed scheme.
- See previous comments.
- *No Comment*
- Looks great.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The strengths include field demonstration of the proposed scheme, which could help its adoption in the long-term.
- See previous comments.

- Having two different test sites is a strength.
- Please see previous comments.

2) **Project Weaknesses**

- The team members are encouraged to disseminate their results and knowledge to other in the energy industry.
- None identifiable.
- See my comment about the approach.
- This project has no obvious weaknesses. It looks amazing.

3) **Recommendations**

- The team members should consider partnering with other utilities to be able to test their approach in other regions.
- *No Comment*
- *No Comment*
- Great work - stay flexible and go Go GO!

Project # 32741a: Unified Control of Connected Loads

Presenter: Teja Kuruganti, Oak Ridge National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Reviewers agreed that unifying the control of connected loads to better optimize and manage energy use in small supermarkets was well aligned with BTO's Buildings-to-Grid (B2G) goals. One reviewer believed that the project's objectives appropriately addressed the challenges that many facilities managers face when retrofitting controls in existing facilities. A different reviewer said that the project's objectives align well with B2G's mission, by demonstrating another application of transactive control on the VOLTTRON platform and by targeting a highly promising end use sector. A third reviewer expounded on the numerous benefits that B2G technologies could unlock in addition to energy savings.

One reviewer believed that the project's multi-level approach would help it achieve its objectives and save energy by using the proposed supervisory control approach. However, another reviewer commented that the control algorithms were "a bit ad-hoc," because scaling these approaches to larger buildings might yield additional hurdles. Describing that the project addressed implementation, security, and energy efficiency, one reviewer wondered whether the proposed system was resilient to system component failures and whether or not the project addressed that aspect of performance.

Reviewers praised the project's early accomplishment of reducing peak energy load through improved efficiency by deploying the project's connected thermostat, which they described as good and promising. Every reviewer also expressed their support for the project's highly integrated approach, with one reviewer remarking that the substantial contacts made with Emerson, Southern Company, store owners, and government experts could help the project's technical approach gain quick adoption. Even though two reviewers believed Emerson's integration of this project's controller into their standard products demonstrated good project integration, another reviewer expected more progress from the partners' work and hoped to see it next year.

Reviewers disagreed about the project's future work. While several reviewers thought the project's future plans were promising, comprehensive, and straightforward, two reviewers thought the plans were too sparse and lacked detail. One of these skeptical reviewer asked whether the project plan called for testing on a variety of different building types and sizes, as well as whether the project team planned to test interfacing with different kinds of energy management systems.

Weighted Average: 3.57 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.50 Accomplishments: 3.70 Project Collaboration: 3.50 Future Work: 3.40

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project's stated objectives are quite appropriate for the challenges many facilities managers face when retrofitting controls in existing facilities.
- Addresses how to decide on when to switch on connected loads based on where they are in the deadband of their temperatures, e.g. based on prioritizing loads on where they are within the deadband.
- The relevance of the project comes from its focus on retrofit compatible technology for inter-connecting loads within buildings, especially supermarkets.
- Technology is definitely relevant to BTO goals of increasing building energy efficiency (address peak demand periods), reduction of emissions (reduced power consumption) and enhancing grid reliability (responding to DR events). Addresses commercial buildings...specifically supermarkets and convenience stores...a growing industry. Technology is layered on top of existing building system (with or without EMS).
- Better energy optimization & management of small supermarkets makes a great example and use case.
- This project to evaluate the opportunity and develop transactive control capabilities as a means to effectively, economically deliver on the opportunity seems core to the B2G mission, both in demonstrating another application of B2G using transactive control & VOLTTRON, and also in targeting a highly promising end use sector.
- If you can make this work, it will be a readily-cited example of B2G and BTO work that should be easily communicated to energy practitioners and to the general public alike.
- One item to note regarding BTO's objective (which is relevant to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).
- The project discussion generally recognizes that broader B2G opportunity, but it may be useful to work within BTO to broaden program objectives and metrics to explicitly incorporate the full suite of opportunities and capabilities, and ensure that the focus within BTO (and in projects such as this) is not unduly restricted to increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:

1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- The proposed multi-level strategy is quite appropriate for meeting project's objectives. Furthermore, the proposed supervisory control approach should enable energy savings in facilities.

- Project suggests to leave existing systems (e.g. rooftop unit) in place but replace the thermostat with a VOLTTRON interconnected thermostat. This reduces installation cost relative to a full control retrofit at a similar benefit as such a retrofit.

- The control algorithms are a bit ad-hoc; scaling these approaches to larger buildings might face additional hurdles. But perhaps larger buildings are not part of the target sector?

- The project is addressing cost of implementation (utilize what is already available), security (VOLTTRON platform) and energy efficiency (dynamic scheduling). One area that isn't addressed (at least via the presentation) is what happens if critical equipment fails? Is the proposed system resilient to system component failure? This goes to grid reliability.

- This all looks very well thought out.

- Very good to see your success in getting the interest and participation of manufacturers, a utility and a small supermarket operator - excellent. That will surely both enhance the project's ongoing work and results, and also facilitate communication with other utilities, supermarkets, and manufacturers, accelerating adoption and development where appropriate

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team has been able to accomplish a significant number of tasks in the last year. The project will certainly have positive impact on the industry.

- Results of a field study were shown, promising results in reducing peak load.

- Good accomplishments; demonstration of the supermarket connected thermostat is good.

- The project team has accomplished quite a bit in the first year...demonstrating improved energy efficiency on an actual building (store with display cases). Project appears to be on the right track.

- It appears that this project is already delivering, including by gaining Southern Company and Dollar General.

- Interesting - congrats!

D. Project Integration and Collaborations

This project was rated:
1) **3.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team has been able to make a substantial number of contacts for enabling quick adoption of the proposed technical approach.

- Integration into the company partner's (Emerson) proprietary controls as part of the field study promises it to become a standard component in their products which should facilitate potential future market penetration.

- Although collaboration with the partners, Southern Company and Emerson, appears strong, I was expecting more progress on the work by the partners. Perhaps in the next year?

- Project team includes government experts, customers (store owners), equipment manufacturer (Emerson) and a utility (Southern Co). The project team was able to install and test technology in a building...demonstrates good integration.

- The very structure/approach of this project involves early and ongoing collaboration with industry. That's a great, practical structure/approach.

E. Proposed Future Work

This project was rated **3.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The proposed future plans are a bit sparse. More details should be provided to appreciate the team's future efforts.

- Future plan for field test and delivery of open source platform are a promising step for wider adaption of the developed technology

- *No Comment*

- Future work is defined, however, level of detail is lacking. For example, does the project plan call for testing on a variety of different building types and sizes? What about interfacing to different kinds of EMS?

- As with the rest of this project, the plans (which are appropriately skinny in your description) are straight-forward, comprehensive (in the sense of spanning key topics, rather than enormous detail), and look great.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers
- Once completed, the whole control approach could lead to significant reductions in energy consumption.

- I think the approach to include manufacturers combined with the secondary retrofit option are an excellent approach to satisfy all customer needs.

- *No Comment*

- The proposed solution will definitely provide value to building owners and grid operators.

- Please see other comments.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The team members have a good understanding of the complexities and challenges of the proposed approach from the point of view of implementation.
- No additional comments.
- *No Comment*
- Except for the fault detection and mitigation, the project is well laid out.
- Looks great.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The ability to develop new retrofit-compatible control technology is what the industry needs for existing facilities.
- Low-cost hardware platform for open-source software based method (tstat) as well as implementation into proprietary controls.
- *No Comment*
- Project strengths include minimum retrofitting required, solution can work with buildings with or without an EMS, and the teaming includes scientists, manufacturers, customers and a utility - increasing the probability of success.
- Please see previous comments.

2) **Project Weaknesses**

- The full potential of instrumentation interoperability could be a challenge difficult to overcome without a set of common standards.
- I think it would be good to show if the peak load reduction also results in an overall energy reduction - which could motivate customers that are not on a peak demand pricing schedule to adopt the technology.
- *No Comment*
- What happens if system components fail? Who sets priorities for dynamic scheduling?
- This project looks great - no weakness to comment on.

3) **Recommendations**

- The team should consider other facilities such as post offices to show the potential of the approach in multiple and different operations.

- See previous comments.
- *No Comment*
- Test against different EMS.
- Great work - stay flexible, stay collaborative, and go Go GO!

Project # 32741b: Universal Hybrid Inverter Driver Interface

Presenter: Madhu Chinthavali, Oak Ridge National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Although one reviewer expressed confusion about how this project's activities related to BTO's Buildings-to-Grid (B2G) goals, most did not; one reviewer even claimed that among the projects they reviewed, "this [project] appears to be the one that is most strongly aligned with BTO's goals." This reviewer commented further that the current lack of open-source inverter interfaces—which could allow third-party control algorithms to work with smart inverters—was a "severe bottleneck" for realizing a true smart grid. One reviewer described this project's universal hybrid inverter driver interface as a truly novel approach to addressing this bottleneck.

With the exception of the aforementioned reviewer, who did not appear to understand the purpose of this project's activities, reviewers generally thought that the project's approach was sound, noting that it addressed hardware and software issues across multiple platforms and carefully targeted a practical opportunity. One reviewer, however, expressed a desire to know more about how the inverter would be tested, specifically asking what distributed energy resources, energy management systems, and manufacturers would be used.

Every reviewer was impressed with the project's early results, describing them as "excellent" and en route to "deliver[ing] a practical technology to a receptive industry." Reviewers also awarded high marks for the project's integration with an unidentified industry partner, although two reviewers felt that little information about the nature of this relationship was presented. One reviewer suggested that the project would benefit from interactions with companies that design and fabricate photovoltaics and other similar systems, while another reviewer wished to see a utility partner brought on board.

Reviewers appeared content with the project's future plans, expressing confidence that the project team would meet its future goals. However, one reviewer was not sure whether the project's future work would address system costs, encouraging the project team to investigate this aspect of the technology if they were not planning to do so already.

Weighted Average: 3.57 # of Reviewers: 5
Relevance: 3.40[1] Approach: 3.50 Accomplishments: 3.70 Project Collaboration: 3.40 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project's objectives are quite relevant since interfacing PV and other renewal forms of energy generation into a functioning grid still is an economic and operational challenge.

- Not clear based on the presentation how the project supports DOE goals and/or I am unaware of the specific DOE goal addressed.

- The lack of inverter interfaces that allows third party control algorithms to interface with the so-called "smart inverters" is a severe bottleneck in the development of the smart grid. This project aims to remove/ameliorate that bottleneck. Among the proposals I reviewed, this appears to be the one that is most strongly aligned with BTO's goals.

- Project is focused on near real-time control and integration of renewable-energy-based power electronics inverters in green buildings by developing a universal driver interface for VOLTTRON platform. There are currently no open-source and controllable inverters. To help increase building energy efficiency and grid reliability, the ability to quickly and reliably interface to renewable energy sources is required. I'm a little concerned about the timeline...is there sufficient time and funds to thoroughly test the technology under a variety of use cases?

- Development of capability to apply VOLTTRON & transactive control to inverters looks like a great example and use case. This project to evaluate the opportunity and develop transactive control capabilities to effectively and economically deliver on the inverter control opportunity seems core to the BTO B2G mission, both for the improvements in inverter operations, but also for demonstrating novel VOLTTRON/transactive control capability.

- One item to note regarding BTO's objective (which is relevant to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., 'virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).

- The project discussion generally recognizes that broader B2G opportunity, but it may be useful to work to broaden program objectives and metrics to explicitly incorporate the full suite of opportunities and capabilities, and ensure that the focus within BTO (and in projects such as this) is not unduly restricted to increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- The approach is quite sound since it involves hardware and software issues across multiple platforms.

- See first comment.

- Approach is sound, nothing to comment.

- Good approach, however, I would like to know more about how the technology will be tested. What DER systems will be tested, manufacturers, etc. Is the EMS part of the equation?

- This is a narrow technical project, and seems carefully targeted to a practical opportunity. It's good to see direct vendor interest and participation, which helps ensure that the approach and intended outcome is in fact practical.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team has been able to achieve several important tasks including the development of advanced VOLTTRON control platform and a hybrid interface.

- See first comment.

- Quite a bit of progress has been made already!

- Excellent progress on the project.

- Looks like the project is on track to deliver a practical technology to a receptive industry.

D. Project Integration and Collaborations

This project was rated:
1) **3.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.20** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- It appears that the team has made an effort to collaborate with other potential industry partners. However, more information about those efforts should be reported.

- Contractor worked with an industry partner.

- *No Comment*

- The project team clearly is working closely with industry manufacturers. I'm wondering if a utility should also be involved...at least in the later stages.

- Assuming that the manufacturing partner is genuinely pleased with the project's accomplishments and will adopt the resulting technology, this project is right on track with its collaborative approach.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The proposed future tasks have been well delineated. Near the end of the project, the team should be able to fully demonstrate the capabilities of the proposed scheme.
- Clear path for moving forward.
- *No Comment*
- The future plans clearly build on past work and address many technical barriers. What about cost barriers? I may have missed this, but what are the costs in producing and installing this technology into buildings?
- See previous comment.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers
- The team has certainly considered most of the technical aspects and challenges for the complete adoption of the proposed scheme.
- See comments on relevance and progress.
- The current and proposed deliverables are needed and I have no doubt will be used by industry and building operators.
- Great to demonstrate another practical VOLTTRON use case.

***Average*: 1** reviewer
- See first text comment.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- The team has diligently considered all the technical challenges for enabling quick adoption of the proposed scheme.
- See first text comment.
- *No Comment*
- With the exception of uncertainty on which use/test cases will be used, the project is well thought out and hits key points of the program.
- See previous comments.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Definitely, integrating power generation from renewal sources of energy with the grid still is a technical and economic challenge. Therefore, the project would certainly enable better adoption of renewal sources of energy in facilities in the foreseeable future.
- See first text comment; good project progress.
- See comments on relevance, approach, and achievement till date.
- The project is needed, it has an excellent project team, has demonstrated excellent early results and there is close collaboration with manufacturers.
- See previous comments.

2) **Project Weaknesses**

- The project would benefit from interactions with industry partners that design and fabricate PV and other similar systems.
- See first text comment - value proposition is unclear to me.
- I don't see any, but I am not a power electronics expert.
- It's not clear what use/test cases will be used for testing the technology. It would be good to have a well-rounded set of test cases that cover a broad range of operating conditions.
- No obvious weaknesses, assuming manufacturing party is generally on board and aiming to adopt resulting technology.

3) **Recommendations**

- Knowledge obtained during the execution of the project should be disseminated as widely as possible.
- Make clearer - in lay terms - what it will achieve and what it will be good for.
- *No Comment*
- Contact a utility and get their input on the technology...they may provide some use/test cases.
- Go GO GO!

Project # 32742: Distribution Transformer Data, Testing, and Control

Presenter: Donald Hammerstrom, Pacific Northwest National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Reviewer believed that the project's focus on reducing electrical losses from distribution transformers by using dynamic transformer controllers on the VOLTTRON platform was "spot-on" with regards to advancing BTO's Buildings-to-Grid (B2G) goals. Several reviewers also commended the project's novelty and creativity, which they felt could result in the discovery of new, smart strategies to managing loads.

The project's approach of comparing the performance and benefits of traditional transformers to amorphous-core transformers was roundly supported by the reviewers. One reviewer thought that the use of historical data would help overcome market barriers, while another reviewer touted the benefits of working closely with utilities to overcome barriers. One reviewer, however, could not determine whether the project would explore transformers from different manufactures or the impact of electric vehicle charges on transformers.

Most reviewers noted that the project was too young to comment substantively on its accomplishments, but also that the project's overall quality and team composition encouraged many reviewers to expect strong results at the next Peer Review.

Several reviewers provided favorable remarks about Santee Cooper's willingness to freely provide eight transformers for use in the project team's experiments, commenting on how these transformers kept project costs down and prevented scope-creep. According to another reviewer, the project was likely to identify workable approaches because they involved an electric utility from the outset, and should produce practical, communicable results for key distribution transformer purchasers and operators because the project team was focused on a single, relatively homogenous opportunity. One reviewer recommended that manufacturers be engaged, commenting that their insights and experience could unlock earlier adoption of project findings.

One reviewer noted that the project team had clearly stated its future plans for overcoming technical and adoption barriers, while another reviewer described proposed future work as a thoughtful, comprehensive approach to the targeted opportunity of disturbed transformers and the demonstration of a VOLTTRON use case. A third reviewer, however, expressed some consternation that the lightly-funded project could run out of resources, especially in the event of an unforeseen transformer(s) failure.

Weighted Average: 3.38 # of Reviewers: 5
Relevance: 3.80[1] Approach: 3.40 Accomplishments: 3.10 Project Collaboration: 3.90 Future Work: 3.40

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Understanding the obstacle to the adoption advanced commercially available transformer is extremely important. Furthermore, use of dynamic controls could enable significant energy savings.

- Distribution transformers directly affect the US grid's distribution efficiency. This project conducts a study that includes both field and laboratory testing components to determine the efficiency of two different types of distribution transformers.

- Improving distribution transformers directly support BTO's energy efficiency and grid resiliency goals.

- The project's objective is to reduce no-load losses of distribution transformers by addressing the market barriers for adoption of the most advanced commercially available transformer technologies and materials, as well as to reduce transformer load losses by designing and developing dynamic transformer controllers to more effectively manage efficiency and lifetime performance...which is very relevant to the BTO objectives of improving energy efficiency, reduce emissions and improve grid reliability. Project appears to be spot on.

- This narrowly targeted project addresses a product class, distribution transformers (DTs) makes a good example and use case for BTO's B2G efforts, and particularly by demonstrating another smart VOLTTRON application. Importantly, better DT specification and better operation of DTs once installed appear highly prospective for economic and environmental benefits, and this creative approach to delivering on it is very interesting.

- By involving an electric utility from the outset, and working with a single, relatively homogenous opportunity, this project has a high likelihood of identifying workable approaches, and following those up in practical, communicable fashion to the key DT purchasers & operators.

- Blending the underlying physical characteristics of DTs and their specific use characteristics (e.g., which involves typically very low load factors and accompanying performance issues; losses that vary significantly with load; age- and temperature-related performance degradation) with the novel low-cost communication and control strategies enabled by VOLTTRON should allow novel, smart strategies (e.g., 'dispatching' groups of DTs according to optimal performance characteristics).

- Very keen to watch how this project develops.

B. Approach

This project was rated:
1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- The proposed approach of relying and using on historical data would help overcome market barriers.

- Approach includes both, testing the lifetime performance of used transformers. Tests include both, pulling energy from the grid as well as feeding energy back to the grid (as will be needed for distributed generation using renewable energies).

- The plan for addressing market barriers appears sound, but it's hard to say much at this stage of the project.

- The project is looking at comparing the performance and benefits of traditional transformers vs. amorphous-core transformers. As part of the examination, costs, efficiency and reliability will be

examined. It's not clear, however, if the project will examine all makes of transformers as well as examine different kinds of amorphous-core transformers. In addition, the project doesn't appear to explore the impact of EV chargers on transformers (level 1, 2 and 3). Given the push (well..at least with the last administration) for EVs, this would be an important issue to look at. Having said this, the approach is pretty good.

- There are several barriers to more fully delivering on the potential for more economic DT performance, and this project's approach, by working from the outset with a utility, seems well thought out and practical.

- Going beyond DTs, this makes a great and novel use case for VOLTTRON, which can only help BTO's B2G efforts.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The team's composition should certainly enable successful project outcomes. Even though it is just a year-long project, the expected outcomes should result in energy savings for users of advanced transformers.

- It is difficult to evaluate the last to questions since the project is in a pretty early stage. I would expect the project to do pretty well on the last two questions in the next DOE peer review.

- It's not possible to say much due to lack of details given in the presentation. But the project is in early stages, so that might be the cause for the small progress seen so far.

- The project appears to be on schedule, but it's too early to tell what the accomplishments will be. Having said this, the project - in my opinion - is going to delivery some interesting and valuable results.

- The initial discussion looks very thoughtful and well-framed.

D. Project Integration and Collaborations

This project was rated:

1) **3.80** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **4.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- All the team members are key players in the industry, which should facilitate adoption among users of transformers in the long run.

- Industrial partner made several transformers available which allowed to reduce project scope and cost. Additionally, the industrial partner made their own data available to the project team to further support the project.

- Very strong collaboration with industry; the project cost is significantly reduced due to donations by industry.

- Project integration (using eGrid at Clemson) and collaboration is one of the major strengths of the project. The fact that Santee Cooper is providing eight transformers bodes well for continued collaboration (not to mention saving project costs). eGrid is a an excellent integration test bed.

- Great to see involvement of a utility from the outset. That will surely help with making the framing and analysis as practical as possible.

- Is it possible to also promptly include one or more manufacturers? There would certainly be interest, and their insights and experience could be very helpful, as well. And it would surely help in getting earlier adoption.

E. Proposed Future Work

This project was rated **3.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The team has clearly stated the project's future tasks to be able to overcome technical and adoption barriers.

- Tests will allow to characterize both, load as well as feed-in performance of different transformers.

- It's hard to say much due to the lack of details; perhaps because the project is young.

- The bulk of the project occurs in the next phase of the project...installation of the test transformers, collection of historical operating data, testing of the two types of transformers and the investigation into the six control strategies. Although the project is still in the early stages, the fact that the project team is using an existing test bed and is collaborating closely with a utility (Santee Cooper) provides confidence that project risks are minimal. Having said that, I do think there is a risk of running out of funds. It is admirable that the project team is getting by on limited funding, however, what happens if there are unexpected events...such as a transformer failure, etc.?

- Looks like a thoughtful, comprehensive approach to the targeted opportunity of DTs, while also demonstrating a VOLTTRON use case - great.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers
- Given the team's composition, inherently the project deliverables should impact the market in the long-term.

- Performance values of transformer evaluated in this project are critical to inform transformer replacement decisions.

- See my comment on the relevance.

- Although early in the project, the listed deliverables (reports) will be very valuable to the industry.

- The project's framing and metrics look good.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The team is aware of the technical challenges to enable adoption of advanced transformers across several markets.
- Answer to this question is based on anticipated results.
- Again, this is hard to say at this stage of the project.
- The project is well defined and focused. A good project.
- Looks good.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The composition of the team should enable faster adoption of the knowledge generated during the project.
- Excellent industrial support, excellent support of other parties, excellent testing approach.
- See comment on relevance; that's the biggest strength.
- The project is well defined and has buy-in from a major utility. Another strength is that the utility is providing eight transformers...really shows that the utility has skin in the game. The principal investigator is also a big plus.
- See previous comments.

2) **Project Weaknesses**

- Team should comment on any possible supply chain issues and longevity of advanced transformers.
- N/A - need to wait for next BTO Peer Review.
- Over-reliance on the data provided by the partner?
- As previously noted, I have concerns over whether there is sufficient funding available for the project.
- See previous comments.

3) **Recommendations**

- It is an interesting project necessary to overcome the perceived level of technical maturity of commercially available advanced transformers.
- Present losses in normalized form rather than in absolute (W or kW) losses to make it easier to interpret data.

- *No Comment*
- If funding allows, adding an EV impact component to the project would be useful.
- Looks great: go Go GO!

Project # 32744: Clean Energy and Transactive Campus Project (CETC)

Presenter: Srinivas Katipamula, Pacific Northwest National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Most reviewers recognized this project's relevance to BTO's Buildings-to-Grid (B2G) goals, commenting that the physical demonstration of transactive control via VOLTTRON was central and essential to the entire B2G effort. One reviewer noted that the project's Phase II expansion to other campuses and buildings should only increase confidence in and familiarity with VOLTTRON's technical feasibility and approach. Another reviewer, however, was concerned about redundancy, saying that they could not understand what additional value this project offered beyond the findings already demonstrated by a previous PNNL project.

Reviewers' opinions on the project's approach were less positive. Almost every reviewer felt that the project had not addressed one or more market barriers, although one reviewer did note that the nature of the project's early-stage research might explain this. One reviewer left the presentation searching for information on the technology's estimated costs versus payback, as well as information on whether or not the project addressed occupant comfort. Several reviewers also expressed a desire to see more collaboration with utilities and/or manufacturers, to ensure that "transactive control capabilities address[d] the most practical and complete set of issues."

Every reviewer remarked that this project had accomplished quite a bit, although almost no reviewers made any further substantive remarks about the project's accomplishments. While the project's very nature focused on seamless integrations, several reviewers wished for greater collaboration. One reviewer lamented that they could not identify the extent to which the project's collaborators had contributed. Several others also wanted more information about how the two advising utilities were involved as well as how many other utilities were being actively engaged. One reviewer offered similar remarks about equipment manufacturers and technology developers, describing that these stakeholder would have "a vital, even dominant role if B2G is to effectively deliver on the enormous potential."

While most reviewers began their comments on the project's future plans by saying that it appeared "on-track," a few reviewers felt that the project team had been unclear about how fully involved utilities and manufacturers would be as the project expands.

Weighted Average: 3.27 # of Reviewers: 5
Relevance: 3.80[1] Approach: 3.10 Accomplishments: 3.50 Project Collaboration: 3.10 Future Work: 3.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project's goals are clear and quite ambitious. The overall approach is sound and necessary to be able to take transactive control technologies closer to full market implementation. The distribution of key tasks have been delegated quite appropriately.

- Project partners test multiple different aspects of integration of generation of power into grids on campus level.

- Generally a good project, but I am not sure what benefit it provides to BTO's vision that hasn't been provided by large scale demos in the past such as the Olympic Peninsula project.

- Project implements transactive control controls on multiple buildings. Addresses BTO's focus on building energy efficiency. Technology is implemented on VOLTTRON - supporting open standards and reuse. I would have liked to see more data on operational results, perhaps in Phase 2 this information will become availability. Nice project.

- This is an early stage project on transactive control, and as such, focuses on relatively early stage, primarily technological, issues. Demonstrating this physical transactive control capability seems to be central to much of DOE's B2G effort, making this project essential. Phase II, by extending to other campuses and buildings will give increased confidence in and familiarity with the technological feasibility and approach.

- One item to note regarding BTO's objective (which is generic to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., 'virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).

- This project's discussion generally recognizes that broader opportunity, but it would be useful to work within BTO to broaden program objectives and metrics to explicitly incorporate these other aspects, and ensure that the focus within BTO (and in projects such as this) is not unduly restricted to/focused on increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:

1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project has clearly identify most of the market barriers; however, it remains to be seen how producers (utilities) would participate explicitly in grid integration.

- Control methods tested using VOLTTRON platform on a campus level; showed that VOLTTRON software can be used on a wide range of hardware platforms

- The project focuses on tech demo by PNNL; though valuable in itself, that is not likely to overcome market barriers.

- The overall project approach is very good. Having said that, there are at least two barriers that I didn't see addressed in the presentation: estimated cost/payback of the technology and addressing occupant comfort. The cost issue is self-explanatory and most likely will be addressed in the next phase of the effort, but nowhere is occupant comfort or preferences addressed. I may have missed this, but it's important not to ignore the occupant of the building.

- This is an early stage project on transactive control, and as such, focuses on relatively early stage, primarily technological, issues. It will be great to see achievement in the project's medium and long term goals, which include more direct and extensive utility direct involvement and utility-driven activity that builds on the initial success of the project, as well as extending to additional campuses and buildings.

- Given the success of this project to date, it would seem valuable to more fully involve utilities and manufacturers to help ensure that the transactive control capabilities are addressing the most practical and complete set of issues.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- A lot has already been accomplished both on the hardware and software sides. Several publications and presentations have already been made, which should facilitate dissemination across the industry.

- Secure communication in both ways was considered during development of VOLTTRON software platform.

- Quite a bit of work has been done.

- I score this project's accomplishments and progress at 3+...almost a 4. Again, the concern over cost/benefit calculations. At this point in the project, I would hope that the researchers would have an idea on the economic payback of the technology. On the other hand, testing of the technology on 10 PNNL buildings is good progress.

- This early stage project, demonstrating basic multi-site, multi-DER functionality via transactive control, seems vital to the success of BTO's B2G efforts.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- By the very nature of the project, a seamless integration of the key project goals and objectives has already taken place. The team is already creating a network of partners to facilitate broader testing of the proposed control scheme.

- Unclear how much industry involvement and interest. Excellent testing playground on campuses.

- According to the presenter; the collaborators haven't done much yet. I assume this will change in the future.

- Project team is coordinating with PNNL F&O as well as the faculty management organizations on various university campuses.

- It's perhaps unfair to down-rate this project due to its collaboration approach, given how early stage it is. That said, it is certainly the case that utilities and/or other service providers will have a vital, even dominant role if B2G is to effectively deliver on the enormous potential.

- In light of that, it would be good to see more intensive discussion of how the two advising utilities are being involved, and of how other non-involved utilities are being actively engaged. A similar argument holds for equipment manufacturers/technology developers. Early and ongoing input could be a real plus.

- Further, it does not appear that much if any consideration has been given to the eventual key role that will be played by state and federal energy utility regulators. E.g., working with utilities, consumers and other stakeholders, PSCs and FERC will develop or approve utility rate design and B2G program/incentive design, and wholesale and retail market design, all of which will be critical in creating effective market signals and incentives under which the B2G technology suppliers, building owners & operators and utilities will operate. These regulatory issues are a somewhat more distant challenge for B2G, but there is considerable relevant discussion ongoing in a host of regulatory venues. Prompter, fuller consideration of regulatory perspectives could be helpful both to the project directly and to BTO's broader B2G effort overall.

E. Proposed Future Work

This project was rated **3.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The project seems to be on track. Key aspects of the project have already been accomplished.

- Good idea to extend testing - when and how will commercial companies get involved into integrating VOLTTRON-compatible products into their systems?

- Appears reasonable.

- The plan calls for more testing...particularly involving the existing and new university partners. I rate the project's future plans as 3+. I have concerns that the actual cost/benefit of implementing the technology may not be fully addressed in the final phases of the project.

- Extending to other campuses and building in other jurisdictions, and more directly involving utilities and manufacturers will increase confidence in and awareness of this early stage technology. Phase II plans look good, but it's unclear just how fully involved utilities and manufacturers will be. For reasons discussed in previous comments, greater involvement earlier may be worthwhile.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers

- The implemented approach has the potential to have widespread adoption in many building districts across the nation.

- Platform includes all required components to curtail consumption.

- The stated targets such as utilities are likely to find the tech demos convincing.

- Project has produced a very large test bed environment that can easily be modified to explore different tech solutions. Technology itself addresses BTO goals of improving building energy efficiency. Technology appears to be scalable and easily transitioned to other buildings.

- Having not read the many documents produced, but rather, having seen the scope of publications, it appears that this project is delivering a key foundational technology in transactive control and B2G.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- The publication record developed as part of the project has certainly demonstrated the desired level of interest in research and development activities.

- Yes, 3 different campus wide installations are used to showcase performance of the developed platforms.

- *No Comment*

- See the previous response. The project is definitely addressing BTO goals.

- Yes, but with a caveat regarding increased involvement of utilities and industry, as noted in previous comments.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project's goals are quite ambitious, which have been executed as planned. The ability to integrate building systems as proposed, has been a remarkable success. Possible expansion of the technology to commercial buildings is within reach.

- In depth testing of developed platform.

- Unclear how this will be transferred to be integral part commercial product (e.g. air handlers, etc.).

- Good technology demonstrations; involves multiple partners and demo sites, and translates previously developed methods onto VOLTTRON. All of these are useful to serve BTO's goals.

- Excellent project. Large campus test bed, multiple buildings involved and multiple barriers are addressed. Basing the technology on VOLTTRON addresses cyber-physical security and scalability. Although presentation didn't present sufficient detail on actual energy savings and cost/benefit analysis, I believe this project is on the right path.

- Demonstrating the technology and identifying practical issues and applications is vital to BTO's B2G effort.

2) **Project Weaknesses**

- None to report at this time.
- See previous responses.
- The main weaknesses I see are :
    - 1. Relevance to BTO's goal: looks like more of what has been already done in Olympic Peninsula Demo and other tech demo projects funded by DOE.
    - 2. Many of the technologies that are translated to VOLTTRON agents in this project (such as the Intelligent Load Control, ILC) appear to be somewhat ad-hoc, with no performance guarantees. For instance, the ILC does not guarantee (it appears, I may be wrong) that the temperature will not go beyond the stated bounds in its attempt to contain peak load. If that is the case, will this enable market adoption?
- As previously noted, there isn't a cost/benefit analysis (at least I didn't see it). I'm also concerned about occupant preferences not being considered.
- Please see previous comments.

3) **Recommendations**

- More communication with power producers might be beneficial in the long term.
- Include commercial companies that sell product with smart thermostats as well as utilities and show that it can be done with available hardware that is already part of new building system installations.
- Complement field trials/demos by performance analysis.
- Modify the final phase of the project to include cost/benefit analysis.
- Go Go GO!
- Great work. Keep pushing the frontiers, and adapt as you move ahead.

Project # 32745a: Virtual Batteries

Presenter: Karan Kalsi, Pacific Northwest National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

Reviewers believed this project's evaluation of the technical potential and transactive control capabilities of using flexible building loads to store energy was central to effectively and economically delivering the energy efficiencies outlined in BTO's Buildings-to-Grid (B2G) mission. One reviewer also expounded on the numerous benefits that B2G technologies could unlock in addition to energy savings.

Reviewers generally expressed some confusion about how the project's approach was addressing market barriers. One reviewer said that the presentation did not adequately mention what the market barriers were, while another was not sure if the approach would enable energy savings and full market adoption. Two reviewers gave more positive remarks, however, with one commenting that the project team had the necessary steps in place to address market barriers, and the other saying that the approach was "wide-ranging and thoughtful." Because the project remained in its earliest stage, reviewers felt that it was understandable that the project's only accomplishment to date had been the development of a virtual storage "phone book."

Even though most reviewers could identify a number of project collaborators from different sectors, several reviewers remained unconvinced that the project's collaborations and project integration efforts were sufficient. One reviewer commented that the project's plan to involve utilities and manufacturers was undeveloped, and that more intensive involvement by these parties could improve the project's design, results, and eventual dissemination into practical applications. Another reviewer expressed that an approach which more explicitly incorporated, built on, and facilitated private sector utility and manufacturer work "would seem worth exploring."

Every reviewer was concerned about the project's future plans. Two reviewers said that proposed future work was unclear, with one reviewer wondering what mechanism would be used to estimate storage capacity. Two others thought that future plans looked strong, but one was afraid that the project did not have enough time to implement the control technology while the other reviewer reiterated his or her wish for more utility and manufacturer involvement. Reviewers gave a number of very different recommendations to improve the project moving forward, including extending the "phone book" to the zip code level and pin pointing the difference in the net effects of demand response vs. virtual batteries.

Weighted Average: 3.25 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.25 Accomplishments: 3.38 Project Collaboration: 3.25 Future Work: 2.75

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- It remains to be seen in the whole concept of virtual batteries (load or supply variation) would eventually be fully adopted across the entire energy sector.

- Using grid-connected devices as a virtual battery is a good addition to conventional electrical storage.

- Project addresses increased grid operations by using flexible building loads as virtual storage resources. Incorporates alternative energy sources (wind, solar). Project addresses BTO's goal to make buildings more energy efficient with minimum cost to building owner or occupant. Development of a "phone book" of virtual battery capabilities is a great idea.

- Energy storage is one of the vital, growing needs of a more economic, flexible, resilient and renewables-ready grid. "Virtual" storage, primarily using thermal characteristics of buildings and equipment, appears to offer a very large, low cost storage opportunity. This project to evaluate the opportunity and specify transactive control capabilities as a means to effectively, economically deliver on the opportunity seems core to the B2G mission.

- One item to note regarding BTO's objective (which is relevant to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., 'virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).

- The project discussion generally recognizes that broader B2G opportunity, but it may be useful to work within BTO to broaden program objectives and metrics to explicitly incorporate the full suite of opportunities and capabilities, and ensure that the focus within BTO (and in projects such as this) is not unduly restricted to increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:
1) **3.25** for the degree to which it focuses on critical market barriers, and
2) **3.25** for the degree to which the approach addresses the market barriers identified.

- The team members have already completed their national opportunity assessment, but it remains to be seen how well the proposed approach would enable true energy savings and full market adoption.

- From presentation, it was unclear what the market barriers are. This might be one of the next steps that the research team should look into - if they mot already did.

- Project team has in place the necessary steps to address market barriers (e.g., availability of "virtual" storage, development of "virtual" storage control technology, open source standards (VOLTTRON), etc.).

- Looks like a wide-ranging and thoughtful approach to a very high-value but novel opportunity.
- One aspect that seems under-developed is how to effectively involve utilities and manufacturers. More intensive involvement could both enhance the project design and results, and also facilitate adoption and

development in practical applications. It's certainly the case that some utility and manufacturer effort is ongoing currently. E.g., the major water heater (WH) manufacturers and several other WH technology suppliers of grid-interactive electric resistance WH and heat pump WHs are working fairly intensively, as are some utilities. Their work builds on the ~2 million controlled WH installed in the US currently (albeit generally using very basic control capability such as timers), and the 'grid-enabled water heater' legislation enacted in 2015, and shows enormous promise. Work is ongoing for a range of other equipment types, as well.

- An approach that more explicitly incorporated, built on, and facilitated that private sector utility and manufacturer work would seem worth exploring.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.75** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** For the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- So far, the team players have met the project expectations even though it started relatively recently.
- Project is a relatively early one - I don't think interim market goal's achievement can be evaluated at this point.
- Project team developed initial "virtual" storage "phone book" in the first year of the project.
- The project is at an early stage, but the initial doc and analyses looks promising.

D. Project Integration and Collaborations

This project was rated:

1) **3.25** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.25** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Even though the project started relatively recently, it appears that each team member or organization has been able to perform the designated team tasks.
- Unclear how much industry is involved at this point.
- Project team members are from government, industry (manufacturer and utility) and academia. Multi-discipline team provides different views/concerns/approaches to the table.
- As noted in a previous comment, it appears that more intensive interaction with manufacturers and utilities would be worthwhile.
- And it is certain that there are several manufacturers and utilities that would be keen to participate in some fashion.

E. Proposed Future Work

This project was rated **2.75** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- It is not clear how the dedicated physical storage capacity would be estimated, especially when taking into account fault ride through considerations when additional renewable sources of energy come on line.

- Unclear.

- Future plans are well thought out, however, I have concerns if project team will have sufficient time to implement the control technology.

- Looks great, with the one caveat about doing more to collaborate much more intensively with utilities and manufacturers.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- Knowledge of available virtual storage will help decision-makers determine how much to invest in high-cost physical storage. This is a very valuable project.

- Looking forward to seeing this advance.

***Average*: 2** reviewers
- It is too early to tell if the objectives and goals of the project would lead to complete market adoption of its deliverables.

- The project evaluated the cost of virtual storage - the proposed virtual storage is at similar cost than traditional energy storages.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- Based on what was shown this is difficult to judge, needs to be evaluated through the reports.

- Project plan appears to address all project objectives.

- Looks great; high-value area.

***No*: 1** reviewer
- Insufficient information was provided to be able to assess if the research area is receiving considerable consideration.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project will try to explore the possibility of using virtual batteries for supply load moderation. This is indeed a challenging project, which might be successful with detailed analysis of load considerations.

- Project assessed how much virtual storage costs, but a bit unclear how they arrived at the cost numbers given in their presentation.

- Creating a "phone book" listing available virtual storage around the country is a great idea. Estimation of available virtual storage is reasonable.

- See previous answers.

2) **Project Weaknesses**

- It remains to be seen how the whole approach might be able to take into account the growth of renewables sources of energy when estimating up-to-date cost-benefit analysis for the energy market.

- Unclear what exact methods were used, unclear how it differs from demand response since - in some sense they do make the grid react in the same fashion. Is it a duplication of efforts?

- Not clear if all building owners will participate and the timeline to develop the control technology may need extending.

- See previous answers.

3) **Recommendations**

- Greater level of technical details should be provided, specifically, those concerning fault ride through considerations.

- Very interesting work. I think it would be beneficial for the PI to make sure to point pit the difference in the net effect of demand response vs. virtual batteries. How do they doffer? What is cheaper, better, more reliable in keeping the grid stable?

- Extend the "phone book" to the zip code level...i.e., increase the granularity of the availability of virtual storage.

- It might be worth thinking carefully about the best terms to use, and in particular, whether "physical" storage versus "virtual" storage (which is the focus of this project) has the proper connotation.

- Virtual seems like the wrong term, and to be clear, all of this is physical storage, whether in one of the ~2 million currently operating peak shaving/load shifting electric resistance water heaters or an intelligently pre-cooled commercial office building.

- Final recommendation: go Go GO! This is great work, and should deliver tremendous benefits for consumers, manufacturers, utilities, environment, etc.

Project # 32745b: VOLTTRON Controller for Economic Dispatch

Presenter: Srinivas Katipamula, Pacific Northwest National Laboratory
DOE Manager: Joe Hagerman

Brief Summary of Reviewer Comments

With one reviewer commenting that "the stated goals of the project read like BTO's mission statement," it may not be surprising to learn that every reviewer believed this project to be highly relevant to BTO's Buildings-to-Grid (B2G) goals. One reviewer said that the project's approach was novel because it allowed both generators and consumers of energy to make sound economic decisions, while another was pleased that the project supported the integration of emerging energy technologies onto the grid.

Most reviewers were pleased with the project's approach, with one commenting that the use of model predictive control (MPC) was the project's strength because it was ideally suited for complex, real-time decision-making challenges—so long as its pitfalls were avoided. Another reviewer said that most of the project's market barriers were addressed, except for an understanding of whether utilities would embrace this technology. This reviewer also wondered whether the technology considered occupant preferences, or would have the capacity to adjust to demand changes in real time.

Multiple reviewers said that the project's progress—despite its early stage—was promising. Several reviewers were impressed that the project team had been able to develop the essential algorithms to enable energy savings in existing facilities. Other reviewers noted that the progress, which had mainly been limited to testing components of the overall system, were positive enough that they did not hold any reservations about the team's likely future successes.

Reviewers were a bit more concerned about the project's collaborations and project integration. One reviewer was not sure what role ORNL would play in the future, while another reviewer did not understand how or when industry would be involved. Despite strong representation from DOE's national labs and academia, several reviewers wished for more utility and manufacturer involvement moving forward.

While reviewers felt that the project's momentum and future plans were moving in the right direction, one reviewer felt that the project could benefit from machine-learning or adaptive neural network algorithms to enable greater energy savings. Another reviewer said that the integration of components into the full system should be the main focus of future work.

Weighted Average: 3.29 # of Reviewers: 5
Relevance: 4.00[1] Approach: 3.10 Accomplishments: 3.50 Project Collaboration: 3.00 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The proposed approach is novel in the sense that it would allow producers and users of energy make good economic decisions. It also incorporates relevant information in the decision-making process, including short-term weather and load forecasting data.

- Clear objectives, supports implementation of new energy production (fuel cells and other) into the grid.

- The stated goals of the project read like BTO's mission statement; clearly this is highly relevant to BTO's vision.

- Project addresses increasing building energy efficiency, increasing grid reliability, provide an open source solution and reduce emissions. Technology is VOLTTRON-based providing scalability and cyber-security protections.

- Better optimization & management of building CHP + AFDD and ACCx makes a good example and use case. This project to evaluate the opportunity and develop transactive control capabilities as a means to effectively, economically deliver on the opportunity seems core to the B2G mission.

- One item to note regarding BTO's objective (which is relevant to all of BTO's B2G work, not just this project): the potential benefits of B2G extend far beyond merely increasing energy efficiency (EE). They include increasing energy productivity, consumer amenity, improving grid economics, reliability and resilience, and enabling more economic integration of variable output or inflexible generation. Further, it is entirely possible and even likely that other B2G capabilities may deliver greater consumer, environmental and industry benefit than EE, and that in some cases, these greater benefits may actually result in increased energy use (e.g., 'virtual' energy storage or providing grid ancillary services using building equipment may increase energy use and decrease EE).

- The project discussion generally recognizes that broader B2G opportunity, but it may be useful to work within BTO to broaden program objectives and metrics to explicitly incorporate the full suite of opportunities and capabilities, and ensure that the focus within BTO (and in projects such as this) is not unduly restricted to increasing EE, but rather is focused on more fundamental metrics including reducing consumer cost and environmental impact, increasing energy productivity, and increasing grid reliability, resilience, and flexibility.

B. Approach

This project was rated:
1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Even though the project started on March 31st, 2016; the team members have been able to develop the essential algorithms for enabling energy savings in existing facilities. In the near future, the team should be able to quantify real energy savings after implementing the approach in the field.

- Offline testing prior to full deployment at test sites.

- The use of model predictive control (MPC) is a strength of this proposal; MPC is ideally suited for such complex real-time decision making problems. However, feasibility, convexity, convergence time, stability etc. are all issues associated with MPC; it's not clear if the MPC formulation used in the project have been selected to avoid those issues. Full avoidance of all may not be possible.

- Most of the market barriers are being addressed (e.g., technical solution exists, need exists, energy savings potential, etc.). One area that is not addressed (or is not obvious from the project presentation) is how involved are the utilities in the technology. Will they embrace the technology? Also, are occupant preferences considered? Finally, will the technology adjust to real-time changes in demand?

- Looks like a wide-ranging and thoughtful approach to a high-value, long-under-adopted opportunity.

- One aspect of the project that seems under-developed is how to effectively involve utilities and manufacturers. More intensive involvement could both enhance the project design and results, and also facilitate adoption and development in practical applications.

- Expanding the approach to more explicitly incorporate, build on, and facilitate utility and manufacturer work would seem worth exploring.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project tasks accomplished so far would enable the team to fulfill the project's expectations. Also, the supervisory control algorithms should be able to make the decision making processes more robust and intelligent in the long term.

- Project status looks promising - examples of what needs to be considered and how forecasts are made were given.

- It's perhaps early in the project; hence progress has been limited to testing of components of the overall system, integrated system hasn't been tested yet.

- Project appears to be on schedule as the team has developed and tested modules/models in the first year. Project appears ready for the next phase (continuous testing). I have high confidence that the P/I will keep the project on schedule. Technical risk appears to be well managed

- The project is at an early stage, but the initial doc and analyses looks promising. Moreover, demonstrating in detail another application of a use case for transactive control and B2G helps the total BTO B2G effort.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- It is not clear what specific role ORNL will be playing in the near future.

- Contractor included both, utilities and end users into his project.

- *No Comment*

- The project team consists of members from two national labs and two universities. Although the team has extensive knowledge of the power sector, it would be good if they included a utility and possibly a manufacturer.

- It seems likely that more intensive interaction with manufacturers, utilities and building owners/operators would be worthwhile.

- It's not clear from the project discussion how industry will be involved and at what point. However, it's surely the case that several manufacturers, utilities and BOMA members would find this of use, have interest in participating in some fashion, and have a range of practical perspectives and expertise to contribute.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Even though the team is on the right track, it would be beneficial to stress the importance of machine-learning or adaptive neural network algorithms to enable considerable energy savings in the remainder of the project.

- Clear path for moving forward.

- Integration of components under development into the full system should be the main focus of future work.

- Next phase is to undertake extensive internal testing to ensure all design functionality is operational and then deploy the technology in an actual building. Approach is sound.

- Looks good, with the one major caveat about doing more to collaborate much more intensively with utilities and manufacturers sooner rather than later.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- The project has great potential for adoption because it relies on VOLTTRON technology, which should enable market penetration.

- Given the PI's track record and approach taken, I have high confidence that the deliverables will meet market needs.

- This project, by demonstrating in detail another application of a use case for transactive control and B2G, helps the total BTO B2G effort.

***Average*: 2** reviewers

- In general a good project but a long way from actual in field standard implementation

- See comment on scope/weakness.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The team has a good overall understanding of the research challenges to make the project a success.

- Very interesting project!

- *No Comment*
- Project is meeting program's objectives. Addresses key BTO objectives (e.g., improved energy efficiency, reduced emissions, increased grid reliability, etc.).
- Looks great, with the caveat that more utility and industry involvement may be worthwhile; high-value area.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project relies both on a proven approach (i.e. VOLTTRON) and adaptive control algorithms to enable energy savings.
- Well thought out approach that starts from software only through limited scope experimental to field study.
- See comments on relevance and approach; those are the strengths.
- PI has a good understanding of the technology and has a track record for undertaking excellent research. Projected energy savings greatly contributes to BTO goals. Automation controls that produce 24-hour operations schedule.
- See previous comments.

2) **Project Weaknesses**

- The team should clearly explain how the adaptive control algorithms would be able to handle dynamic variation over the long term.
- Can't name any.
- The main weakness is the project is too vast in scope to be feasible: "This multi-purpose economic dispatch and control tool and associated open-source algorithms will ensure real-time optimal operation of buildings, increase electric grid reliability, and lead to the goal of a clean, efficient, reliable, and affordable next generation integrated energy system." If a single project delivers all these, well....
- No utilities involved with the project team. Not clear if occupant preferences are taken into consideration. It's not clear if the technology will adapt to real-time changes in demand (i.e., occupancy in a space suddenly and unexpectedly increases due to a pop-up meeting...will the technology adjust to this?).
- See previous comments.

3) **Recommendations**

- It would be interesting to explore the effects of electric car as energy storage units in locations where charging/discharging stations are available.
- I think it would benefit the VOLTTRON platform if the DOE pushed for involvement of more universities. I am thinking along the lines of building retrofit with VOLTTRON as part of competitions with some DOE funding to support the Universities expenses for getting involved. That would allow to get more graduates that know how to implement VOLTTRON into existing buildings.

- Reduce scope and make deliverables measurable. Avoid goals like "Maximize ROI", which is fundamentally impossible.

- Thoroughly test the technology - include use cases that introduce unexpected behavior into the environment. Get utility input.

- Once again, it would be good to bring in utilities, manufacturers and building operators sooner rather than later.

- Finally: go Go GO! This looks like great work, and should deliver tremendous benefits for consumers, manufacturers, utilities, environment, etc.

Emerging Technologies International

Project # 94150a: CERC: Markets and Policy Initiative

Presenter: Carolyn Szum, Lawrence Berkeley National Laboratory
DOE Manager: Marc LaFrance

Brief Summary of Reviewer Comments

In general, reviewers found this project to be extremely relevant to BTO's goals, particularly the project's focus on reducing global building energy use by 40%. Reviewers were impressed with project's approach and its focus on addressing market barriers, particularly for an international collaboration. One reviewer remarked that the project's diverse approaches—like the use of tools, transparent data, financing, and modeling—allowed for a stronger project. Another reviewer noted the importance of gleaning lessons learned from other partners who have engaged in similar endeavors, like ASHRAE and the International Code Council.

Reviewers agreed that this project was making significant progress, that the accomplishments achieved to date were laudable, and that the outcome-based targets were feasible. Beyond general praise for the work completed so far, reviewers also applauded the project for its professional and competitive program leadership—including leaders' ability to demonstrate concrete progress on master planning and execution—while another reviewer noted the project's variety of approaches and data transparency.

Reviewers generally found the project team's level of engagement with stakeholders and industry appropriate. Some reviewers suggested further engagement, however, including with existing code development bodies and with finance and insurance agencies, who could provide lessons learned from their existing financial instruments. Another reviewer commented that alternative forms of dissemination might engage key stakeholders more directly than the project's communication via academic papers.

Most reviewers agreed that the project would provide a valuable product to its target audiences and that the project appropriately emphasized key research areas, though one reviewer observed that it was too early to fully assess the project. Reviewers noted that it was helpful to have an open information platform, and that constructive programs such as this could inspire other countries and the public around importance issues.

Most reviewers agreed with the project's proposed future work, with two reviewers highlighting the importance of engaging with stakeholders throughout the entire project, particularly noting engagement with other programs and organizations that are developing outcome-based building energy codes. One reviewer noted that the project needed additional engagement with the real estate community, and another suggested having an established minimum number of variables to complete an audit. One reviewer expressed a desire to see better balance in the location of pilot projects between China and the U.S.

Weighted Average: 3.55 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.75 Accomplishments: 3.38 Project Collaboration: 3.38 Future Work: 4.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- 4 separate sub-projects which address BTO goal of technical assistance activity - the critical sub – project will be the aspect that measures the success of "outcome-based building energy codes".
- Verify that BTO on track for U.S. …. Justification for China integration - they provide 25% gov & 25% industry. Same split stateside. Current codes typically are mostly prescriptive (miss plug and process loads,). New buildings and existing buildings comparison shows applicability and key issues
- Estimated $1.50 per square meter(SM) cost for an audit. Building energy is not yet considered an asset class. As far as financing is considered, cost of ownership is not a variable. However, we see energy efficiency on the micro scale in residential incorporated as a part of cost of ownership.

- Right on. Excellent program!

- None.

- Yes, project is very relevant to BTO's goals.

B. Approach

This project was rated:
1) **4.00** for the degree to which it focuses on critical market barriers, and
2) **3.50** for the degree to which the approach addresses the market barriers identified.

- Excellent identification of market barriers. Audits as a part of asset consideration appear to be a hurdle that if overcome, can lead to strong success of the project. Good to see the New Buildings Institute and the IMT on the list of partners. Review that other potential partners that have already "trod" down the same path have been engaged to glean lessons learned (ASHRAE, IECC, etc.).

- Well thought and adjusted approach to address all barriers. International collaborations are always challenging and this one is one of the most impressive I have ever seen.

- None.

- Using diverse approaches--tools, transparent data, financing, and modeling--allows for a stronger project that is more likely to obtain positive outcomes.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is currently finishing up year one of a five-year project. Partnership framework has been established. Slide 9: prescriptive performance vs. OBP. Feasible outcome based targets for outcome-based performance have been indicated. Slide 11: impact model framework – model has been calibrated based on current collected data - nothing can truly account for behavioral/operational, but the accomplishment of calibration is a start. Slide 12: research result. Important to establish the minimum variables needed to complete an audit and that could be made public for open sourcing.

- The progress and headways the program has achieved is laudable and amazing. With my background, I can personally feel it.

- None.

- No comments.

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.25** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Slide 5: Outcome based codes … Any thoughts to integrating with the existing code development bodies? Slide 6: Data transparency … What about cost benefit analysis integration? Slide 7: open source audit tool … China currently doesn't have anything. Slide 8: financing: Green financing instrument development - assuming that this is for EE technology implementation. Slide 14: IPMP audit tool - in progress - team is looking at integrating with existing US tools. Slide 15: There are finance and insurance agencies that already provide some of the financial instruments … and could possibly provide lessons learned.

- It's not easy to get every stakeholders aboard, but I see the program has successfully engaged all the interested parties. It doesn't need to be perfect, while being sufficient. Very impressive already.

- None.

- Most communication of results are in the form of academic papers. While these have a place, it will be more useful if dissemination of results, issues, and plans are more directly to the key stakeholders, also engaging them in the discussions, so that relevant stakeholders may better be informed and useful feedback may be obtained.

E. Proposed Future Work

This project was rated **4.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- In regards to implementation, perhaps consider engaging with the real estate community in terms that they will understand. This is where the ability to provide a cost-benefit analysis could either make or break the project.

- Great program so far with a visionary plan. Please keep on track as y'all can!

- None.

- Make sure to be in continuous interaction with key stakeholders along the way, not just at final phases.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- It's always good even as a gesture to initiate and maintain such constructive programs to inspire the countries and public on great causes. Obviously, the program staff put in tremendous efforts and have visible results, so it's not for show and I personally have sensed the positive impacts indirectly.

- None.

- Having an open information platform is useful.

***Average*: 1** reviewer
- Too early to fully assess the project.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Too early to fully assess the project - see additional recommendations for suggested deployment activities.
- It's simply a well-executed program with a vision so far.
- None.
- Yes, good emphasis.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Supports BTO goals. Identifies barriers. Focuses on reduction of 40% of the global building energy use.
- Professional and competitive program leaders and staff have achieved concrete progresses on both master planning and executions.
- None.
- Variety of approaches and data transparency are the project's strengths.

2) **Project Weaknesses**

- Currently it is too early to fully assess the project but it appears that its success depends on the consistency of approach and the resolution of intellectual property (it was unclear as to whether the IPMP agreement was complete).
- Uncertainty with the new administration.
- None.
- Too much focus on academic papers.

3) **Recommendations**

- As the intent is to implement aspects of the project in the United States, don't blindside ICC or ASHRAE and other organizations currently developing outcome based building energy codes. Make sure that they are also directly engaged in conversation. Include CORENet and BOMA as a part of the training/curriculum development as their focus is in providing pertinent information in the management of commercial real estate.

- It's already good to see such an effort exists and has progressed in-depth. Since it is political, there are unknowns, while so far so good.

- None.

- For pilot projects--seems like mostly are planned for two locations in the U.S. and one in China. Would be better if there was another Chinese location/better balance.

Project # 94150b: CERC: Control, Commissioning & Data Mining

Presenter: Mary Ann Piette, Lawrence Berkeley National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed that this project—and its efforts to develop occupant-responsive model predictive control (MPC) that incorporates flexible building loads with behavioral patterns—is highly relevant to BTO's office goals.

With the MPC emulation platform and occupant module developed and validated, reviewers agreed that the project was making good progress at this early stage and would continue to be influential. One reviewer did note, however, that due to a delay in getting data from the identified demonstration building due to the processing of the intellectual property and non-disclosure agreements, existing data from another building was used for this initial development and validation. Reviewers unanimously agreed that the project would be highly valuable to the market and its target audiences, especially if it achieves its stated goals. One reviewer noted that, in considering the target audience, having real world and occupant-based information would aid in better decision-making. Despite initial progress, reviewers believed that the project had not adequately focused on market barriers, particularly those inhibiting industry adoption. To better address market barriers, one reviewer suggested incorporating occupant identification and addressing privacy concerns. Overall, reviewers found that the project was in line with the direction the technology was heading, in terms of better managing commercial real estate energy use.

For the most part, reviewers found that the project demonstrated an understanding of key stakeholders as well as practical collaboration, although some reviewers mentioned areas for improved engagement. For example, one reviewer suggested adding real estate partners for industry adoption to be successful by helping to provide different approaches to asset management. Another reviewer noted that the project's partnership with China capitalizes on the momentum in emerging markets and real estate stocks, and suggested strengthening the bilateral partnership.

Reviewers were generally impressed with the direction of the project. One researcher noted that this project was capitalizing on experienced researchers and industry minds working together to shape the future of the market in the U.S., China, and the world. However, another reviewer raised the question of cybersecurity integration and how it would be addressed in the future. One reviewer also recommended that the project team consider different commercial building types, and to base its selection of building types on market importance.

Weighted Average: 3.39 # of Reviewers: 5
Relevance: 4.00[1] Approach: 3.30 Accomplishments: 3.40 Project Collaboration: 3.40 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Overview - project is in its 1st year. Appears to be like NEST for a commercial building. Today utilities are monthly based. Looks at rapid systems for building controls. Cost or use of energy is typically not considered, building doesn't know how much energy it is using. Looks at more flexible building loads - incorporating behavioral patterns.

- The project focus is obviously cutting-edge and systematic, and it is interesting and intriguing to see the methodology is embedded in the CERC initiative - instead of promoting such ideas only in US' existing and relatively a few new facilities, it is the best to bring in the momentum of China's emerging markets and real estate stocks.

- The project aims at developing free, open-source, occupant-responsive Model Predictive Control (MPC) software; demonstrating the validity of the software at room, building, and campus levels; and enabling scaling and commercialization of the technology. It is very relevant to BTO's goals.

- None.

- Very relevant.

B. Approach

This project was rated:
1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- As one of the project outcomes is the distribution of the open source for industry adoption and research collaboration, there haven't really been any barriers identified for this step. Slide 7: Maybe incorporate occupant identification (RF?) That can be tied back to a comfort survey. There will be privacy concerns. Slide 9: Adaptive action models. Considers 1st arrival and last.

- The project presents innovative and comprehensive technology and methodology to address our buildings' modern and future needs in a most advanced way. I'm very excited to see there is such a "complete" package being proposed and carried out in progress. It's something well matching the context of the scale and magnitude of CERC.

- The approach is summarized below:
    - Develop-hierarchical, occupancy-responsive model predictive control software (MPC) framework.
    - Demonstrate-multiple buildings sites, showcase robustness and verify performance improvements.
    - Distribute-open-source for industry adoption and research collaboration.
- The approach is sound and executable. There has been a delay getting data from the demo building due to processing of IP/NDA agreement. Data from other buildings were used in Year 1 to test the MPC emulation platform and develop and validate occupant module.

- None.

- No comments.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Slide 10: Indicates software platform & architecture development progress. Slide 11: Project team will be creating "base models" for each type of system … raised floor, VAV, etc.

- Great potentials and already started to show through the demos, trainings and publications. Very influential.

- Accomplishments and Progress:
  - For Subtask 1.1 entitled "Occupant Module Development at the Room Level", architecture for occupant behavior (OB) has been developed to exchange information between occupants and MPC at room and building levels. For Subtask 1.2 entitled "Development of Building-level MPC," modules for external data collection, real or emulated system interactions, data-driven model learning and validation, and control optimization have been developed. Also, python scripting, extensible architecture, and automated optimization problem formulation have been designed. For Subtask 1.3 entitled "Room-Level MPC Demonstration Preparation," progress has been made. LBNL and JCI have identified the JCI HQ building in Milwaukee, WI as the site for MPC demonstration at the room level. Discussions between the two organizations are underway to determine the rooms, floors, and systems included in the demonstration and the scope of experiments.

  Market Impact:
  - JCI has offered Milwaukee and Shanghai buildings as demonstration sites for occupant-integrated MPC platform as well as active engagement during demonstration process. LBNL has initiated the process of open-source licensing for distribution of MPC software code. A commercialization plan will be developed in Year 2.

- None.

- No comments.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Slide 13: the core is "integrated systems control." Slide 13: Modelica is the modeling software …. MPC has been successful in other industries. Slide 14: Seems to be an initially strong collaboration team - however, for industry adoption to be successful, further real estate partners may need to be added.

- Great players aboard. It's one of the most sincere group of stakeholders that have vested interest to make it happen.

- Provide the foundation for implementing MPC technologies in commercial buildings in both the U.S. and China. LBNL research team has regular meetings and seminars with the industry partners. Collaboration with two IEA EBC projects: Annex 60 Modelica & FMI tools, and Annex 66 occupant behavior modeling and simulation. Active communication and collaboration with China teams. China has strong interest to reduce energy use in buildings through advanced control technologies. The team at Tsinghua University,

China has been doing research in building controls and district heating systems. Partners, Subcontractors, and Collaborators— U.S. industry partners: Johnson Controls, United Technologies, Disney, Lutron, Lend Lease. China collaborators: China Academy of Building Research, Tsinghua University, Ministry of Housing & Urban-Rural Development.

- None.

- There's a good amount and variety of industry involvement from the U.S. side; would be good to increase amount and diversity of industry partners from China too.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Slide 15: what about the integration of security / proximity cards / wearable tech as a part of occupant inputs? As privacy is a concern, it may be possible to do this anonymously or as one time data gathering exercise for model calibration.

- Experienced researchers and industry minds bonded to shape the future of the market in both countries and the World.

- MPC technology will be developed and tested in partner buildings. After NDA/IP in place, occupant module and demo plan development will be completed using sensor data from the demo building. Real-time occupancy data from sensors and from virtual sensing, (e.g. WiFi signals, Pritoni et al. 2017) for occupancy prediction model training. Adaptive occupant models to predict preferences and interactions with controllable systems, e.g. shade positions, (D'Oca and Hong 2015, behavior.lbl.gov). Library of component models for building HVAC operation and indoor environment prediction will be completed in the first quarter of Yr 2. Commercialization plan will be developed in Yr 2. Other potential U.S. companies may join as project develops.

- None.

- Good plan.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers

- If the project can achieve its stated goals, real-time cost of operation can prove invaluable for asset operation plans.

- Exhibition of great leadership to make it happen, but also leading the industry with advanced and complete solutions.

- The project scope is well within the scope of BOT's program goals, it has a highly qualified team and highly qualified collaborators. The project objectives have been well articulated by the team members and good progress seems to have been made so far.

- None.

- Real world/occupant based information will aid in better decisions.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- Yes, for the most part. As the project is only in its first year, it is hoped that the future commercialization plan will address deployment activities that will overcome adoption barriers.
- A well-thought program and execution.
- All critical areas have been adequately covered and are on the radar screen of the investigators.
- None.
- No further comments.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- MPC is where the market is headed in order to better manage commercial real estate energy use.
- True experts with practicality, experienced in running such collaboration.
- The project is a good one and good effort has been expended so far. The team seems to be on target towards achieving the project goals and objectives.
- None.
- Allowing occupant input/feedback, and being open-sourced are project strengths. Also, this type of fine-tuned and real world/occupant-based building control allows for real issues to be identified and for better solutions to be devised.

2) **Project Weaknesses**

- Working with multiple real estate management organizations can help provide different approaches to asset management. (e.g. equipment use, etc.)
- Uncertainty with the new administration.
- There are no weaknesses that are apparent.
- None.
- Unbalanced industry collaboration (need more from China).

3) **Recommendations**

- None at this time.
- Inspiring and exciting.
- I have no additional recommendations to make at this time.
- None.
- Consider different commercial building types and their needs, especially based on market importance. Make sure to collect occupant data for longer period so that different seasons, different situations, etc. can be captured.

Project # 94151a: CBERD: R&D Simulation and Modeling

Presenter: Philip, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO, noting the project's support for improved building energy efficiency through use of smart, integrated simulation tools for design and operation, as well as its development of new control and diagnostic methods for reducing energy consumption in new and existing buildings.

Reviewers favorably rated the project's approach, though they were divided over this approach's ability to address the market barriers identified by the project team. One reviewer felt that the project *was* addressing the market barrier posed by current simulation tools' failure to meet the needs of stakeholder in early stage building design and operation. Other reviewers, however, felt that cost barriers were not being addressed, particularly around the Early Design Optimization Tool (eDOT) and the Julia software. One reviewer noted that the project's approach revolved around identifying needs and opportunities to improve tools and supporting data, but another reviewer felt that more emphasis was needed on increasing the accuracy of predictive energy modeling and recommended including newer technologies and design strategies.

Reviewers identified a number of project accomplishments, with several pointing to the development of eDOT and its online multi-parameter optimization functionality. Reviewers were also pleased that the project team had articulated key research areas well, believing that the project was on target for achieving its goals. Several reviewers noted that it was too soon for the measurable market impacts from the project to be assessed, though one did express their expectation that stakeholders would benefit from improved analysis tools for early design, rulesets for code compliance, and other tools. One reviewer felt that it remained to be seen how useful the tools ultimately would be in the market.

Reviewers were pleased with the project team's engagement with industry, academia, and other stakeholders, with one reviewer highlight in particular the student exchange program. One reviewer highlighted the many papers produced and conferences attended by the project team, commenting that these activities provided visual impacts of the project's work and recommending that other CBERD and CERC projects emulate this behavior. One reviewer suggested that more collaboration should occur between this and other CBERD and CERC project teams, in order to share lessons learned and best practice approaches. Reviewers applauded the project's international collaboration, remarking that such collaboration enhanced DOE's relationship with India.

Looking forward, reviewers agreed that the project was logically and well planned to reach its milestones and goals, though one reviewer recommended that cost barriers should be addressed more directly, and at an earlier stage, to ensure the project's viability for both U.S. and Indian markets.

Weighted Average: 3.33 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.30 Accomplishments: 3.30 Project Collaboration: 3.30 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Slide 2: halfway through program. Slide 3: attempts to address gaps (design and O&M). Slide 4: GENopt software tool. DOAS issue integration especially for hydronic system buildings.

- The project supports BTO's goals since the outcomes include:
    - Improving building energy efficiency through the use of smart, integrated simulation tools for design and operation
    - Developing new methods for reducing the energy consumption of existing and new buildings – controls, diagnostics

- None.

- Relevant.

- This simulation and modeling project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding improving building energy efficiency through the use of smart, integrated simulation tools for design and operation and developing new methods for reducing the energy consumption of existing and new buildings with controls, diagnostic. This project is solving a buildings barrier through new ideas, approaches and performers. Funding this activity, will not only bring in an international perspective in smart simulations tools and controls but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building efficiency challenges through simulation and modeling.

B. Approach

This project was rated:

1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- Inclusion of newer technologies and design strategies is important to increase the accuracy of predictive energy modeling.

- The approach revolves around identifying needs and/or opportunities to improve tools and supporting data. It also revolves around developing, implementing and testing new, high priority capabilities for existing tools and control systems. Key issues selected for joint research interest and impact potential include the following:
    - Early stage design analysis –optimization and design flexibility.
    - Code compliance tools -extend ASHRAE 90.1 Appendix G capabilities to the India building energy code (ECBC), which is based on 90.1.
    - Optimal control of passive thermal storage to exploit diurnal swing and shift load -model predictive control (MPC).
    - Automated diagnostics -test new and existing methods for DOAS, which are required by hydronic heating and cooling systems, including radiant.

- None.

- No further comment.

- The project's design addresses the market barrier that current simulation tools do not fully meet the needs of practitioners, particularly in early stage design and in operation. Additionally, the US may have many prototype tools but India lacks a tool for performance-based code compliance. This project's plan is laid out

in detail with good description of the main barriers and how the project is assessing the market needs. The project will improve analysis tools for early design, rulesets for code compliance, optimum control strategies for radiant slab systems, and diagnostic tools for dedicated outdoor air systems (DOAS) – creating add-on tools to increase simulation tool usage, per BEM R&D logic model. The market audience is a wide variety of building stakeholders such as Architects, mechanical engineers, code officials, control engineers, operators as well as new and existing commercial buildings in India and the US. Funding this activity, will not only bring in an international perspective on coding and building simulation and modeling software but also enhance DOE's relationship with India.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- P1(slide 5) Creating a design assessment tool so that architects have a better understanding of impacts on the broader aspects of design.
    - (slide 6) chart … aspect ratio is a measurement of the floor plate layout … example: if the SHGC is more opaque, then the overhang can become irrelevant
    - P2(slide 7) ECBC = the India Building code … derived from ASHRAE 90.1 ….. integrated OS (OpenStudio) measure
    - P3(slide 8) MPC … control of radiant slabs …. Choice was based on the slow response of slabs … MPC was proposed as a way to address a model of the dynamics of a room with a radiant slab/weather/occupancy ... Interesting approach
    - Julia software as an EnergyPlus overlay for a closed-loop simulation … Julia is cost prohibitive unfortunately, unless you are an academic.
    - Heuristic control strategies … The approach was to look for familiar patterns, etc.
    - P4(slide 9) Fault detection and diagnosis (FDD) project: DOAS – as a way to complement radiant systems.

- Accomplishments include developing an Early Design Optimization Tool (eDOT) that features an on-line, multi-parameter optimization tool –implemented in Web2Py, uses EnergyPlus and GenOpt. Recent work: Market impact addresses cost barrier for tools for early design. It is probably too soon for measurable impacts to be assessed.

- None.

- No further comments.

- The Early Design Optimization Tool (eDOT) tool is an interactive optimization tool that will benefit the market greatly in making building systems automated and work efficiently. The cost barrier is not addressed and should be taken into consideration earlier in the project rather than later to ensure it is viable for the market in the US and India. The current output GUI is said to work well for engineers and computer scientists and as a temporary output for eDOT computational development but isn't useful for architects. This needs to be addressed to make the output more meaningful and intuitive for architects (a major deployed in the market). The Model Predictive Control (MPC) algorithm and tool chain have also been developed and the Fault Detection and Diagnosis has been tested well but no measurable impacts are available. These need to be seen to assess the usefulness in the market.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.20** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Slide 11: content was pretty much skipped due to time constraint other than NREL / OS note. Slide 12: student exchanges emphasized.

- Project Integration includes the following:
  - Collaboration with NREL on development and implementation of code compliance measures for OpenStudio, in line with the MYPP.
- Partners, Subcontractors, and Collaborators include the following:
  - Collaboration with IIIT Hyderabad on eDOT and ECBC OpenStudio measure development.
  - Collaboration with UC Berkeley on development of model predictive control for radiant slabs and on eDOT interface design.
  - Collaboration with IIIT Hyderabad on design and commissioning of diagnostics test facility, using experience LBNL gained with FLEXLAB.
  - Collaboration with Infosys on testing and demonstration of MPC for radiant slab cooling.

- None.

- On MPC--could be more collaboration between teams working on MPC for China and this team involved in India; share lessons learned, best approaches, etc.

- Project staff collaborates and coordinates with industry, academia, and other stakeholders to a great extent. Providing on site meetings and research partners having face to face interaction with the project experiments. This projects consults with many partners, and sub-contractors which is a good way to get various perspectives to get a wider grasp of the barriers and hence make proportional solutions. Their work has been presented in many papers and conferences which is great at visualizing the impacts of the project for stakeholders. This method should be integrated into other projects for CBRED and CERC to show just how impacting international collaborations can be.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Slide 14: hoping that the resultant work will be evident in the BCL's used for open studio.
- Infosys case study… $25b corporation, almost 200k employees. Will be using their building with N/S primary glazing with radiant systems to see if MPC helps.

- Future plans include several areas:
  - For the ECBC compliance tool:
    - Finish testing of ECBC implementation in OpenStudio.
    - Set up beta testing with practitioners in India –this is expected to lead to Government and, subsequently, commercial support for code compliance software solutions based on EnergyPlus and OpenStudio.
  - For the eDOT early design tool:
    - Focus on user interface, especially communication of results and integration into the design process.

  - For Other Tools:
    - Develop model-based fault detection and diagnosis (FDD) tools for low energy cooling systems, initially at the system and component levels:
    - Set up a simulation-based prototyping and testing environment, based on Modelica, at IIIT-Hyderabad, with assistance from LBNL.
    - Test promising algorithms in IIIT-Hyderabad fault diagnostics test facility.
    - Start with algorithms for DOAS, taking existing FDD approaches and algorithms as starting points.

- None.

- No further comments.

- The project has effectively planned its future in a logical manner by incorporating appropriate decision points and market goals. The plan builds on past projects and continues to address BTOs goals and barriers in both US and India. This collaboration is will continue to benefit the US as it is an excellent means of bringing together top researchers, lab techs, and envelop enthusiasts who may be working in parallel fields together their otherwise would not have. Finish testing of ECBC implementation in OpenStudio and set up beta testing with practitioners in India will lead to Government and, subsequently, commercial support for code compliance software solutions based on EnergyPlus and OpenStudio. The eDOT early design tool will focus on user interface, especially communication of results and integration into the design process which is critical to making sure it will be viable in the market in the US and India. The continued development model-based fault detection and diagnosis (FDD) tools and model predictive control for thermal mass storage in low energy systems will also be simulated and demonstrated to ensure market viability. Additionally, accessing India's facilities and equipment and even being able to make DOE's funds stretch even more by doing the tests in India, especially in these times, further encourages and stimulated this market and in turn benefits DOE.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Hoping that the resultant work will be evident in the BCL's used for open studio.

- The project is within BTO's program goals and objectives and seems to be on target towards achieving those goals.

- The project will improve analysis tools for early design, rulesets for code compliance, optimum control strategies for radiant slab systems, and diagnostic tools for dedicated outdoor air systems (DOAS) – creating add-on tools to increase simulation tool usage, per BEM R&D logic model. The market audience is a wide variety of building stakeholders such as Architects, mechanical engineers, code officials, control engineers, operators as well as new and existing commercial buildings in India and the US. Funding this activity, will not only bring in an international perspective on coding and building simulation and modeling software but also enhance DOE's relationship with India.

***Average*: 2** reviewers

- None.

- No further comments.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- Consideration of new technologies and updating subsequent energy modeling componentry is extremely important.
- Fault detection tools would be an excellent way to catch issues on a real-time basis.
- Key areas have been well articulated by the investigators. The team seems to be on target in achieving project goals.
- None.
- No further comments.
- As previously mentioned, this simulation and modeling project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding improving building energy efficiency through the use of smart, integrated simulation tools for design and operation and developing new methods for reducing the energy consumption of existing and new buildings with controls, diagnostic. This project is solving a buildings barrier through new ideas, approaches and performers. Funding this activity, will not only bring in an international perspective in smart simulations tools and controls but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building efficiency challenges through simulation and modeling.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Perhaps the same project approach can be used in exploring other technologies for integration into energy modeling.
- The project is within the scope of BTO program goals and objectives and seems to be on target in achieving these goals.
- None.
- Performance-based approach is valuable. Effort to make toll more intuitive for architects is good.
- This project's focus is in line with BTOs goals and a major barrier breaker to building efficiency, especially for simulation and modeling. Focusing on the ECBC compliance tool, the eDOT early design tool, model-based fault detection and diagnosis (FDD) tools, and model predictive control for thermal mass storage in low energy systems. This project will positively impact the market. Furthermore, the international collaboration is a great way to increases awareness between countries, fields, and markets. Including a market penetration strategy prominently showcasing and live testing the tools and technologies that come out of this project. This collaboration gives DOE insights into new and different facilities, sites, populations, and energy markets.

2) **Project Weaknesses**

- None at this time.

- There are no weakness that I know of.
- None.
- No further comments.
- The cost barrier is not addressed and should be taken into consideration earlier in the project rather than later to ensure it is viable for the market in the US and India.

3) **Recommendations**

- None at this time.
- I have no additional recommendations.
- None.
- More involvement of architects in the process is important for project success and more applicable results.
- The cost barrier is not addressed and should be taken into consideration earlier in the project rather than later to ensure it is viable for the market in the US and India. Project staff can expand their conversations with more industry partners as well as building envelop experts to gage the industry more holistically.

Project # 94151b: CBERD: R&D Monitoring and Benchmarking

Presenter: Reshma Singh, Lawrence Berkeley National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Most reviewers agreed on the relevance of this project, finding its expansion of the availability of energy benchmarking information to be well aligned with BTO's goals. However, while one reviewer thought that the project's modeling and projections looked promising, this reviewer questioned whether they were measurable and achievable.

Most reviewers agreed that the project was addressing critical market barriers for energy information systems (EIS), including inflexibility and high cost. One reviewer commented that the project was providing an easy, packaged, scalable, and cost-effective "EIS in a box," though this reviewer also highlighted that the tool lacked customization for different building types. Another reviewer positively noted that the project used pilot buildings to develop case studies for specific market segments, like hotels and hospitals.

Reviewers generally agreed that the project was making appropriate progress and achieving notable accomplishments, citing in particular the project's development of an effective communications strategy, a transaction cost framework and analysis, a commercial building benchmarking database, and demo-installations. Most reviewers found the project's outputs to be highly valuable to its target audience and market, noting that the EIS tools' user-friendly, tailored, and specific information had the potential to make it a strong asset management tool. Another reviewer, however, noted that the project was not able to share specific data, despite three years of work and substantial financial investment.

Although reviewers found that the project team collaborated and coordinated well with industry, academia, and other stakeholders throughout the project, some reviewers recommended further engagement. One reviewer recommended that the project should add facility management organizations to the deployment team, while another sought clarity on how the concepts found in the project team's research matched the demands of market and industry partners.

Reviewers were impressed by the project's ability to reduce energy through real-time monitoring, its identification of market need, and its stakeholder engagement. Expecting this strong track record to continue, one reviewer remarked that the project team had effectively planned its future in a logical manner by incorporating appropriate decision points and market goals. Reviewers did identify some project weaknesses, however, including the EIS' ease-of-use from the standpoint of end users. To addresses these weaknesses, reviewers recommended continuing with its outward engagement, as well as sharing its existing data and findings in a way that resonated with stakeholders.

Weighted Average: 3.55 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.50 Accomplishments: 3.60 Project Collaboration: 3.60 Future Work: 3.40

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Slide 3: Issue is the use and availability of energy benchmarking information. Main focus: Office, hospitals (HC), and hotels with intent of providing building energy data transparency
- Yes, modeling and projections looks promising and align with some of the BTO goals (clear, ambitious, relatable), but how are they working out (achievable, measurable, relatable)?
- None.
- No further comments.
- This project's focus is in line with BTOs goals and a major barrier as BTO's mission is to develop, demonstrate, and accelerate the adoption of technologies, techniques, tools and services that are affordable and enable high-performing, energy-efficient residential and commercial buildings for both new and existing buildings. Monitoring and benchmarking very critical to quantifying energy efficiency and those are the topics covered in this project.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- Slide 4: on the EIS side … packaged, scalable, and cost effective "EIS in a box." They are creating the standard to which the EIS vendors would design - consistent variable collection. Attempting to create a broad based program not necessarily customized for each building type … (Presenter stated "if you had 5 minutes with a facility manager what are the 5 prime issues") - have facility managers been engaged?
- Using pilot buildings. Wish you would share more of your achievements.
- Project has ease of use and flexibility in mind, which helps acceptance.
- The project's design addresses the market barrier that Energy Information Systems are commercially available and growing in technical capability but have high transaction costs. This project also focuses on Energy Benchmarking tools even though some are well established but they lack flexibility in required data inputs vs. desired accuracy. Thus the current simulation tools do not fully meet the needs of practitioners. Hence, this project aims to provide EIS guides for specific building types, Technical requirements for EIS packages for specific market segments, and EIS package demos in real building as case studies as well as benchmarking analysis of hotel and hospital data sets.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Slide 8: tech requirements for all 3 are complete … and 7 demo installations are complete (all in India) …. Although project is to address U.S. as well, they tried to find similar building stock for transference of comparability. Essentially only heating loads would be different (mostly electric whereas here in U.S. we have NG use). Slide 8: spec for a building performance database for India … modeled on our Energy Star

version. Slide 9: if only had 4 or 5 things to meter, what would they be (how big, is it actionable, is it reasonably meterable). Slide 12: lessons learned - how the data is presented … some tables some visual ... Does this resonate with facility managers? Slide 13: Rule based alerts in real time. Slide 14: Hoping that packaged EIS reduces transaction cost … not empirical, only industry expertise analyzed cost at the moment. Slide 15: This is meant for the "non-heroic" buildings to get engaged into energy data.

- Large, actionable, reasonably metered. Good dissemination and program strategy.
- None.
- No further comments.
- Both in EIS and benchmarking they have made great strides. For EIS the have provided Office, Hospital, and Hotels EIS-in-a-box technical requirements, performed demo installations and data analysis. They have also created a transaction cost framework and analysis. The communications strategy by dissemination and Outreach through Website, blogs and Conferences was a great way to visualize the impact of the work to stakeholders. As for Benchmarking they have specification of Commercial Building Benchmarking Database for India Based on DOE Building Performance Database

D. Project Integration and Collaborations

This project was rated:

1) **3.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Consider including facility management organizations (e.g. BOMA) as a part of the deployment team.
- Yes, I think you have identified some key concepts and known knowns, and key industry partners, but please share if you are findings these concepts are matching field and market demands.
- None.
- It is good that input is being received from stakeholders throughout the project.
- Project staff collaborates and coordinates with industry, academia, and other stakeholders to a great extent. This projects consults with many partners, and sub-contractors which is a good way to get various perspectives to get a wider grasp of the barriers and hence make proportional solutions. Their work has been presented in many papers and conferences which is great at visualizing the impacts of the project for stakeholders. This method should be integrated into other projects for CBRED and CERC to show just how impacting international collaborations can be.

E. Proposed Future Work

This project was rated **3.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The analysis of the "Value of Information" of packaged EIS vs. custom EIS might be more successful if facility manager's organizations are engaged.
- Without overt actual data (from slide 8), I think you are only going to get so far with another model and proposed features and benefits. Therefore, I don't think you are going to get much interest/ demand/ pull/ funding in the R&D world.

- None.
- No further comments.
- The project has effectively planned its future in a logical manner by incorporating appropriate decision points and market goals. The plan builds on past projects and continues to address BTOs goals and barriers in both US and India. This collaboration is will continue to benefit the US as it is an excellent means of bringing together top researchers, lab techs, and envelop enthusiasts who may be working in parallel fields together their otherwise would not have. Continued efforts for this cycle include only a few measure such as Testing and iterating tech specs for three sectors based on results from the demonstration sites and analysis of "Value of Information" of packaged EIS vs. custom EIS. Additionally ideas for CDERD 2.0 are also building on previous projects and will be valuable to the market.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers
- Has the potential to be a strong asset management tool.
- None.
- Having user-friendly, tailored, and specific information benefits decision makers.
- The EIS vendors, Owners, operators of commercial buildings and Benchmarking programs will be able to benefit through the continuation of this monitoring and benchmarking project as it will address two main challenges for the industry. The project's design addresses the market barrier that Energy Information Systems are commercially available and growing in technical capability but have high transaction costs. This project also focuses on Energy Benchmarking tools even though some are well established but they lack flexibility in required data inputs vs. desired accuracy.

***Average*: 1** reviewer
- It sounds like you have achieved some good milestones, but have not share much specific, actual data from the 3 years + $600k investment.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Yes to a certain extent - see additional recommendations.
- None.
- No further comments.
- As previously mentioned, this project's focus is in line with BTOs goals and a major barrier as BTO's mission is to develop, demonstrate, and accelerate the adoption of technologies, techniques, tools and services that are affordable and enable high-performing, energy-efficient residential and commercial buildings for both new and existing buildings. monitoring and benchmarking very critical to quantifying energy efficiency and those are the topics covered in this project

***No*: 1** reviewer
- Not as much as I'd like to see. I think your partners and potential funders would also be very interested in specific findings from this technology.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Strongly supports BTO goal as real time monitoring has the potential to reduce energy use.
- Identified market need. Identified economies of scale and impact with multiple countries. Identified gaps in current services and highlighted features and benefits of this technology.
- None.
- Stakeholder involvement/input and use of tailored dashboards and action alerts are the project's strengths.
- This simulation and modeling project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding improving building energy efficiency through the use of smart, integrated simulation tools for design and operation and developing new methods for reducing the energy consumption of existing and new buildings with controls, diagnostic. This project is solving a buildings barrier through new ideas, approaches and performers. Project staff collaborates and coordinates with industry, academia, and other stakeholders to a great extent. The project's design addresses the market barrier that Energy Information Systems are commercially available and growing in technical capability but have high transaction costs. This project also focuses on Energy Benchmarking tools even though some are well established but they lack flexibility in required data inputs vs. desired accuracy. Thus the current simulation tools do not fully meet the needs of practitioners. Hence, this project aims to provide EIS guides for specific building types, Technical requirements for EIS packages for specific market segments, and EIS package demos in real building as case studies. As well as benchmarking analysis of hotel and hospital data sets.

2) **Project Weaknesses**

- Operation of EIS from the standpoint of end-users. Mr. is shown that if something is too complicated to implement, it does not get deployed.
- See previous comments up to this question.
- None.
- No further comments.
- Integrate more case study approaches to build the value for market penetration. Project staff can expand their conversations with more industry partners as well as building envelop experts to gage the industry more holistically.

3) **Recommendations**

- Consider engaging facility management organizations (e.g. BOMA) in the discussion for their point of view regarding end use approaches.
- Don't be shy to share existing data/ findings (e.g. installation, contractor knowledge, IT, data connection, and data collection).
- None.
- No further comments.
- Stated in weaknesses. Integrate more case study approaches to build the value for market penetration.

Project # 94151be: CBERD: R&D Building Envelopes

Presenter: Christian Kohler, Lawrence Berkeley National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers were not in agreement on the relevance of the project. Some reviewers found that the project worked to address a building's envelope through new ideas, approaches, and performers on an international stage, with one reviewer noting the project's potential to shift emphasis to more energy-efficient envelopes, rather than systems designed to compensate for poorly performing envelopes. In contrast, one reviewer found that there was not a direct connection between the project and BTO's goals, thought this reviewer acknowledged the project's articulated 30% savings target.

Reviewers were divided on the performance and accomplishments of the project thus far. Positively, two reviewers noted the project's cool roof test chambers, its exposure testing, and its phase change experiments. More critically, however, one reviewer was unclear about whether the project was meeting its project plan and schedule, or whether the data collected matched the project's models or projected energy savings. Another review found that this project could not be differentiated from other, similar projects, and therefore questioned its value. All reviewers agreed that the deliverables of the project would be highly valued by the target audience and market, particularly the published papers, webinars, and outreach tools produced.

Most reviewers found that the project demonstrated industry involvement and had fostered relationships at an international scale, although some suggested further expansion of this engagement with industry. Reviewers suggested reaching out to the Cool Roof Rating Council, as well as building envelope experts, to gauge the industry more holistically. One reviewer noted that it would also be wise to leverage Indian resources for testing and software code development.

To date, reviewers felt that the project had demonstrated a number of strengths, notably its use of market partners to increase awareness between countries, fields, and markets. Another reviewer highlighted the project's emphasis on energy reduction during the manufacturing process. Overall, most reviewers found that the project had planned its future logically, with one describing that the project team had incorporated appropriate decision points and market goals as well as a communications strategy. However, one reviewer suggested developing a lab aging standard to allow other manufacturers to follow the strategy and processes developed, while another reviewer recommended doing more field-based tests in India, even if American-made tiles are used.

Weighted Average: 3.28 # of Reviewers: 6
Relevance: 3.33[1] Approach: 3.33 Accomplishments: 3.25 Project Collaboration: 3.25 Future Work: 3.33

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.33** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Slide 3: focus is on walls / roof / windows …. No foundations at the moment. Slide 5: project considers mixed mode or unconditioned buildings …. PCMs work better in certain climates and applications. Non co-planar approaches

- I don't see any slides that speak to and align with the BTO goals of: clearly articulated 30% savings, ambitious savings, achievable savings with this technology, measurable field data matches models, relatable to residential or commercial buildings as compared to current technologies. Audience attendee mentioned that work on cool roofs have already been done before.

- This project aims at enabling rapid solar shading evaluation for fins, overhangs, and awnings for designers along with evaluating the use of phase-change materials in mixed-mode buildings and creating infrastructure for cool-roofs and phase change materials in India that allows US manufacturers to sell their products in India. From that perspective, it is very relevant to the goals and objectives of the BTO of DOE.

- None.

- No further comments.

- This Buildings Envelope project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding solving a buildings barrier through new ideas, approaches and performers. Funding this activity, will not only bring in an international perspective at building envelopes but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building envelop efficiency challenges.

B. Approach

This project was rated:
1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.17** for the degree to which the approach addresses the market barriers identified.

- Slide 6: Cool roof calculator and test chambers to verify aging. Slide 6: PCM – measurement infrastructure … India uses labs because if a technology hasn't actually been installed and tested, they won't take the chance on implementation. Slide 6: windows … Solar shading algorithm is needed. Exposure tests take a long time – 3 years plus. India – permitting construction is not necessarily an issue (TWA anecdote). The project is important as India will have more people than china soon …. Indonesia appears to have the most - so the market is growing exponentially.

- Lessons Learned on Slide 15 appears to focus more on dodging the market and field barriers than addressing them. Please elaborate on the field challenges. Also mentioned by audience attendee that work has been done before on cool roofs. How is this different that than work?

- Approach for Cool roofs: Assess energy savings in Indian climates via simulation (Indian cool roof calculator), real-building experiment and test chamber in 4 climates. Natural exposure trials in 4 climates in India. Approach for PCM: Develop measurement infrastructure in India, perform field experiment. Approach for Windows: Assist with construction of measurement devices, collaborate on solar shading algorithm development (support DOE BTO MYPP Goal: "Lack of Ability to Simulate Windows or Building Envelope" and "modulate and control solar load to minimize summer cooling and offset winter heating").

- None.

- No further comments.

- The projects design addresses market barriers for building envelope materials, cool roofs, shading solutions. This is laid out in detail with good description of the 3 main barriers and how the project is assessing the market needs. The implementation of the project might be in India, which is also a great value for DOE as it economically enhances their impact of each dollar spend, but cool roof materials/ paints and shading techniques can be applied to the US as well (might need some minor tweaks to address different in temperature and humidity but industry can easily make those adjustments). Additionally, as the manufacturers of the test materials are from the US, if successful in India, this opens up markets US has previously not sold in.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.33** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.17** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Slide 8: fin or overhang is non co-planar, in line with glass - examples are like film or shade (also considered coplanar). The question they started with: Can a calk be done for a window with both? It matters when you want sun in the building and don't want it. Software …. COMFEN … engineer or designer is the end-user?? Perhaps add design-build companies?? Cool roof sampling issues
- Have the testing and experiments in place …. Software has been developed.

- Can you remind me of what the program performance and interim market goals are?
- Regarding slide 20, project plan and schedule, is Task 5.2 complete? What did you find? Did the data match your models? Did the data match your projected energy savings? Not many Indian manufacturers providing test tiles.

- Accomplishments include but are not limited to the following: Built and calibrated cool roof test chambers at three sites. Initiated natural exposure testing. Phase Change experiments underway for over one year. Non co-planar SHGC calculation algorithms implemented in COMFEN and Web Tool.

- None.

- No further comments.

- This project significantly contributes to the achievement of its program's interim market goal as its target audience is Code officials, architects, developers, and building owners that influence commercial and government building product selection in India as well as the US. Having this international collaboration is critical to saturating the market with building envelop technologies and techniques. Furthermore, as previously mentioned, as the manufacturers of the test materials are from the US, if successful in India, this opens up markets US has previously not sold in.

D. Project Integration and Collaborations

This project was rated:
1) **3.33** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.17** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- It appears that the technical side is well represented.

- Have you reached out to the Cool Roof Rating Council and/or members? Glad you've partnered with CEPT. Do more field-based tests in India, even with American made tiles.

- Project Integration: Monthly conference calls between US and Indian teams are being conducted. Partners, Subcontractors, and Collaborators are ORNL, IIIT-H University, CEPT University, Saint Gobain Research, CertainTeed, PlussPolymers.

- None.

- Good collaboration; also wise to leverage Indian resources for testing and software code development.

- Project staff collaborates and coordinates with industry or other relevant stakeholders to a good extent, but can expand their conversations with more industry partners as well as building envelop experts to gage the industry more holistically. Funding this activity, will not only bring in an international perspective at building envelopes but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building envelop efficiency challenges. In addition, the implementation of the project might be in India, which is also a great value for DOE as it economically enhances their impact of each dollar spend, but cool roof materials/ paints and shading techniques can be applied to the US as well. Having this international collaboration is critical to saturating the market with building envelop technologies and techniques. Furthermore, as previously mentioned, as the manufacturers of the test materials are from the US, if successful in India, this opens up markets US has previously not sold in.

E. Proposed Future Work

This project was rated **3.33** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Developing a lab aging standard would allow other manufacturers to follow suit.

- Please see previous comments.

- Next Steps and Future Plans include the following:
    - Develop lab aging practice for cool roofs in an Indian climate.
    - Roll-out web based calculator based on non co-planar shading algorithms
    - Provide webinar training for the solar shading module in COMFEN
    - Analyze results from phase change material field trial

- None.

- No further comments.

- The project has effectively planned its future in a logical manner by incorporating appropriate decision points and market goals as well as a communications strategy. Including this communication strategy such as the training webinars is a prominent way to showcase and live test the tools and technologies that come out of this project. The plan builds on past projects and continues to address BTOs goals and barriers in both US and India. This collaboration is will continue to benefit the US as it is an excellent means of bringing together top researchers, lab techs, and envelop enthusiasts who may be working in parallel fields together their otherwise would not have. Additionally, accessing India's facilities and equipment and even being able to make DOE's funds stretch even more by doing the tests in India, especially in these times, further encourages and stimulated this market and in turn benefits DOE.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- Project has the potential to shift the emphasis on more energy-efficient envelopes rather than systems designed to compensate for poorly performing envelopes.
- The areas served in this project are important and should be investigated.
- None.
- No further comments.
- Multiple papers were published on the research and results so far which is great. The webinars and outreach regarding the web tool is very important in gaining real world experience with the target audience/ markets

***Average*: 0** reviewer

- N/A

***Low*: 1** reviewer

- Please see previous comments.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- Yes, for the most part. See comments under approach regarding the cultural mindset of India and new technologies.
- I feel that the different areas served by this project are receiving sufficient emphasis by the investigators.
- None.
- No further comments.
- As previously mentioned, this project's focus is in line with BTOs goals and a major barrier breaker to building efficiency, especially retrofits, as they are the most expensive as well as time intensive projects, than other internal straightforward, less disruptive retrofits. This project highly aligns with BTOs goals and objectives. Specifically, regarding solving a buildings barrier through new ideas, approaches and performers. Funding this activity, will not only bring in an international perspective at building envelopes but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building envelop efficiency challenges

***No*: 1** reviewer

- What is valuable and unique about these technologies? What's different that hasn't already been studied? Without clear differentiation, how can the models be optimized and field data be appropriate? And related to the project plan and schedule, what does the field data show?

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project does consider manufacturing processes that reduce energy. Project demonstrates technical assistance activities that can be applied during the design stages.

- Have identified market partners and team resources. Have identified strong tasks in the project plan. Have a test apparatus deployed.

- Project tackles a number of diverse but important areas of interest to the BTO.

- None.

- Leveraging Indian resources for testing and software development is a strength.

- This project's focus is in line with BTOs goals and a major barrier breaker to building efficiency, especially retrofits, as they are the most expensive as well as time intensive projects, than other internal straightforward, less disruptive retrofits such as HVAC, lighting or BAS. Focusing on shading, phase changing materials, and cool roofs will positively impact the market. Furthermore, the international collaboration is a great way to increases awareness between countries, fields, and markets. Including a communication strategy such as the training webinars is a prominent way to showcase and live test the tools and technologies that come out of this project. This collaboration gives DOE insights into new and different facilities, sites, populations, and energy markets.

2) **Project Weaknesses**

- None at this time.

- See previous comments. Also, have not heard how the cool roof technology is different than the existing technology. Also have you been tracking the moisture content of the test apparatus or seen elevated levels due to lower drying effects, due to increased albedo? How are the PCMs different from existing thermal mass strategies in different climates?

- There are no weaknesses that I am aware of. The PowerPoint presentation could have been more focused in summarizing the accomplishments of the project a bit better.

- None.

- No further comments.

- Project staff can expand their conversations with more industry partners as well as building envelop experts to gage the industry more holistically. Funding this activity, will not only bring in an international perspective at building envelopes but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building envelop efficiency challenges. Additionally, it is understandable that real world degradation experiments like the cool roof needs time to develop but if there are ways to address the time issue that would only strengthen the project.

3) **Recommendations**

- None at this time.

- None that have not been captured already.

- I do not have additional recommendations.

- None.

- No further comments.

- Expand conversation with additional industry partners to gain additional insight and expertise.

Project # 94151sc: CBERD: Integrated Sensors and Controls

Presenter: Christian Kohler, Lawrenece Berkeley National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO, finding that its key research areas supported BTO's goals and noting that real-time monitoring in conjunction with an analysis of occupant behavior could lead to the implementation of more efficient design strategies in the future. Most reviewers agreed that the project was addressing market barriers, successfully demonstrating an integrated workstation control system—in both U.S. and Indian test-beds—that addressed human factors and would enable easier and more effective energy demand control and integration with smart grids. One reviewer commented that the project successfully tackled the challenge of field testing VOLTTRON with an unreliable grid and generator use. One reviewer was pleased to find that the project's business plans included furniture vendors, addressing a potential financial barrier if tenants cannot include furniture, fixtures, and equipment on lease terms.

Reviewers found the project to be making good progress, having developed a smart plug-strip with load detection and load switching, a smart Hub with integrated sensors, and other technologies. One reviewer expressed that the project had the potential to be a win-win for both building operations managers and occupants, though another felt that the project's deliverables focused too narrowly on commercial building owners and system innovators.

Reviewers were generally pleased with the project's stakeholder engagement, although most reviewers found that the project could have demonstrated better collaboration with partners and industry. One reviewer recommended that this project's methods be integrated into other CBERD and CERC projects in order to showcase the benefits of international collaborations.

Overall, reviewers highlighted the qualifications of the project team, the project's consideration of both human behavior and preferences as well as future energy patterns and technologies, and the development of the smart plug-strip as strengths. One reviewer cautioned, however, that control overrides needed to be available to the occupant if productivity loss is an issue. Another reviewer cautioned that the project needed to consider cultural differences—and therefore differences in occupant behavior—between the U.S. and India. Going forward, one reviewer recommended that the project team expand its conversations with additional stakeholders in order to demonstrate the usability of the project's sensor and controls technologies, and also that the project team develop long-term research plans.

Weighted Average: 3.54 # of Reviewers: 5
Relevance: 3.80[1] Approach: 3.60 Accomplishments: 3.60 Project Collaboration: 3.30 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- 6 months left … $189K/yr. Slide 3: constrained energy resources. Slide 4: Transactive energy approach. History shows that consumers use electricity in response to a price. Tool consideration is VOLTTRON (PNNL).

- The project aims at developing an integrated workstation control system (lighting, plug loads and HVAC) and demonstrating it in Indian and US test-beds based on open source transaction based controls. To that extent it is relevant to the BTO's program goals.

- None.

- Relevant.

- This project's focus is in line with BTOs goals and a major barrier as BTO's mission is to develop, demonstrate, and accelerate the adoption of technologies, techniques, tools and services that are affordable and enable high-performing, energy-efficient residential and commercial buildings for both new and existing buildings. Integrated sensors and controls, the focus of this project aligns with BTOs goals.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.60** for the degree to which the approach addresses the market barriers identified.

- Slide 5: Using the control platforms for granular control (task lighting, plug loads, e.g. MELS … Typically considered misc. electrical loads). Field testing VOLTRON is a challenge due to unreliable grids & generator use in India. Identifies that simulation based transactive controls versus real devices may be a barrier (see slide 5). Mary Ann's White Paper Shift (load), shape(?) shed (?) and shimmy (ancillary services). Slide 7: Lighting and HVAC typically consistent level (minimum) over whole space. Shift to workstation (individual control versus collective control).

- Approach include tackling the following areas:
    - Addressing BTO's MYPP Sensors and Controls Goals which includes enabling integration of buildings with the rest of the electrical grid and providing continuous real-time information on building components and systems.
    - Utilizing open-architecture control platform for buildings with transaction-based controls.
    - Field-testing VOLTTRON with a far less reliable grid (India) and with generators.
    - Addressing lighting, HVAC and plug loads.

- None.

- This level of fine-tuning and individualized energy management both addresses the human factor and also enables easier and better energy demand control and integration with smart grids.

- The project's design addresses the market barriers on enabling integration of buildings with the rest of the electrical grid, providing continuous, real-time information on building components and systems, Address lighting, HVAC and plug loads through sensors and controls for optimizing building efficiency. This project hit major market barriers and addresses with demonstrating an integrated workstation control system (lighting, plug loads and HVAC) in a US and Indian test-bed and releasing source code enabling transaction based control.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Slide 8: iSPACE concept - potentially good PR. Slide 9: Smart Plug Strip - needs chip to identify load type and is Wi-Fi-based. Smart Hub prototype - Wi-Fi-based also. Reality check - all the components that would need to be purchased for execution. Slide 11: business model canvas - different approach instead of a standard business plan based on customer segments. Glad it includes furniture vendors. They will have a barrier in the financials - often times tenant build outs are included in the lease terms and do not include amortizable FFE (furniture, fixtures, and equipment). Slide 13: potential energy reduction to 25W/occupant. Slide 14: software implementation and process considering distributed energy resources (PV, batteries, etc.). Market impact – comfort issue call reduction. Slide 15: lessons learned – good analysis. What about existing buildings and the FFE issue?

- Accomplishments include developing the following:
  - Smart plug-strip with load detection and load switching.
  - Smart Hub with integrated sensors, task light and fan.
  - Transactional software implemented for various components.
  - Field test planned for April 2017 in FLEXLAB at LBNL.

- None.

- No further comments.

- This project has made significant strides to being market ready through producing a smart plug-strip with load detection and load switching, a smart Hub with integrated sensors, task light and fan, transactional software implemented for various components and will do a field test planned for April 2017 in FLEXLAB at LBNL. Throughout the testing staff learned Building occupants don't 'want' Demand Response capabilities. They want a comfortable workspace that they can control. Building owners want both productive/happy employees and grid connected capabilities like Demand Response enabled buildings. Thus, making the control and sensors sync with occupants is the best for both parties.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.20** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- I would like to see actual furniture manufacturers as a part of the team as their A&D departments have been working on this concept for a long time to create market differentiation for their product.

- Project Integration includes the following activities:
  - Conducting weekly calls with Indian and US research partners
  - A visiting student and a visiting professor from India were received in Summer 2016 and Winter 2017
  - Testing of algorithms and technology in India and US

  Partners, Subcontractors, and Collaborators:
  - Lighting Research Center at Rensselaer Polytechnic Institute
  - International Institute of Information Technology, Hyderabad, India
  - Indian Institute of Management Ahmedabad

    - Philips Research

- None.

- Good collaborations.

- Project staff collaborates and coordinates with industry, academia, and other stakeholders to a good extent.
- This projects consults with many partners, and sub-contractors which is a good way to get various perspectives to get a wider grasp of the barriers and hence make proportional solutions. Their work has been presented in many papers and conferences which is great at visualizing the impacts of the project for stakeholders. This method should be integrated into other projects for CBERD and CERC to show just how impacting international collaborations can be.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Would expect furniture manufacturers as a part of the business segments considered for commercialization.

- Next Steps and Future Plans include the following:
    - In April 2017 the team will start an occupied testbed study at LBNL's FLEXLAB facility. This experiment will incorporate all the technologies mentioned in this presentation. The team will measure the energy consumption and load reduction, while evaluating the occupant's response and satisfaction.
    - Based on lessons learned from the iCorps project about the customer segments and value propositions the team plans to target certain business segments for commercialization.

- None.

- No further comments.

- The project has planned its near term future in a logical manner by incorporating appropriate decision points and market goals building on past projects and continues to address BTOs goals and barriers in both US and India. However, only a bit of information was discussed regarding longer term future research possible in this area if CBERD 2.0 continues.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- The premise that "one size fits all" ignores the needs of the individual. The concept of this project has the potential to be a win-win for both the building operations manager and the occupants.

- The deliverables in this project include developing an integrated workstation control system and demonstrating the system in Indian and US test-beds based on open source transaction based controls. This is an important project and is high on the priorities of the BTO's goals.

- None.

- No further comments.

***Average*: 1** reviewer

- The deliverables are focused on the target audience of Commercial building owners and system innovators. This project has made significant strides to being market ready through producing a smart plug-strip with

load detection and load switching, a smart Hub with integrated sensors, task light and fan, transactional software implemented for various components, which are all directly usable by the target audience.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- Yes, as real-time monitoring in conjunction with an analysis behavioral use can lead to more efficient design strategies implemented in the future.
- I believe that the key research areas and deployment activities relevant to the objectives of the project are receiving sufficient emphasis
- None.
- No further comments.
- This simulation and modeling project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding improving building energy efficiency through the use of smart, integrated sensors and controls for design and operation and developing new methods for reducing the energy consumption of existing and new buildings with controls, diagnostic. This project is solving a buildings barrier through new ideas, approaches and performers. Funding this activity, will not only bring in an international perspective in smart simulations tools and controls but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building efficiency challenges through simulation and modeling

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Encouraging. Workstation/personal control has been around forever but has been 'dumb'. Building integration has the potential to prove value.
- The project seems to be progressing well with a good focus on realizing its objectives. The qualifications of the team are one of the points of strength of the project.
- None.
- Very innovative project that takes into consideration both human behavior/preference aspects, as well as future energy patterns and technologies (i.e., smarter responsive buildings better integrated with the grid).
- This simulation and modeling project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding improving building energy efficiency through the use of sensors and controls for design and operation and developing new methods for reducing the energy consumption of existing and new buildings. This project has made significant strides to being market ready through producing a smart plug-strip with load detection and load switching, a smart Hub with integrated sensors, task light and fan, transactional software implemented for various components and will do a field test planned for April 2017 in FLEXLAB at LBNL. Project staff collaborates and coordinates with industry, academia, and other stakeholders to a good extent.

2) **Project Weaknesses**

- Overrides must be available. The moment any of this technology affects productivity "the game" is lost.
- No weaknesses are obvious.
- None.
- Could be useful to consider cultural and developmental differences between the U.S. and India, as it relates to building occupant behavior and expected smart grid integrated building development.
- The project has planned it's near term future in a logical manner to build on past projects and continues to address BTOs goals and barriers in both US and India. However, only a bit of information was discussed regarding longer term future research possible in this area if CBERD 2.0 continues.
-

3) **Recommendations**

- See comments on integration and collaborations as well as proposed future work.
- I do not have further comments.
- None.
- No further comments.
- Expand conversation with additional stakeholders to demonstrate usability of sensors and controls as well as expand on what barriers will be focused on if CBERD 2.0 is funded. Funding this activity, will not only bring in an international perspective to barriers on smart building sensors and controls but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively address building sensor and control challenges.

Project # 94152a: CBERD: R&D Advanced HVAC

Presenter: Mahabir Bhandari, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

For the most part, reviewers agreed on this project's relevance to BTO's goals. Most found that it supported BTO's objectives by solving an HVAC efficiency challenge, though some questioned whether the project's models were achievable, measureable and relatable. In general, reviewers were pleased with how the project addressed market barriers, as well as with how it was addressing market needs, particularly concerning radiant cooling and evaporators with low global warming potential. Though one reviewer found the project's study design creative, a reviewer would have liked to see more data presented.

Reviewers generally praised the projects performance and accomplishments, particularly noting the radiant cooling system, the project's experimental facility, and its engagement with its target audience: building owners and operators looking to reduce operating costs. Additional strengths highlighted by reviewers were the project's identification of market need and potential for non-humid climates, as well as its identified impact within countries with economies of scale. More critically, one reviewer wanted to know what the key learnings were from the project's real-time validated energy data, questioning whether the research should continue to be funded without testimonials or details from current building data to justify its continuance.

In terms of collaboration, reviewers found the project to feature a good balance of researchers and industry partners. One reviewer highlighted the project's on-site meetings, which provided partners with opportunities for face-to-face interactions with the project team.

Reviewers positively regarded the project's clear plans for the future, including its plans to continue its collaboration with partners and build on past success. Reviewers offered numerous recommendations, however, including sharing existing data and findings to attract interest and funding; testing the radiant cooling system for cost, not just for comfort and ease of use; and directly engaging industry stakeholders through communications, not just through journal publications and conference presentations.

Weighted Average: 3.40 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.40 Accomplishments: 3.40 Project Collaboration: 3.40 Future Work: 3.40

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Yes, modeling and projections looks promising and align with some of the BTO goals (clear, ambitious, relatable), but how are they working out (achievable, measurable, relatable)?

- Project aims at the following:
    - Developing a radiant cooling design guideline
    - Identifying and developing non-compressor based dedicated outdoor air system (DOAS) configurations suitable for different climatic conditions
    - Designing, testing and deploying the Micro-Channel Heat Exchanger (MCHX) evaporator integrated small split unit with R32 and low GWP refrigerant propane (R290)

  To that extent, the project is relevant to the BTO's program goals.

- None.

- Relevant.

- This HVAC project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding solving a buildings barrier through new ideas, approaches and performers. Funding this activity, will not only bring in an international perspective at building envelopes but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building envelop efficiency challenges.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- Creative ideas. Solid study design. Good funding and cost match. Would like to see more data.

- Through collaborative knowledge and partnership the team aims at investigating the energy savings potential opportunities in HVAC systems and at deploying novel strategies and technologies in developing energy efficient HVAC systems. The team aims at utilizing capacity building and testing facilities in the area of HVAC systems. The team aims at utilizing a deployment path through the engagement of HVAC industry partners. Key Issues include the following:
    - Non-availability of guidelines with respect to the operation and energy savings benefits of radiant cooling systems in commercial buildings.
    - Lack of HVAC testing facilities in India and HVAC modelling capabilities.
    - Existing non-compressor based DOAS are complex, bulky, suffer from high pressure drops, and require high parasitic power.
    - MCHXs as evaporators for small unitary systems have not yet penetrated the market due to issues related to refrigerant distribution, condensate drainage and form factor.

- None.

- No further comments.

- The projects design addresses market barriers for HVAC by addressing radiant cooling, non-compressor based DOAS, and evaporator with low GWP. This is laid out in detail with good description of the 3 main focuses and how the project is assessing the market needs. The implementation of the project might be in India, which is also a great value for DOE as it economically enhances their impact of each dollar spend,

and the efficient DOAs can potentially enter the US market. Additionally, as the manufacturers of the test materials are from the US, if successful in India, this opens up markets US has previously not sold in. This projects also promotes low GWP refrigerants, stimulating that industry market when these solutions go into the industry for mass production.

C. Accomplishments/Progress/Impact

This project was rated:

3) **3.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
4) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- In person presentation provided more impact information that slides conveyed. Would like to hear more data from US testing.

- Progress and accomplishments include the following:
  - Designing a personalized radiant cooling system.
  - Integrating a radiant cooling system with a wind tower.
  - Building a radiant cooling system experimental facility.
  - Developing a Heat Pump Design Model (HPDM) for a MCHX.

- None.

- No further comments.

- This project significantly contributes to the achievement of its program's interim market goal as its target audience is Building owners and operators which want to reduce operating cost, the HVAC Industry: system and component manufacturers who want new and improved products for commercialization with opening up new market segment and the general HVAC design community. The US commercial market has a target 20% reduction in energy consumption by 2020; 30% by 2030 and the Indian commercial market: target 60% reduction in energy consumption; 10% through retrofits. These HVAC projects directly contributes to those goals.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Yes, I think you have identified some key concepts and progress and accomplishments, and key industry partners. Are the field measurements matching the modeling outputs?

- Project Integration includes:
  - Short-and long-term visits by Indian research partners to ORNL and other labs.
  - Monthly phone calls or e-mails and GoToMeeting communications.
  - US Industry partner, Mahle, integrated and supplied the MCHX as per HPL_IITB design.
  - Indian industry partner, Oorja, is extending support to MNITJ for radiant cooling applications.

  Partners, Subcontractors, and Collaborators include:
  - Research partners and main contributors: Indian Institute of Technology Bombay (IITB) and Malviya National Institute of Technology (MNITJ), India.
  - Research partners in support role: ORNL, USA.

  Industry partners: Mahle, architectural application, USA and Oorja, India

- None.

- Good balance of research and industry partners.

- Project staff collaborates and coordinates with industry or other relevant stakeholders to a great extent. Providing on site meetings and research partners having face to face interaction with the project experiments. This projects consults with many partners, and sub-contractors which is a good way to get various perspectives to get a wider grasp of the barriers and hence make proportional solutions. Their work has been presented in many papers and conferences which is great at visualizing the impacts of the project for stakeholders. This method should be integrated into other projects for CBRED and CERC to show just how impacting international collaborations can be.

E. Proposed Future Work

This project was rated **3.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Without overt actual data, I think you are only going to get so far with another model and proposed features and benefits. Therefore, I don't think you are going to get much interest/ demand/ pull/ funding in the R&D world. Would like to see more specific data as this project is wrapping up.

- Future plans include:
    - Developing a radiant cooling system design guideline.
    - Demonstrating the performance of liquid desiccant-based DOAS compared to Solid Desiccant Wheels and membrane based DOAS –Testing at MNIT.
    - Testing a lab prototype of MCHX_E 1.5 TR unitary HVAC system with R290.
    - Calibrating HPDM model and design recommendations.
    - Engaging industry partners to accelerate the deployment both in India and US market.

- None.

- No further comments.

- The project has effectively planned its future in a logical manner by incorporating appropriate decision points and market goals as well as an engaging industry partners aspect to accelerate deployment in both the US and India. The overall project outcomes are clearly laid out and steps to get there were listed as well as verbally described. The plan builds on past projects and continues to address BTOs goals and barriers in both US and India. This collaboration is will continue to benefit the US as it is an excellent means of bringing together top researchers, lab techs, and envelop enthusiasts who may be working in parallel fields together their otherwise would not have. Additionally, accessing India's facilities and equipment and even being able to make DOE's funds stretch even more by doing the tests in India, especially in these times, further encourages and stimulated this market and in turn benefits DOE.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Project objectives are relevant to the BTO's goals, the project scope is well articulated, the team is qualified, and the collaboration among its members is well coordinated.

- No further comments.

- This project significantly contributes to the achievement of its program's interim market goal as its target audience is Building owners and operators which want to reduce operating cost, the HVAC Industry: system and component manufacturers who want new and improved products for commercialization with

opening up new market segment and the general HVAC design community. Multiple papers were published on the research and results so far which is great. Engaging industry is very important in gaining real world experience with the target audience/ markets.

***Average*: 2** reviewers

- After 4 years + $500k what have you learned from the real-time, validated energy data? Slides 9-14 outline some progress and accomplishments...are you proving or disproving your thoughts? Please share some testimonials or details from current building data. Why should we continue to fun this research? What will be accomplished?

- None.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- I believe that key research areas relevant to the project's and program's objectives are receiving sufficient emphasis.

- None.

- No further comments.

- As previously mentioned, This HVAC project within CBERD highly aligns with BTOs goals and objectives. Specifically, regarding solving a buildings barrier through new ideas, approaches and performers. Funding this activity, will not only bring in an international perspective at building envelopes but also foster DOE's relationship with India and allow DOE to leverage the many buildings experts across the world to collaboratively face building envelop efficiency challenges.

***No*:** 1 reviewer

- You point it out in Slide 4, but I didn't hear anything about reaching these energy targets either through modeling or via validated energy savings.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Identified market need and potential for non-humid climates. Identified economies of scale and impact with multiple countries. Identified gaps in current services and highlighted features and benefits of this technology.

- Project strength is its sharp focus on achieving the goals and on the qualifications of the team members and their collaboration and coordination of their activities.

- None.

- No further comments.

- This project's focus is in line with BTOs goals. Will enhance the market in both US and India and engaging industry will accelerate that process. International collaboration is a great way to increases awareness between countries, fields, and markets. Their work has been presented in many papers and conferences which is great at visualizing the impacts of the project for stakeholders. This collaboration gives DOE

insights into new and different facilities, sites, populations, and energy markets. HVAC side by side comparison is also a unique aspect of this project.

2) **Project Weaknesses**

- Please see all comments up until this question.
- I am aware of no weaknesses.
- None.
- No further comments.
- One thing that was mentioned was that the radiant cooling system for personal spaces such as office cubes was tested mainly for comfort and ease of usability but not cost. Cost should be taken into account now so that if plausible to become main stream in official buildings, other commercial buildings then the comparison can be made. So far so good.

3) **Recommendations**

- Don't be shy to share existing data/ findings (e.g. installation, contractor knowledge, IT, data connection, and data collection).
- I have no additional comments.
- None.
- Would be good if the communications directly involved industry stakeholders more, rather than just being focused on journal publications and conference presentations.
- Take into account cost of personal radiant cooling systems.

Project # 94153a: CERC: Integrated Building Design, Construction, & Industrialized Buildings

Presenter: Diana Hun, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers found this project to be highly relevant to BTO, in that achieving better performance while lowering costs was critical to BTO's mission and objectives.

Reviewers generally agreed that the project addressed market barriers for new and existing buildings in the U.S. and China. One reviewer applauded the project's consideration of thermal transference and connection issues, but noted that market adoption and deployment was unclear at this point in the project. Another review commented that the project had potential to change the mindset of the current construction industry by providing better performance at lower costs, which would improve market acceptance. Reviewers were generally pleased with the project's level of partner collaboration, though a number of them recommended further engagement with U.S. and Chinese industry stakeholders and construction companies.

Despite the early stage of the project, reviewers commented that the project was already a success, with a foreseeable impact on the industry and market. Reviewers highlighted a number of the project's accomplishments, particularly its development of precast walls and air sealing technologies, though one reviewer flagged that the Dundee case study did not fully address the precast prototype. Reviewers also noted that the project's architectural precast insulated walls, building envelope retrofits, and new air sealing technologies demonstrated impressive savings potential, break-through processes, and far-reaching application.

Reviewers described that the project had a clear, outlined plan for its future work, though one reviewer suggested improving the project's methodology, application procedures, and results for the envelope retrofit task, calling retrofits a demanding market with huge potential for real impact. Another reviewer recommended adding more case studies to prove the technology's efficacy.

Weighted Average: 3.56 # of Reviewers: 5
Relevance: 4.00[1] Approach: 3.60 Accomplishments: 3.60 Project Collaboration: 3.40 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Slide 3: envelope focus with appropriate air sealing technologies. Slide 5: structural capacity focus? (as many precast panels used today are load bearing) - No, project's current focus is on cladding panel. Slide 8: What is the binding between the concrete in the insulation? Later noted as considering composite rebar.

- It's impressive in savings potential, real break-through in process, and application magnitude.

- The project aims at developing the following:
  - Next-gen architectural precast insulated walls.
  - Cost-effectiveness evaluation of commercial building envelope retrofits.
  - New air sealing technologies.

  To that extent it is relevant to the BTO's program goals.

- None.

- Achieving better performance while lowering costs is critical to BTO objectives.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.60** for the degree to which the approach addresses the market barriers identified.

- Also considered the thermal transference and connection issues – good. Connector plates are made of glass/PET (took pictures) not sure as to which connection it is for. Market adoption and deployment is unclear at this time as the project is relatively early in its stages of development.

- It presents a huge potential impact to the building construction market and business in China, also to a significant extent to US.

- The market includes new and existing commercial buildings in the US and China. The audience includes architects, designers, and general contractors. The 2030 total energy market for commercial buildings includes the following:
  - Precast insulated walls for new construction (US = 35 TBtu and China = 320 TBtu).
  - Retrofit of existing envelopes (US = 120 TBtu and China = 140 TBtu).
  - Air sealing technologies (US = 43TBtu and China = 49 TBtu).

- None.

- Good approach in improving performance while decreasing costs; will greatly help market development.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Slide 12: Dundee case study - Air sealing LIQUIDARMOR & 3M products (the case study focused on just the air seal prototype and did not include precast).

- Based on current results and achievement in the development of precast walls and air sealing technologies, it's already a success with foreseeable impact in the industry and market place.

- The project started in April 2016 with a planned end date of March 2021 but progress has been made in a number of critical areas covered by the project.

- None

- No further comments.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Good list of partners to start.

- It's time to reach out to more US and China industry stakeholders since it is a CERC project and on tax payers' funds.

- Project integration and collaboration in the area of precast walls include five partners. Also, ORNL/PCI are finalizing a Collaborative R&D Agreement (CRADA). In the area of envelope retrofit, there are 12 partners. In the area of air sealing there are two partners.

- None.

- A very good and diverse set of collaborators from different sectors in the U.S., but only one construction company in China...would be good to get some more industry involvement in China.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Slide 16: Next up - considering Portland cement replacement options. Will there be potential strength issues? Additional case studies to prove effectiveness. Would anticipate that proposed connection substitutions would be tested for failure points and reinforced accordingly.

- The researchers' plan is solid moving forward with foreseeable success and impact.

- In the area of precast walls, here are the planned future activities:
    - For high performance concrete mix, it is planned to optimize mix based on mechanical properties and cost, replace max amount of Portland cement without compromising mechanical properties and cost, and scale up mix at precast plant and further optimize.
    - For non-corroding composite accessories, it is planned to produce prototypes, evaluate performance, and optimize designs.
    - For 3D printed molds, it is planned to print prototypes from actual projects and perform cost analysis.
    - For panel joints, it is planned to develop/test new sealants/details at panel joints.
    - For insulation boards, it is planned to continue efforts using low-GWP blowing agents.

    - It is also planned to complete ORNL/PCI complete CRADA, finalize collaboration plan with CSCEC.

  In the area of envelope retrofit and air sealing technologies here are the planned future activities:

    - For envelope retrofit, it is planned to expand network of potential sources for case studies, target consultants that specialize in renovations, and continue data collection.
    - For air sealing technologies, it is planned to continue evaluations of LIQUIDARMOR to launch as an air barrier system.
    - It is also planned to finalize the collaboration plan with CSCEC.

- None.

- No further comments.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers

- Potential lies within the ability to change the mindset of current construction approaches based on publication of the results.

- Outstanding progress and potential.

- Project goals are important to the BTO and it appears that there is a lot of planned activities which the project team has well-articulated.

- None

- Better performance at lower costs will improve market acceptance.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The project is really only in its first year but appears to present activities that are in alignment with the program objectives.

- Well on track.

- I believe that key research areas relevant to the project's and program's objectives are receiving sufficient emphasis.

- None.

- No further comments.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Precast is one of the most heavily used building materials due to its low cost and shorter manufacturing time than most envelope products. Focusing on ways to improve the performance will certainly help promote a reduction in energy usage if coupled with the right systems.
- Very favorite results in developing new precast walls, and very exciting in its potential impacts.
- Project seems on target with a lot of planned activities. Team has many partners in three key areas.
- None.
- Innovative methods to reduce costs while improving performance and logistics.

2) **Project Weaknesses**

- None at this time - project is in its early stages.
- Envelope retrofit task needs more work on better defined methodology and application procedures and results in detail, since it is a very demanding market presenting huge potential of real impact.
- I am aware of no weaknesses.
- None.
- Very heavy involvement of U.S. partners but only one partner in China.

3) **Recommendations**

- None at this time - project is in its early stages.
- A very capable team with very impressive progress and accomplishments. Project is on track to potential huge success.
- I have no additional comments.
- None.
- No further comments.

Commercial Buildings Integration Data Tools

Project # 222102: Putting Data to Work

Presenter: Julie Hughes, Institute for Market Transformation
DOE Manager: Harry Bergmann

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's objectives, noting that the project supported the advancement of energy efficiency in commercial U.S. buildings by helping to deploy the BTO-supported SEED platform. One reviewer remarked that the project clearly served BTO's goals.

Reviewers were mixed on the project's approach. On one side, a reviewer commented that targeted efforts towards cities and energy efficiency programs were critical, and that developing an all-inclusive energy data toolbox was sensible. Another reviewer commented that planned deliverables had a lot of potential value to the wave of local governments adopting energy benchmarking policies, as well as to other stakeholders interested in better leveraging energy data. On the other side, however, one reviewer did not believe that the project team had identified the correct barriers to energy efficiency adoption, remarking that the project team appeared to have concluded that lack of information was the key barrier limiting participation in energy efficiency programs in cities. This reviewer believed that a lack of information was *one* key barrier, but also that some cities already had mature energy efficiency programs and building owners were still not taking advantage of these resources, listing several possible explanations (e.g. financial, technical, logistics, etc.). This reviewer questioned if and how the project team was going to change this behavior by addressing these other barriers.

Looking at progress-to-date and impacts, one reviewer noted that the project already had substantive accomplishments, while another described the work performed as providing a useful—though limited—data set for understanding how to best support use of the SEED tool and gather feedback on its usefulness. One reviewer noted the accomplishments of partner cities D.C. and NYC, but felt that the presentation failed to make clear how much success should be attributed to the project team versus officials in those two cities. Another reviewer remarked that the presentation failed to highlight any *specific* measures or strategies included in the project's toolkit.

Reviewers positively rated this project's collaboration with partners, noting that there was clear integration with key participants and stakeholders, and that the project team appeared to have made collaboration with advanced users of the tool a fundamental aspect of the project.

Looking forward, one reviewer felt that the presentation put forward a logical, understandable approach to next steps, while another reviewer would have appreciated more details on proposed future work. A third reviewer remarked that the logic was not clear on how tool deployment would translate into energy savings, but encouraged the project team to go "beyond" communicating best practices. Another reviewer echoed this encouragement, recommending that the project team consider how to address other barriers to energy efficiency program adoption, such as financing, project management, and stakeholder training.

Weighted Average: 2.93 # of Reviewers: 3
Relevance: 3.33[1] Approach: 3.00 Accomplishments: 2.67 Project Collaboration: 3.50 Future Work: 2.67

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.33** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project plays an important role in BTO's objectives as it supports the advancement of energy efficiency in commercial buildings across the U.S.

- This project is helping to deploy the BTO supported SEED tool to help advance energy efficiency.

- Clear that it serves BTO goals.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Project4 has not successfully identified the key barriers to program adoption.
- As presented, it appears IMT has concluded the issue impacting low participation of energy efficiency programs in cities is lack of information.
- While this is one of the barriers, it is arguable that this is the only KEY issue. In most of the states and cities (as presented on page 11 of the presentation) there are already energy efficiency policies and programs in place. Additionally cities like Los Angeles, Seattle, Boston have very mature energy efficiency programs and a market/audience that is receptive to the message.
- While the IMT work is still of value to cities with limited resources, it is not viewed as primary catalyst to bring down key barriers to program adoption/expansion as reported. There are lots of data points on the topic from various sources in the market. Building owners don't take advantage of incentives or other programs for many reasons (financial, technical, logistics, etc.). How and why is this project going to change that behavior was not made clear from the presentation.

- The project is helping NYC and Washington DC to pilot use of the tool and provide feedback to help identify opportunities to evolve the tool to overcome barriers to its use.

- Targeted efforts towards cities and EE programs is critical. Developing it all into a toolbox approach is sensible.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- It's not clear how much "credit" should be attributed to IMT versus the officials in D.C. and NYC. The presentation did not clearly describe WHEN and HOW the IMT was a catalyst to change planned efforts of the cities.
- Presentation made note of accomplishments of the partners (D.C./NYC) and indicated early conversations with 13 leading cities are currently taking place to inform the development of the toolkit.
- The presentation failed to highlight any specific measure or strategies that will be part of this toolkit.

- The experience of NYC and Washington DC in depth and interviews with some additional cities provides a limited but useful data set for understanding how to best support use of the SEED tool and to get input on potential uses and opportunities for enhancement. The project has not yet produced its most significant learnings documents but appears to be on track.

- Substantive accomplishments made to date.

D. Project Integration and Collaborations

This project was rated:

1) **3.67** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project team is engaging feedback from 13 leading cities to ensure this tool will be usable. They have spoken with utilities and energy service providers to gain valuable input on the toolkit.

- The project team appears to have made collaboration with advanced users of this tool a fundamental aspect of the project.

- Clear integration and collaboration with key participants and stakeholders.

E. Proposed Future Work

This project was rated **2.67** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- In the presentation, the mode logic from tool deployment to energy savings was not made clear. HOW the toolkit will "expand the market for energy efficiency in multifamily and commercial buildings" has not been clearly defined.
- Toolkit must address other elements beyond "communicating" best practices. Many white papers are available that discuss these themes, being backed by BTO, the toolkit should be of additive nature to the market.

- Would have appreciated more detail on future work.

- Logical, understandable approach.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The deliverables have a lot of potential value to the wave of local governments adopting energy benchmarking policies and potentially to other local governments, utilities, and energy program administrators interested in better leveraging energy data to support efficiency improvements.

- Support for benchmarking and retrofits is critical to move both contractors and building owners towards adopting energy efficiency approaches.

***Average*: 1** reviewer

- Project deliverables will be of best use to City government officials and program implementers, who can utilize the learnings from DC/NYC.
- Cities which already have an energy disclosure program with data requirements similar to the NY or DC will benefit the most. Others can leverage some of the marketing and statistics as proof of concept.
- The value to other stakeholders cannot be readily determined given no specific examples of the toolkit was shared.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- As presented, the IMT project focus is to develop a toolkit that will enable other cities to adopt programs and policies that have been successful in DC/NYC.
- The focus and resources deployed appear to be reasonable.
- More could be done with more resources behind this project, but they are receiving sufficient emphasis.
- They are targeting the right areas.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Key cities adopting DOE tools will facilitate the outreach of BTO's goals to cities where energy efficiency is not yet mainstream.
- This project is designed to understand how to best leverage local data and BTO tools to help advance energy efficiency. I appreciate the attention to the practical use of the tools and their context in the process of supporting change.
- Effectively supports the types of benchmarking needs critical to cities.

2) **Project Weaknesses**

- Little detail offered on strategies; stakeholders outside of city officials are involved.
- It is unclear how involved the Institute for Market Transformation is in the early phases of the project, and to what extent the project is positioning IMT to learn from and capture the lessons learned by the pilot cities for the benefit of others.
- No discernable weaknesses.

3) **Recommendations**

- Consider addressing other barriers to energy efficiency program adoption such as financing, project management and stakeholder training in the toolkit.
- No additional comments.
- None.

Project # 222107: OpenEfficiency Initiative

Presenter: Gregory Thomas, Performance Systems Development
DOE Manager: Harry Bergmann

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's goal of advancing energy efficiency in buildings by increasing the availability of high performance tools for industry stakeholders. Reviewers were less positive, however, on the project's approach to accomplishing that goal. One reviewer described OpenEfficiency's working premise as providing a central hub that could streamline user adoption of DOE tools, noting the project's claimed efforts to streamline information sharing between tools and platforms. However, it was not clear to this reviewer how important information barriers were to tool adoption. Another reviewer reinforced this sentiment, commenting that most users already had the skills to use DOE tools, as well as workflows in place.

Looking at the project's progress-to-date, reviewers felt that OpenEfficiency did not appear to demonstrate a significant amount of uptake at this stage, and also that it was difficult to assess the value of OpenEfficiency for supporting the market for related tools. One reviewer noted that the presentation listed several key impacts that the project would have on whole building programs, but offered no factual evidence or theory-of-change logic to support these claims. Another reviewer expressed interest in learning more about the baseline measurements and metrics that would be used to evaluate the project's impact.

In terms of project integration and collaboration, one reviewer felt that the success of the OpenEfficiency platform would ultimately be dependent on the project team's understanding of gaps in the workflows of stakeholders, counseling the project team to *not* aspire to meet *every* stakeholder's needs, because trying to do so would overcomplicate the tool's design and increase implementation costs. It was recommended that—in terms of workflows, data, and security requirements—the project team identify the most likely user of the platform, define business requirements, and develop the tool to meet those needs. One reviewer did note that, on the supply-side, the project team appeared to be coordinating appropriately with the developers of the individual tools.

Reviewers expressed consistent concerns about the project's proposed future work. One reviewer remarked that the project did not make a clear case for OpenEfficiency's importance, and that the project leaned on the value of DOE's tools to justify itself. Another reviewer commented that planned work did not appear focused on the achievement of specific deliverables beyond documenting project-specific design features and outcomes. This reviewer recommended that the project team should ensure that pilots are carefully evaluated, with particular attention paid to the specific contributions made by the OpenEfficiency platform to pilots' successes.

Weighted Average: 2.15 # of Reviewers: 2
Relevance: 3.50[1] Approach: 2.50 Accomplishments: 1.50 Project Collaboration: 2.75 Future Work: 2.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project is in direct alignment to BTO's goal, by enabling availability of high performance tools to the industry

- This project is relevant to the goals of helping to advance energy efficiency in buildings.

B. Approach

This project was rated:
1) **2.50** for the degree to which it focuses on critical market barriers, and
2) **2.50** for the degree to which the approach addresses the market barriers identified.

- Open Efficiency's working premise appears to be that having a central hub will streamline user adoption of DOE Tools which ultimately have the potential to contribute towards BTO's goals.

- The project claims that it is addressing key market barriers in the ability to share information between tools/platforms, but this is not supported (nor contradicted) by evidence from the providers of the related tools. Unclear how important these barriers are.

C. Accomplishments/Progress/Impact

This project was rated:
1) **1.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **1.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Presenter did not provide any strong evidence on the impact of this project to the market.
- What baseline and metrics are being used to evaluate the value was not well defined. (ex. # projects submitted through the Open Efficiency platform, reduced review times as experienced by customers and/or Program Administrators).
- On slide 8 - the presentation lists several key impacts that the project will presumably have on whole building programs, but no factual evidence or logic is shared. Some of the items listed have other key drivers (policy, workforce, security) with higher impact than the project deliverables. Presentation noted improved realization, reduce effort to adopt new program design, deeper savings without offering no real links on how the deliverable does that. In short the project outcome was VERY optimistic.

- The project does not seem to demonstrate a significant amount of uptake at this stage. It is difficult to assess from the amount of use how valuable this project is for supporting the market of related tools.

D. Project Integration and Collaborations

This project was rated:
1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Success of the project is dependent on the project team's understanding of the gaps in the workflow of stakeholders. This tool may NOT solve every stakeholder's need, and that should be fine as trying to do that would simply overcomplicate the design and increase implementation cost by adding new features ("bells and whistles") per the request of the collaborators.

- The project appears to be coordinating with appropriate tool provider partners.

E. Proposed Future Work

This project was rated **2.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- As reported by the presentation, the planned work does not appear to be focused on a achieving any specific deliverable beyond documenting project specific design features/outcomes. The value and future of the project seems leaning on the outcome of several pilots, all with different stakeholders and workflows.

- The project should ensure that not only are the pilot projects evaluated, but the specific value of this project in contributing to their success should also be evaluated.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 0** reviewers
- N/A

***Average*: 1** reviewer
- It is difficult to judge the value at this stage of the project.

***Low*: 1** reviewers
- Most users that have the skills to use the DOE tools, already have a workflow in place.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 1** reviewer
- The key activities seem to be appropriate.

***No*: 1** reviewer
- On slide 3, reduced owner costs, deeper energy savings, and integrated energy savings prediction were outlined as project objectives. There was limited evidence on the focus efforts to address them.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Where applicable, the project serves as a hub to DOE Tools and resources.

- The project demonstrates an understanding of some of the critical tools in this space and a plan for supporting information sharing between them.

2) **Project Weaknesses**

- Lack of focus, could mean overdesign or several mini hubs with unique solutions.

- The project does not make a clear case for its importance, which necessitates more evidence from the perspective of the related tools. The pilot projects it is engaging with are limited in number and it is unclear how much evaluation is being done about the role of this project in supporting those pilots.

3) **Recommendations**

- The tool will not likely be used by stakeholders with developed workflows and data/security requirements.
- Determine the most likely user, identify business requirements, and develop the BEST tool that meets those needs/barriers.

- No additional comments.

Project # 222111: Location, Location, Efficiency!

Presenter: Rose Buss, City of Milwaukee
DOE Manager: Priya Swamy

Brief Summary of Reviewer Comments

Reviewers agreed that this project was relevant to, and a good fit for, BTO's goals, given its aim to make investing in energy efficiency less complicated by showing that such investments do not have to be expensive and can increase the overall value of a building. One reviewer thought the project's approach to this issue did target significant known market barriers, particularly the limited capacity of building owners and managers to be aware of and engage with energy issues. However, another reviewer felt that the project was tackling the wrong barriers—citing access to funding as the most significant hurdle—and felt that any value-add from DOE's funding was not readily apparent. A third reviewer called this a challenging project from the start, because small business owner and operators do not have the bandwidth to readily absorb and react to the project team's engagement efforts.

One reviewer acknowledged that the project was making some progress engaging building owners and managers and working with local partners, but also flagged that actual program participation appeared to be moving slowly. Another reviewer was starker, describing the project as being "far away" from meeting its objective of 100+ buildings audited, and describing the project's accomplishments as being "very limited" and "not what would be expected from a program funded by federal dollars." A third reviewer was not surprised to see that the project was behind on its goal, nor to hear about the project's difficulties.

Reviewers positively rated the project's integration and collaboration, describing the project's approach to collaboration as sound and the project team as well connected with the right stakeholders. One reviewer added more detail, highlighting that the project team was working with key partners in the utility sector and in Milwaukee's business improvement districts; this reviewer expressed, however, that the project team might still need to explore new or different partnerships to succeed in its goals.

One reviewer thought that proposed future work appeared reasonable and justifiable, though another expressed a desire to see more robust ideas on how to make adjustments given its slow uptake to date. Given this lack of results, one reviewer recommended that the project should refine its value proposition, focusing more on developing reliable resources that are capable of serving the market and less on "peer to peer" information exchange.

Weighted Average: 2.07 # of Reviewers: 3
Relevance: 3.00[1] Approach: 2.00 Accomplishments: 1.67 Project Collaboration: 3.00 Future Work: 2.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project is relevant as it's aimed at making the process of investing in energy efficiency less complicated, to show that it does not have to be extremely more expensive, and that it increases the overall value of the building.

- This project is relevant to the goals of advancing energy efficiency.

- Fits BTO goals significantly.

B. Approach

This project was rated:
1) **2.33** for the degree to which it focuses on critical market barriers, and
2) **1.67** for the degree to which the approach addresses the market barriers identified.

- The wrong barriers have been identified, hence the low response. Access to funding is a major hurdle.
- The approach lacks innovation. The value of the DOE funding is absent from this effort. It appears the city could have achieved these same results by simply reaching out to regional stakeholders.

- This approach does target significant known market barriers such as limited capacity of building owners/managers to engage on energy issues and limited existing awareness of energy efficiency improvement opportunities.

- This is a challenging project from the first concept, because small business owner/operators just will not have the bandwidth or capability to readily absorb and react to engagement efforts like these. It's a noble effort - just tough to execute.

C. Accomplishments/Progress/Impact

This project was rated:
1) **1.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **1.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Project is far away from meeting its objective of 100+ building audited.
- The value of DOEs funding is not seen.
- The approach and accomplishments are very limited and not exemplary as it would be expected by a program funded by federal dollars.

- The project appears to be making some progress in engaging building owners/managers and working with local partners. However, the amount of participation in terms of number of buildings and the degree of progress synthesizing lessons from the pilot work that might inform future strategy for the field appear to be moving somewhat slowly.

- Presenters stated they are behind on goal, and lessons learned describe the difficulties. These are not surprising to see.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- N/A
- The project is working with some key partners in the utility, business improvement districts, etc. It may need to explore new/different partnerships to succeed in its goals.
- They are certainly connected with the right stakeholders, and, the design for integration and collaboration is sound.

E. Proposed Future Work

This project was rated **2.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- A low participation is indicative that a proper supply chain is not in place and/or a clear value proposition hasn't been made to customers.
- Project should not be focusing on "peer to peer" exchanges of information at the moment.
- Focus should be on developing the proper resources that are capable and reliable to serve the market.
- Creation of policies that favor utility investment into energy efficiency.
- I would like to see more robust ideas on how to adjust the work of the project given the apparent slow uptake to date.
- Reasonable and justifiable.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 0** reviewers

- N/A

***Average*: 2** reviewers

- This project has the potential to develop useful learnings about engagement strategy with building owners and how to leverage BTO tools in that process. Looking for more of that thinking with honest reflection on appropriate ways to leverage the tools.
- Still early to see if the specific design of this project will bear out high impact outcomes.

***Low*: 1** reviewer

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers

- It is hard to judge whether sufficient emphasis is being given. In a world of more resources, more could be done.

- Don't see any deficiencies.

***No*: 1** reviewers
- A low participation is indicative that a proper supply chain is not in place and/or a clear value proposition hasn't been made to customers.
- Project should not be focusing on "peer to peer" exchanges of information at the moment.
- Focus should be on developing the proper resources that are capable and reliable to serve the market.
- Creation of policies that favor utility investment into energy efficiency.

H. Additional Comments and Recommendations

1) **Project Strengths**

- N/A

- This project is targeting critical and common barriers to energy efficiency progress. I believe the intent is well crafted and that it is important to invest in projects like this to identify better program delivery methods to overcome these barriers to help energy efficiency efforts better respond to the needs of building owners and others.

- The intent and design is sound. Small building owners are a tough crowd to engage and move.

2) **Project Weaknesses**

- Low innovation to delivery of energy efficiency. Impact of DOE funding is not apparent.

- The project report admits that uptake has been slow. I would like to see more robust discussion of how the project can adjust.

- It appears the project designers may have been optimistic on how much they could accomplish, in their targeted time, with these types of customers.

3) **Recommendations**

- A low participation is indicative that a proper supply chain is not in place and/or a clear value proposition hasn't been made to customers.
- Project should not be focusing on "peer to peer" exchanges of information at the moment.
- Focus should be on developing the proper resources that are capable and reliable to serve the market.
- Creation of policies that favor utility investment into energy efficiency.

- I am glad to see investments in projects like this one that focus more on supporting use of the tools BTO is creating. I hope this project team is able to feed learnings back to the teams leading relevant tool development.

- None.

Project # 25150: Commercial Building Energy Asset Score

Presenter: Nora Wang, Pacific Northwest National Laboratory
DOE Manager: Harry Bergmann

Brief Summary of Reviewer Comments

Reviewers were mixed on this project's relevance to BTO's goals. One reviewer described the project as directly tackling a critical challenge to moving the marketplace towards greater understanding of—and action on—building energy efficiency. In contrast, a different reviewer felt the project's deliverable had limited value, other than to cities and states that have decided to adopt the asset-based approach to energy efficiency. A third reviewer commented that similar tools were already available in the market.

Reviewers were similarly mixed on the project's approach and its progress-to-date. One reviewer felt that the project's visualized scoring output was very useful and necessary, while another reviewer felt unclear about the importance of the project's primary barrier—a lack of building energy performance information inherently tied to a building's fixed assets—at least relative to other barriers limiting building energy efficiency improvements. One reviewer remarked that the project appeared to be making progress toward its goals, while another felt that no evidence had been presented to determine the quantitative value of this project's deliverables.

One reviewer thought the project team was making too many changes to the Asset Score tool too quickly, and recommended focusing deliverables on addressing user needs rather than the "flavor of the month." Another reviewer recommended that the project team develop more clarity around the value proposition of an asset-based approach to building energy efficiency, with particular focus on whether such an approach would supplement or supersede a performance-based approach like that used by ENERGY STAR Portfolio Manager; this reviewer warned that an asset-based approach to building energy efficiency could appear duplicative to some audiences, despite its unique value.

Reviewers positively regarded the project's collaborations and proposed future work, though not without some hesitations. Around collaboration, reviewers commended the project team for engaging a large number of stakeholders to provide ongoing input on the Asset Score, but one reviewer cautioned that no clear theory-of-change was presented to explain why a broader community of stakeholders might someday value the Asset Score and leverage its information to drive change. Looking toward the future, one reviewer felt that the project team had good plans for continuing development of the Asset Score tool, but others felt that future work on the Asset Score could benefit from more focus, a longer-term vision, and the generation of field data demonstrating the score's real-world value.

Weighted Average: 2.88 # of Reviewers: 3
Relevance: 2.67[1] Approach: 2.83 Accomplishments: 2.83 Project Collaboration: 3.00 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project deliverable has limited value other than Cities/States that have decided to adopt the approach. Valuation will vary by region.
- Similar tools are available in the market.

- The project is creating a tool to help understand building energy performance.

- Directly tackles a critical challenge in moving the marketplace towards greater understanding and motivation towards building upgrades.

B. Approach

This project was rated:
1) **2.67** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- N/A

- The project acknowledges barriers regarding a lack of building energy performance information inherently tied to fixed assets in the building, and aims to tackle this barrier. However, it's not clear how important tackling this barrier is relative to others that limit building energy efficiency improvements.

- The visualized scoring output is very useful and necessary. This allows building owner/operators, financial decision makers, and contractors transparently see and agree on the building needs.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.67** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- N/A

- The project appears to be making progress toward its goals.

- Steady progress shown. I would assume the project manager and team recognize how such an approach builds upon and can either supplement or supersede Portfolio Manager, and so understands how the value proposition for using this approach will come to fruition.

D. Project Integration and Collaborations

This project was rated:
1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Large number of stakeholders are being engaged to provide ongoing input on ASSET SCORE.

- The project appears to be doing a good job of engaging some key stakeholders related to the immediate work of the project. However, it doesn't present a clear theory of change regarding how a more broad community of stakeholders will value the information here and leverage it to drive change.

- I'm familiar with several of the stakeholders mentioned. This is a good selection, and, the presentation shows efficient progress.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Future work could benefit from more focus. No field data was shared to assess the use of the ASSET SCORE.

- The project has good plans for continuing the development of the tool and incorporation of more building types.

- None.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer
- A critical roadblock in moving building owners towards cost-efficient retrofit is the understanding of the energy usage and cost impacts. This is a well-desired path and eventual tool that appears to significant lower that barrier.

***Average*: 2** reviewers
- Users are looking for a free, honest asset scoring tool. These users are primarily buildings that cannot be scored in EPA's PM [Portfolio Manager].

- I find it difficult to judge the value, per earlier comments.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers
- N/A

- More could be done with more resources behind this project, but they are receiving sufficient emphasis.

- None

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Leverages knowledge of many stakeholders to seek continuous improvement and facilitate market adoption.

- This project seems to be well on its way to achieving its goal of creating an asset-based approach, tools that leverage asset data, and an initial data set.

- Useful, effective output
- Robust development and demonstration approach
- Comprehensive coverage of commercial building types
- Well researched development to ensure believability and acceptance

2) **Project Weaknesses**

- Too many changes too soon.
- No evidence was presented to determine the quantitative value of this project's deliverables.
- Project failed to outline the principal differences with EPA's Energy Manager. Beyond the collaborators, a clear distinction is required.

- I appreciate that the asset-based approach is distinct from more performance-based approaches to understanding energy performance, and that it can add complementary value to the process of identifying efficiency opportunities. However, the project does not present a clear theory of change re: how important it is that the market be able to use and begin to use a more asset-based approach. This approach is likely to feel somewhat duplicative to some audiences despite its unique value, and we need more clarity on the value proposition here and how it will be valued in the market.

- Minimal; no significant weaknesses perceived.

3) **Recommendations**

- Focus deliverables to address user needs, and not "flavor of the month" needs.
- A long term plan should be outlined.

- No additional recommendations.

- None.

Project # 25204: SEED Development and Deployment

Presenter: Nicholas Long, National Renewable Energy Laboratory
DOE Manager: Harry Bergmann

Brief Summary of Reviewer Comments

Because SEED enables users to track and analyze building energy information to facilitate consideration of energy efficiency opportunities, the project's two reviewers agreed on the relevance of the project to BTO's goals. The reviewers also generally agreed with the project team's open source software approach to SEED and the support given to the user community to contribute to the development of the SEED Platform, with one reviewer calling this approach appropriate given the importance of usability among SEED's stakeholders. In contrast, however, one reviewer warned that this approach could result in the tool being "over-built" to satisfy user needs, and recommended (1) formally defining the primary functions of SEED and then (2) prioritizing these functions over "custom requests." These warnings and recommendations aside, reviewers positively described the project's high-level of integration with SEED's user community, as well as the project's strong engagement with thought leaders among local government program administrators, national lab partners, and others.

Reviewers described the project as making good progress toward its goals, particularly with respect to the development and evolution of the SEED tool. One reviewer highlighted that SEED had been integrated with many projects both inside and outside of DOE, while another noted that there was evidence of local governments beginning to use SEED as a core program management tool. Looking forward, one reviewer was satisfied with the project's proposed future work around feature improvements, though the second reviewer felt that SEED had a lot of potential beyond its initial application as a tracking tool for local governments, expressing a desire to see more exploration of this potential.

Weighted Average: 3.20 # of Reviewers: 2
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 3.25 Project Collaboration: 3.50 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project supports BTO Multi Year strategy. It is a component of a suite of tools designed to accelerate the adoption of energy savings technology in buildings.

- This tool is very relevant because it enables the tracking and analysis of building energy information in a manner that enables consideration of energy efficiency opportunities.

B. Approach

This project was rated:
1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **2.50** for the degree to which the approach addresses the market barriers identified.

- The project team is relying on the user community to drive the development needs. This is appropriate as usability (after credibility and applicability) is a key metric that will determine the value of the platform to stakeholders.

- This project has recognized some of the challenges that its intended audience of program administrators are facing, and seems to have done a good job of engaging with them and adjusting the tool development based on their needs.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- SEED has been integrated in many projects both inside and outside DOE.

- The project is making good progress toward accomplishing its goals with development and evolution of the tool based on user needs, and evidence of local governments beginning to use the tool as a core program management tool.

D. Project Integration and Collaborations

This project was rated:
1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project is highly integrated with the user/developer community. SEED collaborator communication is varied both in terms of medium and frequency.

- This project is doing a good job of engaging thought leaders in its intended audience of local government program administrators as well as the other key national lab partner and others.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Project team has identified several areas of feature improvement opportunities based on user feedback.
- I think SEED has a lot of potential value beyond the initial primary application as a tracking tool for local government use around benchmarking program compliance. I would like to see more exploration of this.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- Developing a common data platform for managing building data can serve the needs of many users, including policy makers, energy consultants, building owners.
- This project is providing a valuable tool that a specific partner audience has said they need to better accelerate energy efficiency.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers
- SEED project is focusing on making access to real building performance data easy. Focus has been on integration with other tools and automation of reports to facilitate use.
- More could be done with more resources behind this project, but they are receiving sufficient emphasis.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- An open and transparent process has the potential to "real" user-focused improvements.
- This project is designed to respond to a specific need identified in the market and appears to have produced a tool ready for use by its intended audience.

2) **Project Weaknesses**

- Tool could be over-built in the process to satisfy user needs. Adding new features can destabilize prior upgrades unless checked, but this in turn slows deployment.
- No comments.

3) **Recommendations**

- Primary functions of SEED should be formally identified and prioritized before "custom" requests.
- I think the project needs to envision a range of future uses of the tool.

Project # 25205: BuildingSync Development and Deployment

Presenter: Nicholas Long, National Renewable Energy Laboratory
DOE Manager: Harry Bergmann

Brief Summary of Reviewer Comments

The two reviewers for this project agreed on the relevance of the project to BTO's goals, but they generally disagreed on each of the other project evaluation criteria.

Looking at approach, one reviewer thought that the project appeared to tackle the barriers it was designed to tackle, but the other felt the approach taken to designing a new schema needed to be revised if BuildingSync was to be adopted. This criticism was based on the reviewer's assessment that BuildingSync was designed to be high-value alternative to current schemas, rather than a complementary/additive solution to gaps in those schemas. This reviewer warned that the close relationship between the project team and ASHRAE could appear adversarial to other projects and/or industry stakeholders, thus slowing BuildingSync adoption.

Reviewers' assessments of progress, impact, and collaboration also yielded disagreement. One reviewer thought that while it was challenging to evaluate, the project appeared to be making good progress. The other reviewer, however, felt that a new schema was not necessary to achieve BTO's goals, as industry already had existing solutions in place. One reviewer was able to summarize the project team's collaborations and outreach, whereas the other reviewer found it difficult to evaluate the project's degree of collaboration.

Looking forward, one reviewer thought that the project's future plans—which included building in more functionality to automate data validation—seemed wise. In contrast, the other reviewer thought the presentation did not make clear connections between the current state of the project and other long term goals, at least beyond the goal of further integrating BuildingSync with DOE tools (i.e. SEED and Asset Score). One reviewer recommended focusing on promoting the additive benefits of BuildingSync for the industry, as part of a broader effort to refine BuildingSync's value proposition and demonstrate why an existing developer should adopt BuildingSync over an alternative option.

Weighted Average: 2.33 # of Reviewers: 2
Relevance: 3.00[1] Approach: 2.25 Accomplishments: 2.25 Project Collaboration: 2.75 Future Work: 2.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project's aim is to develop an open standard to facilitate the exchange of building-level design data.
- The project is relevant.

B. Approach

This project was rated:
1) **2.00** for the degree to which it focuses on critical market barriers, and
2) **2.50** for the degree to which the approach addresses the market barriers identified.

- For a successful adoption, the approach to designing a new schema should be revised. The role of Building Synch does not appear to be promoted as complementary but rather has a "new" way to achieve compatibility between data. Having ASHRAE support is not necessarily the best approach. Beyond key lab partners, a more substantial industry coalition should be sought.
- This project appears to be tackling the barriers it was designed to tackle.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- A new schema is not necessary (i.e. not a show stopper) to achieve BTO goals. Industry already has existing solutions in place.
- It is hard to evaluate the degree of progress in this project, but it appears to be making good progress.

D. Project Integration and Collaborations

This project was rated:
1) **2.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project team has enabled open communication/feedback through GitHUB and hosts quarterly meetings for working groups.
- I find it difficult to evaluate the degree of collaboration.

E. Proposed Future Work

This project was rated **2.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The project noted of plans of a developer competition to spur adoption in third party tools. This appears to be a modest attempt to integrate stakeholders beyond the group of parties involved in testing DOE tools.

- Beyond the integration to existing DOE tools (i.e. SEED), the presentation did not make any clear connection between the current state of the project and other long term goals.
- The role and function of Building Synch in the industry seems highly dependent on the success of ASSET ENERGY TOOL and SEED.

- The future plans to build in more systems around automating data validation seem wise.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 0** reviewers
- N/A

***Average*: 2** reviewers
- Deliverables are valuable to stakeholders involved with DOE tools; value to larger audience is not immediately clear.

- Not enough context to judge.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers
- The project is supporting SEED which directly aligned with BTO goals.

- This project appears to be well focused on its key objectives.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- N/A

- This project appears to be making progress with respect to its goals.

2) **Project Weaknesses**

- From the presentation, it appears Building Sync was not designed to be a complementary/additive solution to gaps in current schemas, but rather a high value alternative.
- The biggest challenge is that it could appear adversary to other projects and/or industry stakeholders. Apparent exclusivity of partners/collaborators and scope creep may slow adoption.

- This is a very technical project and I find it difficult to evaluate without more knowledge of the tools that it helps to enable information sharing between.

3) **Recommendations**

- Focus the objective and purpose of Building Synch. Focus on promoting the additive benefits (beyond integration to DOE tools and backing from ASHRAE Standard 211) that this project brings to the industry.

- Project should focus on demonstrating WHY an existing developer should decide "drop" current design work flow and adopt Building Synch. That value proposition is not clear.

- No additional comments.

Project # 25301: Measurement and Verification (M&V) 2.0 Demonstrations

Presenter: Jessica Granderson, Lawrence Berkeley National Laboratory
DOE Manager: Sarah Zaleski

Brief Summary of Reviewer Comments

Reviewers felt that the evaluation of energy efficiency improvements—the focus of this project—was critical to the success of BTO and the energy efficiency community, and also an activity that was well aligned with BTO's CBI strategy. One reviewer commented further that developing cost-effective evaluation processes was also critical to supporting the growing number of energy efficiency programs at the utility, state, and federal level. Reviewers described this project's approach to developing, demonstrating, and documenting the effectiveness of next-generation monitoring and evaluation tools (M&V 2.0) as appropriate, and also commented that the project demonstrated an excellent understanding of key barriers and challenges and how to address them.

One reviewer thought that this project was making significant progress toward its goals and was starting to produce some useful analyses. In contrast, a different reviewer felt that the project had not yet generated any "definitive" contributions to the energy efficiency industry, commenting further that there appeared to have been limited quantitative progress over the past 3 years. This reviewer nonetheless expressed that the project held significant promise, however.

Reviewers agreed that there was clear evidence of the project's integration and collaboration with industry and utilities. One reviewer made note, however, of the project team's limited engagement with a particular industry actor, commenting that discussions with this actor should have been initiated much earlier due to the actor's reputation concerning M&V issues. This reviewer also recommended that the project team reach out to the Association of Energy Engineers about providing support in the areas of training and outreach to industry stakeholders, as well as reaching out to energy professionals and data scientists to ensure that the outcomes of the project are valuable to core users.

Reviewers described the clear, robust direction of the project's proposed future work, commenting that the project team had laid out a proper plan focused on demonstrating the value of deliverables to stakeholders via "real" pilots. However, one reviewer recommended making it more clear how utilities might use M&V 2.0 tools, relative to individual practitioners, given that the project appeared focused on M&V at the building-level whereas energy efficiency program administrators needed community- and portfolio-level impact analyses.

Weighted Average: 3.37 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.67 Accomplishments: 3.17 Project Collaboration: 3.33 Future Work: 3.33

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project aligns with the BTO's CBI strategy by "providing design and management tools and performance data to reduce perceived risks and address market barriers that have inhibited wide-scale adoption." This is done by delivering to the industry cost effective M&V tools.

- Evaluation of energy efficiency improvement is critical to measuring success and improving future plans of BTO and the energy efficiency community of practice. This project is performing important research and analysis to inform various efforts of BTO.

- Developing cost effective evaluation processes is critical to meet the growing development of EE support on the utility, state, and federal level.

B. Approach

This project was rated:

1) **3.67** for the degree to which it focuses on critical market barriers, and
2) **3.67** for the degree to which the approach addresses the market barriers identified.

- The project's approach to develop, demonstrate via pilots and document M&V 2.0 findings is appropriate.

- The approach demonstrated excellent understanding of key barriers and challenges and smart approaches to addressing them.

- No pertinent weaknesses or deficiencies seen.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project has not yet generated any "definitive" contribution to the industry that can be widely spoken about.
- It has nevertheless initiated several collaborations with industry stakeholders including a pilot demo with partner utilities.
- There is significant promise in this project.

- This project is making significant progress toward its goals by engaging utilities and conducting research and analysis to explore these M&V tactics, and is starting to produce some useful analyses.

- Solid progress, clear direction towards stated goals. Accomplishments are well founded.

D. Project Integration and Collaborations

This project was rated:

1) **3.33** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project team is currently working with municipalities, investor owned utilities and regulatory commissioners. There are also plans to engage EVO. The project should however initiated that discussion much earlier, as EVO is the leading industry partner when it comes to Measurement and Verification. Also the Association of Energy Engineers is a stakeholder that can provide support in the area of training/outreach of industry stakeholders. Energy professionals and data scientists should be engaged to ensure the outcome of the project is valuable to the users.

- Good collaboration with utilities.

- Clear evidence shown of how integration and collaboration is established within industry.

E. Proposed Future Work

This project was rated **3.33** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The project team has laid out a proper plan that focuses on demonstrating the value of the project's deliverables to stakeholders via "real" pilots. These pilots run will be integrated with new and ongoing utility energy efficiency programs and will be expected to generate the needed verification of the methodologies and provided quantitative cost savings estimates. The project team has also indicated the willingness to have recurring meeting with stakeholders to ensure the project is on track and of relevance to users.

- I would like to see more discussion of how evaluation might work when combining these new M&V methods that you are finding work well for some buildings, with other methods that might need to still be used for buildings that aren't a good fit for these methods.

- Clear, robust direction provided in future steps.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- This project is producing analysis that I have not seen elsewhere that helps us understand the potential of these new M&V methods.

- A cost effective M&V design is strongly needed in the utility EE industry. Such cost-effectiveness allows funding entities to put more dollars and focus on the market investments, and less money spent on justifications for impact based on evaluations.

***Average*: 1** reviewer

- Accuracy and cost effective M&V is necessary to foster increased investment in energy efficiency and renewables. Nevertheless the project has not provided any hard evidence that the proposed M&V 2.0 is both more cost effective and accurate than existing methods.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The project seeks to enable market adoption of the proposed M&V 2.0 methodology. The project team is taking the necessary steps to develop, evaluate and communicate the benefits to key stakeholders.
- More could be done with more resources behind this project, but they are receiving sufficient emphasis.
- None.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project leverages existing energy efficiency programs to serve as "proving ground" for the proposed M&V 2.0 methodology. This accelerates both the learning, feedback and communication with stakeholders. Unlike other projects that may seek to develop first then test, the project team appears to have taken a pro-active and inclusive approach to solving the industry challenge of achieving accurate and cost effective M&V.
- This project is conducting useful analysis and helping to identify potentially important new M&V opportunities.
- Strong statistical design and approach
- Strong, timely collaboration with key stakeholders

2) **Project Weaknesses**

- There is limited quantitative progress over the past 3 years. The 2017 work schedule seems accelerated to fit the project end date.
- No major weaknesses. It would be great to see larger data sets and more attention to integration with other M&V methods.
- No perceivable or substantial weaknesses.

3) **Recommendations**

- Program Administrators are in need of community level and portfolio level impact analysis, however the project seems to be solely geared for M&V activities for individual buildings. Perhaps the discussion on how individual practitioners vs utilities will use this tool should be made more clear.
- No additional recommendations.
- None.

Project # 25340: Whole Building Performance Data Tools (BPD, SEED, BEDES)

Presenter: Paul Mathew, Lawrence Berkeley National Laboratory
DOE Manager: Harry Bergmann

Brief Summary of Reviewer Comments

Reviewers agreed that this project was directly aligned with BTO's goal of making tools available to industry to enable the assessment of energy-efficient measures by tracking, analyzing, and managing energy data. One reviewer described the project's approach in this endeavor as reasonable, commenting that it was great to see the integration of three of DOE's tools (i.e. SEED, BPD, and BEDES) and to see attention paid to the separate but inter-related needs of the tools' users. The second reviewer, however, felt there was a lack of clarity about how this project overlapped with the ongoing development of the individual tools, making it a bit difficult to understand the role of this project relative to others. This reviewer recommending integrating this and the other projects under one management umbrella to avoid "sub-optimization."

One reviewer felt this project was making progress around each of DOE's three tools, and that there was good demonstration of market uptake. The other reviewer noted that while other commercial solutions were available, academia and utility programs might find value in DOE's offerings

One reviewer positively commented on the project's industry-spanning partners, among which are software developers, utilities, cities, and DOE's national labs. However, the other reviewer found the project's collaborations difficult to judge based solely on the presentation, noting that the project demonstrated significant engagement with users but also expressing a desire to see a "bigger picture view" on potential uses for the tools, SEED in particular.

Looking forward, one reviewer felt that the project did not provide a lot of specific details around future plans, while the other acknowledged that, ultimately, the future of this project would be contingent on the future success of each individual component.

Weighted Average: 3.00 # of Reviewers: 2
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 3.25 Future Work: 2.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project is directly in line with the BTO goal to make available to the industry, tools that will enable the assessment of energy efficient measures.

- Tools focused on enabling the tracking, analysis, and management of energy data for the purpose of advancing building energy efficiency.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The approach is reasonable.

- Great to see integration of three tools here, and attention to the key separate and inter-related needs of the user audiences.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project has achieved good milestones including adoption into ASHRAE Audit Std.

- The project is making progress in each of the three tools that are part of the project. Good demonstration of market uptake.

D. Project Integration and Collaborations

This project was rated:
1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Group of collaborators spans across industries, including software developers, utilities, cities, DOE Labs.

- This is difficult to judge based only on the presentation. The project demonstrates significant engagement with users, but I would like to see a bigger picture view around the potential uses and value of SEED especially and some potential data analysis needs.

E. Proposed Future Work

This project was rated **2.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Future of the project is contingent of each individual component, SEED, BPD, BEDES.

- The project did not provide a lot of specific detail in the area of future plans.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- The suite of tools will be of benefit to its intended users. While other commercial solutions are available, academia and utility programs may find value in these tools.

- These tools have specific utility and are responsive to some key audience needs.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 2** reviewers
- N/A

- More could be done with more resources behind this project, but they are receiving sufficient emphasis.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project is making use of parallel projects that are well supported by stakeholders and collaborators.

- This project is producing and supporting engagement with tools that are needed in the marketplace.

2) **Project Weaknesses**

- Each individual component seems to be led by other program managers and/or collaborators requirements.

- Lack of clarity and overlap with other projects made it a bit difficult to understand the role of this project vs. other efforts in relation to some of the tools referenced. It is unclear how the separated roles of LBNL and NREL on SEED are affecting the project, for example.

3) **Recommendations**

- Integrate the projects under one management umbrella to avoid sub-optimization.

- Please continue the fantastic robust engagement with the intended audiences of these tools in your ongoing support of this project. Project success to date appears to be partly driven by good audience engagement.

Commercial Buildings Integration
Finance

Project # 222101: Financial Management for Retail Energy Efficiency

Presenter: Erin Hiatt, Retail Industry Leaders Association
DOE Manager: Holly Carr

Brief Summary of Reviewer Comments

Reviewers agreed this project supports the overall BTO goals and objectives. Both reviewers praised the project's inclusion of space occupants, arguing they are an important market segment and require resources to make the business case for energy efficiency to their management or building owners.

The reviewers were split on the project's approach; while the project was praised for focusing on major market barriers, reviewers felt the project did not have a strategy for addressing and overcoming the issues. Both reviewers were concerned that the project team did not appear to touch on the split incentive problem or how to overcome it. One also questioned if structural barriers and impediments identified by the team were being fully addressed. Another reviewer suggested the project focus more on energy management strategies and low and no-cost technologies to potentially build momentum for investment-grade energy efficiency improvements. One reviewer praised the project team's embrace of hands-on workshops and differing levels of education alongside the written and digital guides.

The project's progress, accomplishments, and impact were rated well by reviewers. Both reviewers agreed the project was working well towards raising awareness by reaching many stakeholders across a variety of audiences. While one reviewer thought the team had a great platform for reaching a huge segment of retail, another wondered if this outreach would help meet the project's larger goal – increasing access to capital. The reviewer agreed with the project team's premise that more awareness should lead to greater uptake, but felt that not enough information was presented on the team's evaluation of financial opportunities and their feasibility for companies.

Reviewers praised the project's integration and collaboration with diverse stakeholders across industry, including building energy managers, corporate finance, and implementers. One reviewer noted, however, that perhaps building owners (when the tenants are retailers) were not sufficiently engaged.

The project's proposed future work was rated well by reviewers, with one writing the future plans looked "excellent." One reviewer noted that trying to measure uptake in a meaningful way to measure effectiveness would be useful, but likely very difficult to achieve.

Weighted Average: 2.98 # of Reviewers: 2
Relevance: 3.50[1] Approach: 2.75 Accomplishments: 3.00 Project Collaboration: 3.00 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Space occupants control their buildings as tenants or owners and so must be partners in seeking energy savings.

- The project targets an important market segment and some of the folks within these stores that need the education and tools to better make business case for EE to their management(and maybe landlord)

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **2.50** for the degree to which the approach addresses the market barriers identified.

- No mention or attention to the split incentive problem and green leasing. Several that were identified (i.e. key issues 3-5) are important but I didn't see a strategy to address them.

- The project does a good job of focusing on some of the major market barriers to getting EE projects approved and implemented in the retail industry. The focus (helping energy managers get educated to and access to financing tools and strategies) was well defined and addressed the majority of barriers associated with implementation. The project (as presented) did not seem to touch as much on overcoming the split incentives in the industry, or the credit-worthiness of the customers who are considering these financing options.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Seems the project will increase awareness and knowledge but whether it will increase access to capital, a key given purpose, is less clear. More awareness should lead to greater uptake of opportunities if there are sufficient financial opportunities and they are really feasible for companies. Slides and presentation do not make clear that is being assessed or addressed.

- Project has done a good job reaching a ton of people, lots of different audiences, and different levels within the companies they are working with (from store level managers up to the CFO.)

D. Project Integration and Collaborations

This project was rated:
1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Outstanding effort except not sure sufficient engagement with building owners when retailers are tenants.

- Good job recruiting a large cross section of energy managers to get involved in this project, and getting an impressive name in corporate finance (Deloitte) and implementation partner (Schneider) engaged in implementation and evaluation.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Plan forward makes excellent sense.

- Looks like a good program that could still reach a lot more folks who could leverage it effectively. Trying to measure uptake in a meaningful way to measure effectiveness would be useful, but probably very difficult.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- They look terrific, though I can't say as we were not given them to read.
- Good product delivered through multiple different channels focused on the topic and the audience

***Average*: 0** reviewer
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 1** reviewer
- Nothing further to add.

***No*: 1** reviewers
- Good focus on energy managers and CFOs, and strategies to leverage internal and external financing for EE projects.
- It would be good to see some more focus on energy management strategies and low and no-cost technologies, and how these can help build momentum or sweeten the deal for the investment-grade energy efficiency improvements.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Seems very well executed and managed, grounded in strong understanding of the industry barriers, great platform for reaching huge segment of retail.

- Good idea to help a wide range of folks within a retail organization understand and secure financing for EE
- Good job bringing in Deloitte and Schneider to add credibility to the project deliverables
- Good to see doing hands-on workshops and also providing different levels of education in financing, along with the written and online guides people can use.

2) **Project Weaknesses**

- Not sure all real barriers to progress are being addressed - what prevents retail from redoubling its efforts? Not sure sufficient partnership with building owners. Not sure structural impediments identified are being fully addressed. Not sure metrics will capture increased activity.

- The project has demonstrated good progress on reaching a lot of people with the content, and reaching folks at different levels and audiences within a company (from energy managers to CFOs).
- Hard to measure the outcomes of these projects in terms of more people leveraging new financing strategies to get project done, and the energy and financial benefits of these projects.
- The project doesn't address (or doesn't seem to address well enough) the challenges of split incentives and what can be done by tenants who can't attract reasonable financing rates and may not have cash on hand (in this case, energy management strategies for efficiency and negotiating better utility rates may be the most effective short-term for this.)

3) **Recommendations**

- Hope to see the Fellows program carefully evaluated and if really working then expanded. Seems like a great idea.

- If there is an innovative new EE technology that would be broadly applicable to a market segment, or a new technology that is "newly financing-able", it would be good to leverage this program to educate on technologies - for example now that certain types of metering and simple building controls are becoming more cost-effective and can be financed or enhance the financing terms of a project if they are implemented in conjunction with a lighting or HVAC upgrade.

Project # 24209: Leveraging SBA to Finance Efficiency Solutions for Small Businesses

Presenter: Rois Langner, National Renewable Energy Laboratory
DOE Manager: Holly Carr

Brief Summary of Reviewer Comments

Reviewers agreed this project supported overall BTO goals by targeting an important and hard-to-reach section of building owners and tenants. One reviewer was supportive of the project's partners and the toolsets used to engage these businesses and building owners, arguing it was beneficial the project was focused on non-major markets and different geographies. One reviewer said that this work addressed a "critical" market segment and had a clear awareness of barriers, with another noting the project team had a good deployment strategy for materials which addressed "the most critical and actionable activities" for improved energy efficiency.

Reviewers questioned the project's approach regarding the target audience for its educational materials, with one saying it was unclear if the project was targeting small business tenants in various-sized buildings or small building owners. Reviewers both noted that these audiences differed significantly in terms of building type and business relationship and would benefit from tailored material. One reviewer questioned if educational and awareness efforts would translate into changed technology deployment or operating practice for the target audience. Both reviewers believed the partnership of SBA was beneficial, though one reviewer wanted to see additional strategies for getting more SBA regions onboard. Another reviewer recommended building partnerships via green leasing programs, or partnering with national associations who represent small businesses, to address the issues raised by this project.

Reviewers acknowledged the materials produced by the project team, but had concerns about how the project's progress and impact were being tracked. One reviewer wanted to see additional program evaluation metrics implemented, to track the uptake of efficiency loans in target SBA regions. The other reviewer acknowledged the difficulty of tracking impact on investment, suggesting the new 504 loan program as a tracking mechanism. One reviewer desired a better understanding of how small businesses were leveraging the project's materials, noting it would be useful to know if these materials were significantly influencing procurement decisions and/or major renovations that trigger a loan. Specifically, one reviewer recommended the project attempt to disaggregate the marginal impact of this project against other larger programs (e.g. utility or other governmental programs) and again market forces that could also be driving investment in this market segment.

The project was positively scored for project integration and collaboration, with one reviewer explicitly praising the project for working with the "right" collaborators and "getting the word out." One reviewer suggested additional clarity in the presentation materials, to show the tie between the project goals and outcomes and the stated needs of small building owners. The other reviewer pointed to the need for measurement of uptake of the energy efficient technologies and management strategies pursued by the project.

For future work, reviewers thought the project demonstrated a good awareness and understanding of the broader goals and the importance of partnering with the SBA, with one reviewer wanting to see additional strategies for a broader partnership. One reviewer was very positive on the project's plan to get information to service providers and equipment vendors, as another information dissemination strategy for small businesses. Another reviewer recommended looking at tailoring aspects of this project to a smaller market segment within the group, with either a common industry or building type serving as a controlled test for tracking impacts from the project.

Weighted Average: 2.58 # of Reviewers: 2
Relevance: 3.50[1] Approach: 2.75 Accomplishments: 2.25 Project Collaboration: 3.00 Future Work: 2.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Small buildings and small business tenants seem very important to the goals.

- This project targets an important and hard-to-reach section of building owners (and tenants), and building type (smaller buildings in many cases).
- The group has a good channel partner and toolset to ty to engage these business/building owners. Also good that they are focused on non-major markets and different geographies to deploy their materials.

B. Approach

This project was rated:

1) **2.50** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- It unclear how much focus is on small business tenants in large buildings or small buildings, or how much focus is on small building owners. Certainly the educational materials would vary for people in real estate vs. people who are tenants, though one that speaks to both concerning how tenants and owners can work together - following the "green lease" model would help. Green leasing info is available online. It is also critical to get SBA to back the program; if they don't encourage their applicants to address energy, their applicants will have far less or no incentive to do so. There is no strategy for getting there - but I do feel the SBA regional test-beds is the right way to go and the new admin transition is challenging, but nonetheless, there's a need to develop a strategy to get more SBA regions onboard.

- They are addressing a lot of the market barriers in this market - lack of capital, tight margins, lack of good information, etc... and aligns the benefits they can see (reduced operating expenses, increased rental income/resale value, etc...) All of this can help them be more efficient, productive, and successful.
- Getting the materials out through major financing mechanism and channel partners who know these small business owners well through their interactions with SBA.
- Because this is just awareness and education, it will be interesting to see whether or not it leads to better technology deployment or operating practices. Will the SB owners act on their own and find the capital to make these investments, a technology partner to install energy efficiency technologies, and communication materials that help them make their buildings more competitive (and their businesses more competitive.)

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- I gather the outcome sought is the production of materials but the real goal is to impact the uptake of efficiency loans. It's clear the first is being achieved but I see no evidence or metrics to determine how much of the later is being achieved. Some form of program evaluation, perhaps comparing loans for energy in the two target SBA regions vs others?

- The materials look great, and are focused on the right things
- The channel partnerships with SBAs and delivery mechanisms through community partners.
- It looks like it is hard to tell (and will continue to be hard to tell) what the impact will be on investments in energy efficiency. The new 504 loan program's incentive for efficiency in $5 million+ loans is a cool way to track who is taking advantage of these energy efficiency upgrades and getting the credits associated with these programs.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- It's hard to know from the presentation materials how well the program is tied into what small companies and small building owners are saying they need.

- Great job working with the right collaborators
- Good job getting the word out to businesses at events, marketing and communication channels, etc...
- Great resource guide and meaningful materials
- Would be good to have some measurement as to the uptake of these EE technologies and management strategies. Tracking mechanisms don't exist so it is good that they are trying to find a way to overcome this barrier, but not clear whether project team will get there.

E. Proposed Future Work

This project was rated **2.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Clearly there's awareness that broader SBA partnership will be critical but I didn't see much strategy for doing that.

- Good understanding of what still needs to be done to achieve the goals that the project hopes to accomplish - more small businesses making better decisions and more investments in energy efficiency. Like that they are working with SBA to track these investments better, launching a website and other tools to automate the deployment of their materials to the right people. Also like the idea of getting the info out to service providers and equipment vendors to help them in their sales to these small businesses.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 0** reviewers

- N/A

***Average*: 2** reviewers

- Average because I could not review the products.

- The product looks great and I believe this information would have a lot of value for the small businesses who are leveraging it. It is hard to tell how many of them are using it and whether it is significantly influencing their procurement decisions and major renovations that trigger a loan.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 0** reviewers

- N/A

***No*: 2** reviewers

- I support what is being done but have suggested a few additional emphases that could help drive the agenda forward. My real answer here would be yes and no, not one or the other.

- There was not an option for "not sure" - I am not sure whether this project is having a meaningful impact on the market. It looks like it should and the materials and channel partners are great. I want to see the data that shows people are using it and it is moving the market.

H. Additional Comments and Recommendations

1) **Project Strengths**

- This is a critical market segment to support and materials have been produced and regional SBA partnerships established. There's also clear awareness of barriers.

- Great channel partnership with SBA and the channel partner organizations that help small businesses take advantage of these loans.
- Good materials focused on the most critical and actionable activities they can take to invest in energy efficiency and renewable energy.
- Good deployment strategy for the materials

2) **Project Weaknesses**

- It's unclear whether materials properly differentiate between small buildings, small firms who are tenants in small buildings and small firms who are tenants in large buildings. There also seems to be insufficient attention to the creation of partnerships between tenants and owners via green leasing programs. I would also suggest driving demand for support by gaining partnership with national associations who represent small business, hoping they could use their collective strength to press buildings owners and the SBA to address these issues.

- Need to figure out how to track the impact that this program has on actually making investments in energy efficiency. Would also be good to disaggregate the MARGINAL impact that this program is having vs. other larger programs (utility, government, market trends) that may be driving more investment in this market segment for energy efficiency technologies.
- Would be good to target separate materials for small building owners, building owners who have a lot of small businesses as tenants, and owner/operated smaller buildings owned by small businesses - the building type and the business relationships are really different in these different types of building and owner/tenant models.
- It is beyond the projects' control, but getting all loans to track what type of investments are the small business loans going to (beyond the $5 million+ loan program with a focus on tracking energy efficiency projects).

3) **Recommendations**

- I'm very supportive of the program, even though I've made what I hope are constructive critiques. I also understand that much of what I suggest may be occurring but not covered in the presentation package I've reviewed.

- Tailoring an initiative on a smaller market segment of this group and measuring them as a ore controlled test of the uptake of this type of efficiency investment. Maybe focus on an industry segment (drycleaners? restaurants?) or building type (class B, strip malls, etc...) and see if you can share specific EE upgrades or strategies and deploy them across a lot of similar buildings or people in the same market segment.

Project # 24230a: Energy Efficient Building Appraisals

Presenter: Andrew White, JDM Associates
DOE Manager: Holly Carr

Brief Summary of Reviewer Comments

Reviewers agreed this project was relevant for overall BTO goals, with both agreeing that financing and appraisal education represent key shortcomings. One reviewer argued that lenders needed additional information on how energy efficiency improved property values and they needed to see this information reflected in appraisals. Another reviewer noted the tools and educational content produced by the project would be relevant after the project term was completed and could be easily shared for further education among appraisers.

This project was scored well for approach, with both reviewers suggesting additional avenues for data disaggregation. One reviewer noted that premiums would vary geographically, and recommended that a data infrastructure which disclosed energy performance and features be used to establish the size of premiums in various markets. Another reviewer recommended further disaggregation along building types, noting it made sense to begin with commercial offices but argued it would be interesting to see how findings translated into the market for other building types. One reviewer felt positively about the project's focus on a few key educational areas, as well as the project team's outreach to the appraisal community. Another data concern noted by a reviewer was the need for data sets of transactions that could be used to determine the project's impact overall on the appraisal process, enabling more effective evaluation of energy efficiency in the appraisal process.

Both reviewers had questions on the project's accomplishments, progress, and impact. One questioned the overarching goals of the project and how well they were being achieved, specifically wondering how well the overall industry's acceptance of the project's outputs would be accepted. Another wanted additional evidence on how working group members had executed all key elements of the strategy.

This project was scored highly for integration and collaboration, with both reviewers agreeing that the project team did a good job getting industry leaders engaged and that partnerships were well-targeted. One reviewer specifically called out the working group as being a great resource for providing both advice and feedback on project tools. Another reviewer wanted to see additional documentation on how engaged partners were in this effort, and how they were making a difference as a result.

Reviewers raised concerns regarding this project's next steps. One reviewer noted that the future work did not appear to address identified issues from lessons learned, while the other was unclear about who would pick up the project once DOE funding ended. One reviewer noted it would be nice to see more groups making public commitments to use the work products of this project. Another recommended that in the last part of the performance period, the project team should focus on overcoming barriers and devising a strategy to get all appraisers and banks to recognize energy's value and routinely use energy in their appraisal processes, leading to better lending terms for more energy efficient buildings.

Weighted Average: 2.80 # of Reviewers: 2
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 2.50 Project Collaboration: 3.50 Future Work: 2.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- In order to achieve the BTO goals for reducing EUI, there will need to be financial resources available for that purpose. Lender financing will be a critical financial resource, along with building owner self-financing, tax credits, and more. It will be easier to persuade lenders to provide this financing if they can see how they improve property values and that will require having those values reflected in the appraisal process. Currently, appraisals do not adequately reflect energy performance premia and this project will assist greatly in redressing that problem.

- This addresses many of BTO's market transformation goals. It focuses on a large building energy user, focused on a current shortcoming in the market (appraiser education and valuation of energy efficiency in commercial building valuation), and does it in what appears to be a fairly cost-effective way. It also provides tools and educational content that will be relevant well after the project has been completed, and can be easily shared for education among appraisers.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project does not seem to do enough to ensure that the information needed by appraisers about building energy performance or features will be obtained by them and whether the information they need that relates the performance or features to value will be available and/or accurate. The "green premium" is not fully understood and new information is coming out all the time so at the very least it is important that a panel of experts review and update the information in the training at least every 2 years. It is also likely that the premia will vary geographically, so a basic data infrastructure that discloses energy performance and features which can be used to establish the size of the premia in various markets is needed. This could, for example, become a part of the data on commercial buildings maintained by county assessors. This should be explored via engagement by this project with groups such as the International Association of Assessing Officers.

- Good that the team has focused their energy on a couple of key points of education in how energy efficiency should be factored into appraisal process (benchmarking correctly, using Portfolio Manager, etc...).
- Good that the team is leveraging strong contacts within the appraisal industry as messengers and partners, and using the online continuing educational tool that appraisers use for other classes to disseminate this content. Also good to work with AIA and Appraisal Institute on this, and have them bought in.
- Good to launch a couple of pilots in different types of markets (DC and Atlanta), would also be great to go to a true "tier 2" city (Cleveland? Salt Lake City?).
- Like the effort to get more competent appraisers AND for the real estate owners and buyers to ask for trained appraisers and provide them with easily understandable energy efficiency data in a consistent way.
- Would be good to see how they are working with appraisers in different building types. Makes sense to start with commercial office, but would be interesting to see how this translates into markets for other building types (starting with the key markets that are benchmarked in ENERGY STAR.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The material objectives of creating and testing the course seems on track but the higher order goals of increasing knowledge, driving demand, and overcoming barriers are not well documented. To what extent are these higher goals being achieved? To what extent will the course become a part of all appraisers' training and to what extent will banks accept the assessments? That seems key to judging success for this project.

- Got questions into GRESB survey. Generated good materials and presented at a lot of conferences.
- Generated some good materials and have started getting working group folks to modify their sample documents to help them edit internal documents as part of their appraisal business processes. Changing the information they are requiring appraisers gather about properties they are evaluating.
- May be changing the way that Altus Group and other big appraisal companies are doing their appraisals. Getting major appraisal "customers" to request this be a part of every evaluation they do.
- Would be great to see a transaction where this worked. Any evidence that working group members have been able to execute all the key elements of this strategy, and deliver a strong report aligned with the template materials (hopefully this is coming soon).

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project lists most of the right groups to engage but to degree to which the engagement is occurring and making a difference is not documented. Moreover, given the need addressed earlier to establish the data infrastructure needed to support this market innovation, it seems important that the basic information sources, such as county assessors or CREFC be engaged. See http://www.crefc.org/irp/.

- The project team did a great job getting the leading property owners, property financiers, property buyers, and of course the broader appraisal community (including key influencers and both major trade associations.)
- The project team also seems to have built an active "working group" that is not only providing industry and content advice, but also using and customizing these tools.

E. Proposed Future Work

This project was rated **2.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Next Steps don't seem to reflect Lessons Learned. My interpretation of this question is that future work should address identified barriers, and that does not seem to be reflected in the material I've reviewed.

- This question is tricky, as project is slated to end in September of this year. The project is set up to continue to have impact on future market transformation, but it looks like it will have to be led by AIA and Appraisal Institute or NAREIM, REITs, or other appraisal "customers." Unclear who is going to pick up the torch to move the market forward once this project sunsets. The Appraisal communities' online

education tool is a great way to keep this going. Would recommend that the "customer" industry groups try to get some similar commitment from their members to use these appraisal tools and generate case studies.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewers

- Based on description it sounds like content is really well targeted, the folks taking it are taking the info seriously, and the information actually will improve how EE is captured in the appraisal process. Need to more thoroughly review actual content to confirm it really is as good as it sounds, but it sounds really strong.

***Average*: 1** reviewer

- I selected average because I don't have the deliverables to review.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 1** reviewer

- Again, not sure how this question relates.

***No*: 1** reviewer

- There isn't a data set of outcomes associated with this program to figure out whether or not it is having an impact on the appraisal process and more effective evaluation of EE in the appraisal process. Hopefully in the next 12-18 months this will generate a data set of transactions that can be studied to further refine the program.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The basic goals are sound and very important. There is also a very good understanding of the nature of appraisers (fragmented), the appraisal process and the role of lenders. Many of the key players are being engaged.

- Strengths were included in previous questions, but include the following:
    - Engaging all relevant communities (appraisers, customers of appraisers, etc...)
    - Getting significant buy in from the stakeholders (customers encouraging their appraisers to use it, appraisers learning how to evaluate EE better, etc...)
    - Building tools that can live on past the end of the project, and that are easy to disseminate
    - Focusing on the key material elements of EE that wouldn't have been traditionally captured in appraisals and that really do add value for building owners.

2) **Project Weaknesses**

- We have not reviewed the course content but it will be difficult to get change in appraisal practices given the state of information on localized premia from efficiency. And there is no strategy identified to overcome that issue or issue that the course content is based on the most recent and best economic science on how efficiency features and performance affect value. It would also be good to recognize the information limits that make energy in appraisals possible.

- Could focus pilots on more regions (including smaller markets)

- Could touch on key real estate sectors beyond commercial (all of which need this more desperately than commercial office)
- Would be nice to see more people making public commitments to require this of all their appraisers, or incentivize this type of appraisal in their choice of an appraiser.

3) **Recommendations**

- In the last year, while the course is being completed, focus heavily on barriers and how to overcome them. Suggest using visioning/backcasting to answer what it will take to get to a place where ALL appraisers and banks routinely use energy in the appraisal process in a way that recognizes its value and leads to better lending terms for more energy efficiency buildings.

- Good stuff - wish it had another year to generate some more success stories from implementation (beyond # of appraisers trained and # of conferences they have presented this at).

Project # 24230b: Financial Performance of Energy Efficient Buildings

Presenter: Deb Cloutier, JDM Associates
DOE Manager: Holly Carr

Brief Summary of Reviewer Comments

Reviewers agreed this project supports the overall BTO goals and objectives by focusing on driving smart energy efficiency investment and addressing data availability issues. One reviewer noted that a large latitudinal panel dataset would be "invaluable" for the business case of energy efficiency investment and had the potential to deliver something of really high value. Another noted that meaningful financial and transaction data connected to energy efficiency and green building data would be a powerful tool for meaningful lease-level data that could be tied to real estate valuation in light of energy efficiency.

Reviewers were split on the project's approach. While one reviewer praised the project's identification of major market barriers and questions needed to generate a good data set, a different reviewer argued the project had demonstrated the data supply barrier had not been overcome and felt the traditional approach of finding data partners was not working well. This reviewer further suggested a reassessment of the approach by working with other existing groups that already pool energy and real estate data for research purposes.

Reviewers were concerned with the project's accomplishments and progress to date, with both reviewers expressing concern over the project team's ability to access data. Additionally, reviewers were concerned that once the data was collected, there were no guarantees it would be quality data. One reviewer thought that, with uncertainty surrounding the ability to access data, it would be beneficial to get data sharing commitments in writing from partners. One reviewer was pleased to see the planned pilot to test data collection and methodology with a sample of 130 properties. One suggestion was made that additional data, such as geospatial data sets linked to building data for research controls, should be included.

The project team was commended for working with partners who could provide major financial data sets, but one reviewer was concerned that not all the right people had been included from both other groups that work on this issue as well as leading private individuals.

Reviewers were concerned with the project's proposed future work, with both reviewers agreeing success was highly related to overcoming data access hurdles—and one noting they did not see a plan for overcoming this barrier. Another was concerned with the full scope of the project, questioning if it was also dependent on data access. One suggestion was to have additional external reviewers outside of Peer Review to provide insights into overcoming existing obstacles.

Weighted Average: 2.60 # of Reviewers: 2
Relevance: 3.00[1] Approach: 3.50 Accomplishments: 2.25 Project Collaboration: 2.50 Future Work: 1.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- A large longitudinal, panel (repeat observations) data set would be invaluable for building the case that EE investments are worth expanding and that could not be more central to the BTO core goals. However, the project itself has been less successful than was hoped in obtaining the data and so I cannot give the highest score.

- Focused on driving smart investments in energy efficiency. Also addressing a data availability issue that is a critical challenge to studying the financial impact of green buildings and energy efficiency investments and performance. IF they are able to collect meaningful financial and transaction data and connect it to energy efficiency and green building data, this would be a very powerful tool to deliver more meaningful lease-level data that can be tied to the real estate valuation in light of EE.

B. Approach

This project was rated:
1) **4.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project itself has shown that the data supply barrier has not been overcome. I do not think we can know with certainty how to overcome the problem, but I think the traditional approach of finding and recruiting data partners is not working well. I would suggest a reassessment of the approach. One promising way forward is to work with groups that already pool data for research and benchmarking who have been working on energy issues. This includes the National Council of Real Estate Investment Fiduciaries and the Real Estate Research Institute. Both are nonprofit. On the for-profit side, it might be possible to pull together a group of data warehouses and I would first look to Trepp and Morningstar and Fannie Mae on the debt side and then CoStar and Real Capital Analytics on the for-profit side. I would also approach the largest asset owners, such as CalPERS who are influential because they are key constituents for all of these data providers. There is also a problem that must be solved with the core data standards, such as the Commercial Real Estate Finance Council Investor Reporting Package (CREFC IRP) which does not require reporting of energy separately, but lumped with all utilities. You'll find that data handled by Trepp and Fannie Mae, for example, all are based on the IRP standards. Finally, it's critical that no barriers to accessing the data are created for academics who want to access the data. The ICPSR at the U of Michigan is a model worth considering.

- Great identification of the major market barriers, and figuring out what is meaningful to ask for to generate a good data set. Looking at transaction data and key NOI factors (lease revenue, operating expenses, lease rates, etc...) is a good way to really measure financial value of energy efficiency initiatives at an asset level across a wide range of real estate assets.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- "It all depends on whether we can get the data" was said twice at the peer review event. This is a red flag suggesting the path to success may need to follow a different direction. There are a lot of well-intentioned and good people involved but I wonder whether some sort of groupthink is impeding honest self-criticism on the team. Perhaps a fuller external review panel of fresh people who can be given a fuller brief would be wise before doubling down on a worrisome plan that seems to be reaching some impasses.

- The project sounds like it is still just getting started, and they are still working through the challenges to get owners and property managers (and brokers and industry associations) to share the meaningful data. They have set themselves up to succeed (with standardized metrics and a good working group and a secure data strategy), but still unclear if it will work. Would be good to have a commitment by some of the participants in writing to provide some data in a meaningful format in a reasonably close timeframe.
- Good to hear that they had a pilot with an owner with 130 properties to test whether they can get the right data and whether or not they can figure out whether or not they can see a correlation.

D. Project Integration and Collaborations

This project was rated:

1) **2.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- I do not feel all the right people have been brought together. There may be turf issues I'm unaware of but I feel there are some key people with experience with real estate benchmarking and data sharing that are not at the table. I've mentioned RERI and NCREIF; NCREIF in particular has a staff who does nothing but this sort of work and has succeeded with it for years. But there are also key private leaders, like the head of Real Capital Analytics who would offer his advice pro bono, I'm sure. I'm also aware that GRESB or Trepp or the other private orgs that compile and sell data have their own agendas and those may be pulling on this process in a difficult way; even universities jockey to be the leader/first mover. I would work with the institutional investors (CalPERS, etc.) who are so influential that all these others will follow.

- Good that they are working with folks who can provide the major financial data sets, and have figured out ways to share data in a way that is secure and well organized. It will be interesting to see who provides data, who can provide it in a well-organized way, and whether this can make meaningful data for research across assets in different classes, cities, etc...

E. Proposed Future Work

This project was rated **1.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- I don't see a plan for overcoming the recognized data access hurdles. That's critical to success.

- Success will depend significantly on whether they get enough meaningful data. Was not clear exactly what the scope of the research will be - maybe it will depend in part on what data you can get and for what type of buildings.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 0** reviewers
- N/A

***Average*: 1** reviewer
- This project has the POTENTIAL to deliver something of really high value, but it still is not clear that it will get there. The project team seems to have done everything that they could to set themselves up to capture good data, if the real estate owners who have the data are willing to share.

***Low*: 1** reviewer
- It all depends on the data obtained and how accessible they are with minimal hurdles to researchers.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- Comment 1

- *No Comment*

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The idea of it - that we have a large scale, longitudinal, panel data set at both the building and tenant scale dealing with both the equity and debt side is brilliant; and the people on the team are excellent people and they're engaging with many excellent partners.

- Critical issue of lack of meaningful financial information to value energy efficiency projects and performance in real estate. This need is real and if they get the right data the results will be powerful.
- Good to bring in the big brokers, property managers, and asset owners to generate a good set of data.
- Really good plans on how to make this data sharing secure, standardize the data provided, and connect it to meaningful data points that can generate meaningful financial analysis.

2) **Project Weaknesses**

- The execution is flawed insofar as the data being collected falls short of the aspirations. I'd also suggest there are other data that will be needed, such as geospatial data sets linked to the buildings data for research controls (e.g. EPA Smart Growth database, US Census data, HUD location efficiency index data, macro and local real estate trends data, etc.). There are also critical needs in our data standards like the CREFC IRP and NCREIF so data normally collected breaks out energy bills and use. And I don't hear a late course correction being made that addresses the barriers that are impeding the data flow. They must be overcome.

- Still do not have a lot of data provided, or timeline for when they will get this data (and how much)
- Still do not know whether this dataset will be any good, or lead to the data necessary to do good financial analysis on energy efficiency projects and programs.

3) **Recommendations**

- Bring in the external review team; consult with RERI and NCREIF. Hold a special convening to take a deeper dive into project review/course correction. Start small, then bring in new entities that could help.

- Maybe consider starting shallow and then going deeper - every real estate company knows the rent they will get and the term on the lease. This should be easy to standardize and probably well-organized for each company.
- Try to figure out the most effective tools for companies that do not have well organized details on lease clauses and terms (especially around "unrecoverables" on capital and operating expenses.) Maybe this is in term sheet signed by broker and internal leasing agent, or in a lease abstract that is well standardized through acquisition or legal department.

Project # 25342: Energy Factors in Commercial Building Finance

Presenter: Paul Mathew, Lawrence Berkeley National Laboratory
DOE Manager: Holly Carr

Brief Summary of Reviewer Comments

Reviewers agreed this project supports BTO goals, with both noting that lenders and the mortgage industry had tremendous potential to impact broader investment in energy efficiency technologies and reduce energy use intensity. Both reviewers were impressed with the planned reports and market studies as being highly valuable for fostering the "eco-modernization" of lending practices. One reviewer noted that this project was unique in the field, as it is one of the few to examine default risk in the CMBS market—which lacks visibility nationwide—and because the findings could be applied to other lending pools that do not necessarily engage in the CMBS pool.

Both reviewers agreed the project's approach was sound, with one praising the decision to look at currently available market data to examine in conjunction with TREPP data for trend analysis. One reviewer suggested the project team should consider addressing the lack of data problem, which makes it difficult to analyze the effect of energy efficiency on default risk. Another reviewer noted that it would be beneficial for the group to get commitments from stakeholders for additional market research, as well pilot studies to test and measure the actual default rate against the baseline. One reviewer was concerned that the team did not discuss how the work gets incorporated into mortgage companies' process for integrating findings into their mortgage development processes, and thought a checklist of best practices could be useful.

The project's accomplishments, progress, and impact were also viewed favorably by both reviewers. One reviewer praised the inclusion of local and regional stakeholders, recommending this action be expanded to include national associations in a significant way. Another reviewer praised the use of available public data from new sources, as well as the inclusion of pilots that test new mortgage structures and property condition assessments. However, a reviewer cautioned that the limits of data should be emphasized.

Reviewers positively reacted to the project's integration and collaboration with external stakeholders, specifically calling out the project's involvement with mortgage lenders as beneficial. One reviewer was pleased to see the project team working to incorporate energy efficiency into every mortgage as a part of the overall mortgage process. Another felt the team's engagement with lenders was an overall strength and recommended a meeting with others working on this issue to discuss the implications from this research and future needs.

The project's proposed future work was scored favorably, with one reviewer very interested to see the planned case studies. Another reviewer suggested that the project team consider getting developers involved in the process to incorporate mortgage impacts into their decision making process. One reviewer suggested the team consider the need to amend standards that might impact the usage of energy efficiency data in load datasets going forward.

Weighted Average: 3.10 # of Reviewers: 2
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 3.25 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Lenders are key to financing efficiency and so both research on the relationship to risk and engagement with bankers on how to use that information in underwriting are key steps toward reducing EUI.

- Having an impact on the mortgage industry with regards to energy efficiency can have a tremendous impact on broader investment in EE technologies and programs. Focusing on mortgage lenders and the mortgage buyers is also valuable in ensuring there is a market demand and products available to meet that demand.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- They are not addressing the lack on data problem which will make it hard to monitor the effect of energy efficiency on default risk. The key there, I think, is the Commercial Real Estate Finance Council Investor Reporting Package which should be amended to have loan servicers report building energy efficiency values.

- Good approach to look at currently available market data first to see what sort of trends they can use (benchmarking disclosure from cities who are publishing this data) with the TREP data to see if there is anything that can produce mortgage default risk.
- Would be good to see this group get commitments from stakeholders (big mortgage "takers" and mortgage "makers" to help them more aggressively in market research, and test a pilot to see what the appetite is for this product and then measure the actual default rate against the baseline. Good that they are actively engaging lenders as they build datasets and try to make a case to create a market for these mortgage products (which seems to be implicitly another goal of this project).

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The bankers engaged thus far seem to be local/regional; it would be useful to engage national associations, which is suggested in the presentation but it's unclear the degree to which this will be a substantive dialogue.

- Great to see that this team used available public data from new sources and actually generated a defendable report that energy efficiency/management and price volatility actually had a measurable impact on the default rate of borrowers.
- Great that they are digging deeper with pilots to see whether or not mortgages can be priced or structured to better capture and incorporate this risk into their process. Also like that they are developing pilots for a property condition assessment by the mortgage lenders.
- Would like to see a mortgage provider actually testing a mortgage product near-term that would value this as part of the product, and to see how well this mortgage does in the marketplace once mortgage holders become aware of it and use it as part of how they think about energy efficient building purchases.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- As noted, I'd like to see more engagement with the national associations of mortgage lenders and CREFC

- Working closely with mortgage loaners and are testing their assumptions based on publicly available data. Working to hear from these lenders to see how important different factors are and putting EE into a language that is meaningful to them.
- Good that they are working to incorporate energy efficiency into EVERY mortgage, and making sure that it is considered as part of the mortgage process. It would be interesting to see how they engage the bankers and how they communicate out that they are now seeing this risk and quantifying how it translates into loan size, rate, and other terms.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The case studies will be very useful to see.

- They have a good plan for their end-game - getting all who offer mortgages to properly account for energy efficiency and energy management in the mortgage process.
- It would be good to consider the following:
    - Get developers to incorporate these mortgage impacts into what they decide to build and how they decide to renovate.
    - Consider a specifically market mortgage product with attractive terms for these energy efficient properties. This would drive demand to these properties and (possibly) allow mortgage companies to get better mortgage holders into their portfolio and reduce their default rate.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- The report will be very valuable for fostering eco-modernization of lending practices.

- Current deliverable (market study based on city benchmarking data) is really impressive and seems to have generated a lot of interest in looking deeper at this data.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 0** reviewers

- N/A

***No*: 0** reviewers

- This is one of just two projects I know of related to default risk in the CMBS market. More funding is needed on a national basis to improve our insight about the relationships here, as well as to expand the work into other lending pools (e.g. regional/community banks) that are important but don't sell loans into the higher risk CMBS pool.

- It would be great to better understand how the end game of this research (getting mortgage companies to work energy, price, volatility, and EE into their mortgage rates and terms) is achieved. The follow-up research is meaningful and continues to move us down the line towards more interest in this from the mortgage community and potential mortgage customers.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Reasonably strong evidence of relationship, good focus on underwriting and PCA, good engagement with lenders about how it might affect lending practice.

- Covered already in answers before
    - Focused on an important part of real estate finance for energy efficiency, and market failures in incorporating EE in the valuation process.
    - Interesting first study on publicly available data that makes a strong case for mortgage companies to take this seriously
    - Good plan for next pilots in partnership with mortgage companies interested in this data.

2) **Project Weaknesses**

- Would like to see limits of data emphasized and need to amend CREFC IRP (or other standards that would cause energy efficiency data in loan datasets).

- Still a little tough to see how and when this gets incorporated into how mortgage companies work this into their mortgage development process. It would be good to have a checklist of best practices or clear and easy ways for them to do this (a roadmap or quick steps). The project seems to be leaving a lot of the "how" on how to incorporate energy into their valuation process on the mortgage lenders. Will they take the time to do this, and is it worth it to them to get it right (so they can have a lower default rate and better mortgage performance)?

3) **Recommendations**

- After completion, which is soon, DOE should convene this group AND the few other groups working on default risk (An and Pivo and the group at Chapel Hill) with CREFC and Mortgage Bankers to discuss implications and future needs.

- A roadmap on how to incorporate energy price, volatility, and energy efficiency into the mortgage development process.
- A template mortgage product priced the right way to incorporate this into the cost or terms of a mortgage, to see what appetite is for this in the market. Would be an interesting way to influence major gut EE retrofits, how to design a new product for EE, or even to pursue energy based green building certification in existing properties.

Commercial Buildings Integration Technology Deployment

Project # 22230: Getting Beyond Widgets: Utility Incentive Programs for Commercial Building Systems

Presenter: Cindy Regnier, Lawrence Berkeley National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

This project was rated very highly by reviewers for its relevance to overall BTO goals and objectives. Reviewers agreed that the three integrated design strategies that would contribute to demand side management energy savings were relevant and would help meet progress towards BTO's goals. One reviewer noted that practical solutions for systems-levels approaches and savings had been "hard to come by," and thought that this project's development of complex methodology helped fill a gap in new and existing commercial buildings.

Reviewers generally agreed that this project's approach was effective. Reviewers agreed that the project team clearly identified barriers and had a strong methodology design for how to overcome them. One reviewer questioned whether the team was fully addressing the range of utilities that existed nationally, which could impact broad acceptance of the systems approach described. Another reviewer praised the team's incorporation of relevant feedback into up-front study methodology, changing what could have resulted in "lessons learned" into information that could address a wide range of relevant questions.

Reviewers commended this project for its accomplishments and progress towards its goals, with nearly every reviewer commenting on the measured results in the final project year. One reviewer, however, expressed doubts that the systems targeted by the project would produce the level of expected efficiency, expressly doubting workstation-specific lighting with daylight dimming. Another reviewer questioned whether utilities would actually adopt the project results as integrated packages with deemed savings.

Project integration and collaboration were well regarded by reviewers, with utility partnerships described by different reviewers as "strong", "active", "great", and "highly-effective." One reviewer expressed concern at a lack of partnership with end-users, while another worried about national applicability given the geographic concentration of partners, as noted above. The project team was also praised for how it shared information with stakeholders—particularly utility program audiences—via meetings, publications, and regular communications.

Reviewers praised the project's proposed future work, noting that next steps and future plans appeared clear, that they contained evidence of "closed loop feedback," and that the team planned to incorporate lessons learned throughout the project close-out process. Two reviewers cautioned that uptake of project findings might be more difficult than outlined by the presenter, with one cautioning that utilities might need additional resources to identify the best opportunities.

Weighted Average: 3.42 # of Reviewers: 6
Relevance: 3.67[1] Approach: 3.50 Accomplishments: 3.42 Project Collaboration: 3.25 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.67** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Systems-level efficiency programs have been broadly identified as an important opportunity to capture savings beyond those available from single component approaches, however practical solutions for getting to systems-level approaches and savings have been difficult to come by. Developing these solutions will be an important element in BTO's efforts to reduce buildings energy use and improve the energy use intensity of new and existing commercial buildings. For these reasons, this project is very important in helping BTO make progress towards its goals.

- Ability to expand the envelope for utility rebates will improve owners' opportunities to perform upgrades and save energy.

- Developing a comprehensive and cost-effective methodology to quantify system-level savings for utility DSM programs on a deemed savings basis is the next step in moving beyond utilities' cumbersome ET pipeline approach. And will help insure that higher levels of savings are captured. The relevance of this project was rated as 'outstanding' because it is going to take analysis and software development efforts at the National Lab scale to successfully develop this highly complex methodology.

- Seems to be a well thought out project and approach; and I agree that we need to go beyond the traditional widget incentives. Assuming they are correct in their estimates the systems approach should contribute significantly to BTO goals

- Problem statement and project need are clearly articulated and highly relevant to BTO goals.

- Project includes (3) integrated design strategies that contribute to demand side management energy savings contributing to BTO's goals.
- Estimated savings have been determined for each integrated system.

B. Approach

This project was rated:
1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.50** for the degree to which the approach addresses the market barriers identified.

- The project is focused on barriers specific to increasing utility programs for efficient systems including the policy/regulatory barriers unique to each of the states/utilities partnering with the project.

- Using FLEXLAB to measure and validate the different "systems" provide hard data on the benefits of matching multiple types of systems together.

- Effective approach. Engaging investor owned utilities as well as municipal/publically owned utilities covers range of regulatory requirements.

- They mention a few utilities they are partnered with - but - are they fully addressing the range of utilities that exist nationally? Will there be broad acceptance of this systems approach? What about areas (like Oregon) that have a third party energy efficiency program and incentive funding approach with NGOs that are involved (Energy Trust of Oregon, NW Energy Efficiency Alliance, etc.)? How will this approach gain acceptance with these areas?

- Approach was very clearly described, and very sophisticated in tackling the very thorny challenge of developing methods and documenting results that will enable how integrated packages of components work together to deliver "package" savings. Well-crafted study design that incorporates relevant feedback in

terms of what end users need to know upfront so that what could have been "lessons learned" were translated into up-front study methodology to address a wide range of relevant questions. Great job!

- Market barriers have been identified - main issue being that most utility incentive programs rely on the energy savings associated with a single widget. Greater savings are obtained with integrated solutions, but measuring the results is a challenge since they are inter-dependent. This project is structured to provide the measured results needed by the utilities for incentive programs.
- Offering utility incentives will accelerate market adoption of these integrated solutions.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is on track to meet its objective with rollout of three programs promoting efficient systems on track for launch by three utilities over the 2018-2019 program cycle. Test results demonstrate expected savings on the order of 20% of whole building energy use in existing buildings. Further testing of systems installed through the utility programs over a longer period (3+ years) will verify longer term field performance. This represents significant progress towards BTO goals of 30% EUI improvement in existing buildings and 50% EUI improvement in new construction. Savings in the three partner utilities, assuming 20% participation are substantial.

- Final year of 3 year project. Results were verified as predicted. Looking into rolling out to other utilities to expand the program.

- Measured energy savings of integrated End-use Systems suggest that whole buildings savings are within predicted ranges.

- I'm rating them lower on these two questions because I'm not quite sure that the systems they have targeted will produce the level of efficiency they hope for. Particularly the third project described on slide 13 (Integrated End Use System 3 - workstation specific lighting with daylight dimming).

- Results are impressive; "proof will be in the pudding" - will utilities actually adopt these as integrated packages with deemed savings? Despite the well-designed study approach, lessons learned still indicate gaps that I believe are likely to remain significant barriers to adoption by utilities and others in terms of deemed savings, or even full confidence in the broad applicability of these results.

- Measured results have been obtained and all utility partners plan to roll out a program.

D. Project Integration and Collaborations

This project was rated:

1) **3.17** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project integration with utility partners and potential future utility collaborators appears to be strong and partners happy with the results to date. The presenter did not go into detail about if/how the project worked with manufacturers, designers, or installers other than to mention that the involvement of multiple trades in installations may require additional program design elements. To fully evaluate the project, it would be helpful to understand whether the systems tested are currently available as complete systems, if any additional training for designers or installers are needed, etc.

- The project team has taken good steps to share the information on the project with important audiences, particularly in utility program audiences.

- 3 major utility partners.
- Presented at various meetings, published a paper and communicated with utilities.

- Developing and deploying project with multiple utilities and multiple end-use systems is a highly effective way to accelerate market adoption. It cuts out all of the middlemen and develops the systems in-situ. A very effective use of resources.

- It seems there is good collaboration with the partners/stakeholders they've identified but as I mention in an earlier comment - do they have all the required collaborators to be successful nationally? Particularly in areas where there are NGOs or other parties involved in energy efficiency and incentive programs - such as in the Pacific Northwest.

- Great collaboration with utility partners. End user engagement is lacking; even if adopted by utilities, end user demand for resulting incentive program would be critical in driving uptake.

- Active participation with utility partners and communications with other collaborators.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Next steps and future plans are clear and finite as the project is nearing completion. The assessment of potential M&V approaches and program manuals are likely to be of particularly high value.

- Appears they are wrapping up the project and gathering the information to present to the DOE.

- These steps will be vital to bridge the gap between a 'great' idea and a 'fully functioning' one. Utilities will need some type of screening/scoring tool to identify best opportunities for this type of system-level savings and to help guide incentive program marketing efforts.

- I see evidence of closed loop feedback and it appears they intend to incorporate lessons learned as they proceed through the project.

- Lessons learned and utility engagement appear to be on track to drive this project to relevant conclusion. Presentation was smooth, but actual uptake may be substantially more lumpy than anticipated.

- Development of M&V plans, assessment methodology and program manuals will be critical for the DSM program success.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- Good data which provides confidence in the program.

- No comment.

- None.

- The A/E industry greatly needs this type of data and incentive programs to support integrated design strategies.

***Average*: 2** reviewers

- I rated this average for lack of an option indicating that it is premature to judge. Major deliverables including final savings analysis, program manuals for partner utilities, and final program package have yet to be completed.

- The deliverables have not yet been produced so it's not yet possible to accurately rate them. I'll give them the benefit of the doubt and will assume they will be at least average. Perhaps they will be outstanding when they are finally delivered.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The project is focused on demonstrating energy savings and a critical deployment pathway for systems-level efficiency measures with significant potential to support BTO goals.

- Providing verified data and partnering with respectable utilities companies shows the emphasis is being placed on accurate opportunities for end users.

- No comment.

- None.

- The amount of data collected to support utility incentive programs is extensive so the fact that this program will be adopted by the three utility partners demonstrates that there has been sufficient emphasis. I would consider developing publications to share with other utilities to encourage continued adoption of DSM incentive programs.

***No*: 1** reviewer

- As mentioned earlier, I'm not sure the 3 systems are the correct highest payback systems. Particularly system #3 the workstation lighting. Perhaps in buildings where lighting is the dominant load but I would think that case is rare. I'd suggest developing at least one or two more integrated systems that are likely to be higher payback - and consider integrating ongoing M&V systems to help assure persistence of savings.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project focused on developing and testing out a potential solution to a timely problem. It seeks to clearly address major barriers -- the lack of certainty about energy savings and cost-effectiveness, lack of straightforward methods for EM&V, difficulties designing programs that align with existing TRMs and deemed savings approaches -- and work directly with interested utility partners to identify systems and approaches of interest to them. Great use of the innovative FLEXLAB facility.

- Good data via FLEXLAB trials.
- Good partners with utility companies
- Increased opportunity for additional savings

- Developing a comprehensive and cost-effective methodology to quantify system-level savings for utility DSM programs on a deemed savings basis has the potential to make an exponential improvement in how utilities meet their energy savings goals - and will simultaneously increase market adoption of efficiency technologies.

I believe they are on the right track - it is important to look at integrated whole building systems in addition to the existing approach to provide incentives for "widgets"

- Very relevant topic, well designed study, and a great set of work that will establish groundwork for viability of adopting a "beyond widget" approach to utility incentive programs.

- The ability to test a building's performance based on integrated systems was critical to the successful data gathering to support predicted energy savings that utilities can roll into incentive programs. The incentive programs will greatly impact market adoption.

2) **Project Weaknesses**

- Unclear how the project engaged manufacturers, designers and installers/trades. Communications and outreach to date seems largely focused on utilities and the efficiency program community. Outreach to a broader set of stakeholders seems to be lacking. Project was constrained by the need to go with the systems preferred by partner utilities (totally understandable and important) and as a result, all three projects centered on lighting technologies. It would have been nice to see how HVAC or other systems performed.

- Ability to get other utilities onboard.
- How to advertise opportunities to additional customers.

- None.

- Not sure they have all the right players involved when scope expands to national scale.
- Not sure they are using a reasonable cost per kWh ($0.16). It seems high to me but that may be due to my location in the Pacific Northwest where we are used to electricity unit costs that are half that. This could be an important consideration in project economics and payback calculations.

- Lack of end user engagement, challenges of multi variable studies introducing high levels of uncertainty in broad replicability of results, and challenges of accommodating the interactive effects of specific vendor implementations of each technology (which may significantly affect the composite performance) remains unaddressed, and potentially a significant barrier.

- Can't think of any.

3) **Recommendations**

- N/A

- Information on initial investment to implement the technology.

- Future project success will depend on development of a scaled screening/scoring tool that all utilities can use to identify best opportunities in their territories for this type of system-level savings and to help guide their incentive program marketing efforts.

- Consider adding M&V into the systems to ensure persistence - include EMIS or FDD tools as components in the integrated systems.

- None.

- Continue to support the DSM through the M&V plans. Share the results with other utility partners to further adoption of incentive programs in other areas.

Project # 22291a: Demonstration - Ibis Networks and Dynamic Water

Presenter: Michael Deru, National Renewable Energy Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project supported BTO goals and objectives, with one reviewer pointing to the need for performance testing and energy savings validation of individual technologies as a necessary step for deemed savings under utility incentive programs. Many reviewers agreed the Ibis Networks' IntelliSockets would help reduce energy consumption, but one questioned how the dynamic water technology would directly help with BTO's goals. Another reviewer wanted additional, specific information on potential energy savings from each technology to better gauge its level of contribution toward BTO program goals.

The project's approach received mixed scores from reviewers. While several thought the project team had a good plan—with one specifically praising the team's measurement and verification (M&V) plan and selection of test beds—several reviewers wanted additional information on specific market barriers encountered by the two technologies tested. Reviewers offered suggestions on key market barriers, including cost, cybersecurity risk, and the strong market channel that chemical companies have with operations and maintenance contractors.

Reviewers were split on the project's accomplishments, progress, and impact to date. Multiple reviewers praised the project for its installation, national brand partners, and its overall adherence to the project plan. Several reviewers wanted additional data on potential energy savings, cost, and building operations, which could help building owners and operators understand the potential costs and benefits from adoption.

While reviewers praised the outreach strategy of sharing project results with Better Buildings and the GSA Green Proving Grounds, multiple reviewers wanted to see additional outreach and collaboration with stakeholders other than the retail partners hosting the Ibis technology demonstrations. Reviewers suggested that organizations such as energy efficiency organizations, utilities, and building owners and operators should be included in outreach plans in the future. Several reviewers praised the team's collaboration with technical staff, pilot partners, and end users at demonstration sites.

Reviewers generally agreed that the current next steps and planned future work looked good, but many felt that specific details were lacking. Reviewers suggested that additional information would be beneficial on how to broaden the project into other markets and partners or how to incorporate lessons learned. One reviewer was concerned that a M&V plan had not been developed for one of the technologies, even though the installation was expected shortly. Another reviewer felt that risks of delay in demonstration projects was not adequately addressed.

Weighted Average: 2.71 # of Reviewers: 6
Relevance: 3.17[1] Approach: 2.58 Accomplishments: 2.75 Project Collaboration: 2.83 Future Work: 2.67

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.17** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project is designed to provide data on field performance and energy savings of emerging efficiency technologies to help address barriers to greater adoption. These objectives align with BTO program goals to identify and deploy new technologies to improve EUI of new and existing commercial buildings.

- Two different opportunities for saving resources.

- Performance testing and energy savings validation of individual energy and water efficiency technologies provides utility incentive programs with the data they need to begin designing deemed savings incentive programs. CBI's support allowing this work being done at a National Lab level ensures that the analysis is accurate and will meet or exceed regulators' requirements. Some third-party research efforts on individual efficiency technologies' savings and performance do not meet regulators' standards - making ET to Market projects of this type essential.

- There are two technologies demonstrated - the IBIS Networks IntelliSockets for plug load management and the DWT water treatment. As I understand the stated BTO goals they are to reduce energy consumption in commercial buildings. While I understand the importance of water as a resource and the value of water conservation it's not clear to me the water project ties directly to BTO goals - does it?

- Plug loads are a key source of unmanaged (and largely untracked) energy load. Cooling towers are currently managed by a chemically intensive process, in a manner that is similar to pool treatment - managing to minimum effective condition in a "one size fits all" way. Significant "white space" for these two technologies, real world results needed to spur adoption given market unfamiliarity with these technologies.

- Both the plug load management and dynamic water treatment technologies will help support BTO's goals.
- It would have been helpful for this reviewer to have some estimation of impact towards goal. This project seems to focus primarily on accelerating adoption of a couple of newer technologies.

B. Approach

This project was rated:
1) **2.50** for the degree to which it focuses on critical market barriers, and
2) **2.67** for the degree to which the approach addresses the market barriers identified.

- The project identifies some critical overarching barriers to greater adoption of emerging technologies in general -- lack of verified savings and performance, uncertainty and risk inherent in adoption of new technologies -- but doesn't drill down on specific barriers to the two technologies that are the focus of the project.

- Two different approaches to reducing utility use. Had a good plan to go from inception to completion.

- Effective research and demonstration approach.

- I don't see much (any?) detail related to market barriers so I'm rating both of these questions a 1
- In my opinion cost could be a significant market barrier. When asked during the presentation about the cost of the Intellisockets the presenter said they would likely be in the $100-$200 range. It would likely take a significant number of these sockets to have the impact on managing plug load that they describe. In addition it appears there is an ongoing subscription service cost to gain access to the data. Without knowing those costs it is difficult for me to provide a high rating on effectiveness.

- M&V plan appears to be well thought through, and the selection of test bed locations appears sound. Approach is focused on documenting performance of these techs, which is critical, and a solid communication plan is described. Key market barriers were not described however - for plug load control, significant cyber security risk and end user engagement with information; for AWT, the strong market channel chemical companies have with O&M contractors. Results will need to overcome skepticism of O&Ms that this technology will deliver over the long haul performance that will not degrade (and will enhance) the performance of a very large and expensive piece of equipment that provides core capability (cooling) for a building's occupancy.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is still in its early stages so there is limited information to report on accomplishments or impact. The project has clear objectives and has identified a good approach for demonstrating the technologies and disseminating findings. The presenter did not provide the level of detail on potential energy savings from the technology on a per-building or aggregate basis to gauge the level of contribution toward BTO program goals.

- Have multiple installations scheduled for May, with one already completed. Good National Brand partners.

- Project is on track.

- I do feel the Intellisockets are a valuable tool to gain better insight into plug loads but without knowing the likely cost (at least an estimated cost) of the hardware plus the hub and the ongoing subscription it's hard to determine if the project has a chance of succeeding in the market. I do like the idea though and at the right price I think it could be very successful.

- Great job by the team on keeping these two projects that could be challenging to move forward on track, on time, and moving forward in an effective way.

- Only 1 site has been identified for the DWT-UET technology. What is the building type? Will the results obtained from this installation be enough to help building owner/operators understand the potential benefits in their buildings?
- Not clear what kind of data is planned. What results are being targeted to share in the case studies?

D. Project Integration and Collaborations

This project was rated:
1) **2.83** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.83** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The presentation didn't mention how the project would integrate with stakeholders or collaborators other than the retail partners that will host the Ibis technology demonstrations. Target audiences (primarily building owners) were identified, but the outreach strategy seems limited to reporting on project findings through Better Buildings and GSA Green Proving Ground materials. More detailed outreach and deployment strategies involving a larger number of stakeholders would be beneficial to extending savings.

- Communication through Better Business Initiative channels.
- Communicate through Better Buildings and Green Proving Grounds.

- Large National brand chains as partners.

- Very high quality integration/collaboration with technical staff, pilot partners, and instrumentation subcontractor. BBI communication channels ensure a large audience for promotion of results.

- I would think it would be helpful to include entities involved in energy efficiency program delivery in the field - utilities, energy efficiency organizations (like the Energy Trust of Oregon, NW Energy Efficiency Alliance, etc.) as they could provide useful feedback about likely acceptance in the market place and potential price points that work.

- Great job working with both the industry proving the technologies and the end users in demonstrating and communicating outcomes.

- The DWT-UET stakeholders were not clearly defined. It seemed like the manufacturer, Dynamic Water was involved but were building owners/operators included? Including them would help to understand how the data gathered can be disseminated to address their concerns/questions relative to adoption.
- The Ibis, plug-load management system, is more defined relative to sharing results.

E. Proposed Future Work

This project was rated **2.67** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Next steps and future work are well laid out and represent the bulk of the project effort. One of the early lessons reported for the project is that it is "difficult to plan demonstration projects around activities of real buildings." The risk that these difficulties could significantly delay the project or even potentially eliminate one or more planned demonstrate site isn't addressed.

- While current plan looks good, specifics on how to move forward are a bit lacking. Would like to see better details on how to broaden the project into other markets and partners.

- Implementation guidance and DOE Tech to Utilities effort should help accelerate market adoption.

- Not much detail provided; little evidence of closed-loop feedback to incorporate lessons learned along the way.

- Future work / stages not described in detail in presentation.

- Concerned that a M&V plan has not yet been developed for the DWT-UET technology and installation is expected to start in May. This will be critical in gathering the needed data to share outcomes.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- BBA and GSA-GPG put out high quality materials showcasing promising emerging energy efficient technologies for target audiences. Materials targeting specific key audiences and other relevant stakeholders would be valuable.

- These two technologies will be ready for utility incentive program design.

- None.

***Average*: 3** reviewers

- With better data, the value may become more evident. At this point, there are too many questions.
- Little detail available about actual deliverables; difficult to rate in advance; providing an average rating on assumption they will be at least average.
- I understand that measurement and verification data will be gathered, but without understanding market barriers, how will the publication be developed to promote adoption?

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The emphasis on installing and testing emerging technologies in real world demonstration sites fits well with project and program objectives.
- The plan seems to be solid, but more time and validation is required.
- Focused on testing and documentation of water and energy savings technologies.
- None.
- Integration and collaboration with Better Buildings and GSA GPG will extend the reach of the project results.

***No*: 1** reviewer

- It's difficult to tell which key partners are involved with which systems (Intellisockets vs. water treatment system)... this makes it difficult to tell if the right players are involved. I suspect though that there should be a wider range of partners.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project has a clear and well-defined scope to demonstrate two particular technologies in real world settings then publish and disseminate results through established DOE and GSA program channels.
- Ibis. Ability to control plug loads that typically remain on during unoccupied times.
- Dynamic Water Treatment. Ability to control corrosion and reduce water usage.
- Comprehensive efficiency technology testing is sorely needed to move technologies to market. The National Labs/BBI/HIT Catalyst ecosystem is a proven bridge from R&D to high levels of market adoption.
- I believe the Intellisockets and data analysis tools will be an interesting and potentially valuable system. It would be very interesting to try and learn more about plug load in our buildings.
- Two key technologies with effective demonstrating and M&V plans
- Both technologies in this project have an opportunity for greater market adoption leading to energy savings supporting BTO's goals. The technologies are beyond emerging - they have been in the market for several years. The approach of identifying demo installations to measure results and publish documents to

encourage greater adoption is strong. Most owners want to understand where these technologies have been applied and speak to building operators.

2) **Project Weaknesses**

- Lack of clarity on how findings will be tailored to key target audiences and broader set of relevant stakeholders.
- Potential risk of demonstration disruptions is not addressed.
- Potential savings are not clearly communicated -- even in terms of rough estimates of impact. Much more information on water savings and energy savings from DWT would be helpful. It would also be helpful to understand what the energy consumption of the DWT system itself is and how much that offsets the savings from cleaner heat transfer surfaces. Are there other energy savings opportunities?

- Ibis. How to change occupants behavior on why not to plug loads into non-controls outlets.
- Dynamic Water. Cost of reactors and frequency they need to be changed. Monitoring water quality.

- None at this point.

- Potential costs and even possible administrative complexity. There would likely be a significant number of Intellisockets to manage and I would imagine building occupants could remove them or plug different equipment into them that would corrupt some of the collected data.

- Cyber security needs to be addressed for plug load control to ensure that the market space is not ultimately compromised by a "celebrated" hack. Cost benefit for both technologies will need to be clearly described.

- Concern is primarily on the limited number of installations for the DWT-UET. More installations would build a more robust library of case studies that address their specific building use-type.
- Additionally, both technologies have been around long enough to have identified major market barriers so the results gathered from the demo installations can address these issues.

3) **Recommendations**

- N/A

- Better data on performance of each individual technology.

- Suggest in-depth focus on DWT reactors – replacement and installation costs and difficulty, additional trade ally training, etc. This is the type of complexity that could result in an unanticipated market barrier after commercialization.

- Put more thought into the likely barriers and the real cost-effectiveness of the system.
- I have not commented on the water treatment system as I'm not sure it provides much contribution for energy reduction as stated in BTO program goals.

- None

- See previous comments.

Project # 22291b: Advanced RTU Campaign

Presenter: Michael Deru, National Renewable Energy Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed that this project was highly relevant to BTO's goals and objectives. Multiple reviewers agreed that rooftop units (RTUs) represented a large energy load for commercial buildings, and that advanced RTUs and control retrofits offered significant energy savings potential.

Reviewers called this project's approach "robust", "effective", and "impressive." Reviewers praised the team's identification of key barriers and proposed solutions, the broad set of stakeholders and partners involved in the project, and the use of lessons learned to inform future work. Reviewers also praised the information created by the team and disseminated among multiple outlets to inform stakeholders and potential partners on energy savings opportunities. One reviewer specifically praised the team for working with building codes and utility incentive programs. Critically, one reviewer noted that while the project team mentioned that savings from variable speed drive technology in RTUs could be challenging to verify, the team did not propose a method to address this issue.

Reviewers agreed that the project team was meeting target goals and had seen some significant accomplishments to date. One reviewer noted that—based on lessons learned—there were still opportunities to increase market adoption, especially by better understanding the energy savings from variable speed RTUs. Several reviewers praised the team for the qualitative and quantitative data they presented on the project's impact. One reviewer suggested additional engagement and education of those RTU contractors that replace existing equipment, as they might be able to share the impacts of high efficiency equipment with building owners.

This project was praised by reviewers for the large number of partners—representing all major stakeholder groups—that were upgrading RTUs. Reviewers called this collaboration "good", "responsive", and "effective and comprehensive", with one reviewer noting that there was clear evidence that the team was effective in collaborating with key partners to move the market. Reviewers suggested that in the future the team might try to increase collaboration with trade and industry groups as well as the design and construction communities.

Reviewers generally rated the project well for its proposed future work, with several noting the team's plan to address identified barriers and risks and leverage lessons learned to advance market transformation. Several reviewers praised proposed future work around documenting the persistence of savings from automatic fault detection and diagnosis, but one reviewer wanted additional details.

Weighted Average: 3.50 # of Reviewers: 5
Relevance: 3.80[1] Approach: 3.60 Accomplishments: 3.50 Project Collaboration: 3.40 Future Work: 3.40

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- RTUs are one of the largest energy consumers in commercial buildings and new advanced RTUs and controls retrofits offer great energy savings potential. The project's objective to accelerate and expand adoption of this significant energy user aligns well with broader BTO program goals.

- Very relevant to reducing utility cost across the nation.

- The project statement says it all: "RTUs condition over 60% of U.S. commercial floor space and have a typical life of over 15 to 20 years and replacement is often only after failure with a new version of the old unit."
- With the recent development of advanced controllers for the retrofit market, this is a significant opportunity for market transformation.

- This project addresses a key and critical aspect of the commercial building inventory - RTUs. Significant progress has already been demonstrated in the presentation details and it is clear their target (RTUs) are a high potential area for contribution to the BTO program goals.

- Rooftop units comprise a large percentage of the energy use associated with commercial buildings. Energy savings associated with RTU's will contribute greatly to BTO's goals.

B. Approach

This project was rated:

1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.60** for the degree to which the approach addresses the market barriers identified.

- This is a robust project. Key barriers are identified along with proposed solutions for addressing the barriers. The project is designed to work with a broad set of stakeholders to address most market barriers identified.

- Barriers are identified and solutions are proposed. Has aligned with many owners, manufacturers, suppliers, service providers, etc. Using market leaders to perform outreach.

- Effective research and technical campaign:
    - demonstrate performance
    - identify and promote best practices
    - provide biz case support
    - share lessons learned with all participants.
    - engage a wide range of stakeholders.

- They have an impressive list of partners and a significant degree of participation/involvement.
- They mention that savings from variable speed drive technology in RTUs can be challenging to quantify/verify but they don't propose a method to address.

- Project has identified the various methods owners deploy for rooftop equipment replacement and established relationships with these key partners. Working with building codes to increase equipment efficiency requirements and utilities for incentive programs are effective ways to overcome market barriers.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project has some significant accomplishments and met/exceeded deployment goals. Energy savings to date are impressive -- almost 18 TBtu over the first 3 years--and will contribute substantially to BTO program goals. Presenter did a good job of providing quantitative and qualitative data on the project's progress and impact.

- Lots of data to prove the performance of the program. Annual results have met target goals since 2013.

- Effective campaign with wide market impact.

- RTUs should be a high potential opportunity for efficiency due to their high degree of market penetration. The project team has a significant and impressive list of partners; they have done a nice job of quantifying the opportunity and progress to date.

- Deployment goals have been met every year. However, based on lessons learned, there are still opportunities to increase market adoption. Better understanding of energy savings associated with variable speed RTUs is one area. Another is educating RTU contractors who are often engaged by owners to replace existing equipment. If these contractors are able to share the impacts of selecting high efficiency equipment (energy savings, lifecycle costs, payback) owners are more likely to choose the high efficiency option.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The program has over 290 partners representing all major stakeholder groups. The project experience and progress reported suggests that the project team has worked closely to collaborate with stakeholders and closely coordinate on all elements of the project. For example, the presenter discussed their efforts to work with utilities to figure out why participation dropped after two years of growth and address the issue.

- DOE oversees the Campaign. 212 supporting partners.

- Effective and comprehensive Campaign team, partners, subcontractors, and collaborators.

- Clear evidence that they are effective in collaborating with key partners; RTU challenge and its ability to move the market (RTU manufacturers) is a good example.

- There has been good collaboration with a broad spectrum of stakeholders.

E. Proposed Future Work

This project was rated **3.40** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Proposed future work will explore additional opportunities to increase project impact, address additional barriers uncovered over the course of the project to date and transition project resources and activities to the market. The project team has identified barriers and risks and is working to address them: pushing for introduction of more basic units w/out premium features to address cost barriers; development and expansion of comprehensive utility programs to complete additional efficiency improvements with an emphasis on those that will allow downsizing of RTUs to mitigate the issues of added weight and costs; addressing concerns of smaller building owners.

- Large group of participants during initial phase. Easy to take data and apply it to any market across country.

- Documenting persistence of savings due to AFDD is an important outcome of this work and will help bring accuracy to utility incentive program calculations.

- The next steps/future plans are good; but a bit light on detail. There are a few clear priorities (AFDD, improved calcs/modeling and support for utility programs) but I think they could say more about how they will continue to incorporate lessons learned and continually refine/improve.

- The team is leveraging successes and using lessons learned to further advance market transition.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers

- Significant technical resources on DOE project website; information disseminated through webinars and many articles and other program related materials. Business Guide and Green Lease Language are assets for project partners.

- Deliverables are quantifiable and successful.

- A wealth of useful information, best practices, and shared guidance were produced by this project.

- Campaign website, green lease language and high efficiency RTU specification are great examples of useful deliverables that should make it easier for key stakeholders (building owners) to adopt the recommended best practices.

- Good data has been collected regarding the number of RTUs installed and associated estimated energy savings.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- Project team and partners appear focused on maximizing advanced RTU deployments to maximize savings towards critical program goals.
- Key areas are being identified and data supports the work.
- No comment.
- Nothing else to add here; this is a great project!
- Based on the number of partners engaged and industry collaborators as well as success, I think the program is very focused on the objectives.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Coordinating efforts of comprehensive set of stakeholder partners.
- Responsive to partner needs; collaborates to address issues and barriers as they arise and incorporate lessons learned
- Project has met or exceeded deployment goals
- Strong efforts to publicize results and recognize partner efforts
- Very low cost program -- good leveraging of private sector funds to yield impressive results
- Amount of data and partners for initial phase.
- Ability to apply results to any market across the country.
- Please see comments on relevance.
- Well defined list of partners; good detail on size of opportunity; good metrics quantifying progress to date; good list of deliverables and resources
- The potential energy savings and contribution to BTO goals is significant. The project team has identified market barriers and identified partners to help overcome these barriers.

2) **Project Weaknesses**

- N/A
- I do not see any.
- Trade and industry organizations only represent ~ 3% of total campaign partners yet in the retrofit market, installation often accounts for a large percentage of unanticipated barriers to adoption.
- While the list of partners/collaborators is quite good it occurs to me that the design/construction community could have something to offer and they may not be adequately represented. Particularly mechanical design.

- The only area I see for improvement is with the contractors that are engaged directly by owners for a equipment replacement. Educating this sector with the energy savings potential, life cycle cost payback will be important to achieve greater market adoption.

3) **Recommendations**

- N/A

- Project is going in a good direction.

- Suggest increased focus on very low overall participation rates in utility incentive programs for advanced RTU controllers. What are the barriers and how can they be overcome?
- Suggest using campaign influence to encourage manufacturers of efficient RTUs, like single zone vav units, to use non-proprietary communications between the RTUs and their Tstats to allow for interoperability with other types of Tstats (web-enabled).

- Add closed loop feedback to incorporate lessons learned.

- Gather more post-operational data on the energy savings associated with variable speed units. There seems to be a lack of good data to inform owners of what to expect.
- Continue to work with utilities to integrate this equipment in their incentive programs.

Project # 22292: Smart Energy Analytics Campaign

Presenter: Jessica Granderson, Lawrence Berkeley National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers generally agreed that savings from energy management information systems (EMIS) would support BTO's goals and objectives. One reviewer, however, expressed concern that while the technology provided opportunities, it was unclear if key decision makers—identified as utilities and program funders—agreed that EMIS and fault detection and diagnosis (FDD) contributed to energy efficiency.

The project's approach was praised by reviewers, with one noting that the "campaign approach" provided needed information to partners. One reviewer suggested additional barriers for the team to consider, however, including push-vs-pull information availability and utility incentives for EMIS and FDD.

Reviewers were mixed on the project's accomplishments and progress to date. One reviewer praised the project team for the number of partners and square footage included in the campaign, while another highlighted the lessons learned and their impact on demystifying some of the complexity and confusion surrounding the technology. Another reviewer thought the presentation needed to include more specifics on how to overcome the challenge of finding "time/capacity to use tools," noting that while the team provided a good set of resources on how to source and implement EMISs, additional thought needed to be put into ensuring the persistent use of the systems. Another reviewer noted that the actual savings to date were fairly low, suggesting that the project team should focus on ways to increase participation and market share.

Reviewers' views on project integration and collaboration were mixed, with some reviewers calling the project's collaborations "robust" and "effective," but others recommending more recruitment from end users—including energy managers, energy engineers, facility operators, and contractors—for a more "complete" key partner list. Another reviewer suggested additional partnership efforts with utilities, including having these systems included in incentive programs to overcome first cost challenges.

The project's proposed future work was viewed positively by many reviewers, though they touched on different aspects of the future work that they thought should see increased effort moving forward. Two reviewers called out the work around minimum code requirements as a good idea that could be very successful if implemented. Similarly, two reviewers agreed that the synthesis and incorporation of lessons learned could lead to more efficient building operations. Two other reviewers suggested that partner recruitment and engagement needed to be a focus, with one suggesting a recognition program to elevate participation and the other suggesting increased participation at energy conferences.

Weighted Average: 3.03 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.00 Accomplishments: 3.13 Project Collaboration: 2.88 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- EMIS allows building owners to measure and identify performance of their HVAC systems. Opportunities to correct deficiencies are greatly increased when EMIS are used.

- Proliferation of complex EMIS technology continues to increase while user-knowledge of the functionality and potential to identify energy savings measures of these products remains very low. EMIS technology has the potential to identify and in some cases, implement, system- and whole building-level energy efficiency improvements at scale but given the current complexity of offerings, confusing marketing materials, and inability to test out systems before purchase - these products remain underutilized and their potential to identify energy savings un-validated.

- I'm a strong believer in this technology; I'm rating as a 2 instead of a 3 because I'm not sure that the key decision makers (utilities; program funders) agree that EMIS and FDD systems will contribute directly to energy efficiency. I think more policy work may be required to make this case successfully.

- The energy savings potential provided supports BTO's goal.

B. Approach

This project was rated:
1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Good approach with good partners.

- A campaign approach provides needed information on EMIS cost and benefit and market information to partners to facilitate adoption at scale.

- I think more detail is required describing the plan and tangible steps they'll take to overcome the key barriers; there are clues throughout the presentation but I think the details should be more clearly stated.
- Additional barriers to consider:
    - Making time to use the information available from the systems; these tend to rely mostly on a "pull" approach where the users will log in to the system to take advantage of the information. Many can also push information out via email and threshold alarms/messages but that requires some level of user involvement to set up. A potential method to overcome the barrier would be to encourage system developers to pre-configure certain "push" features that will ensure information is made visible to users.
    - Utilities and their funding partner organizations should be encouraged to offer incentives for EMIS and FDD systems. Sometimes they are reluctant to do so because the system itself doesn't directly deliver energy efficiency; however if used well they certainly contribute to savings and can help assure persistence of savings.

- Aligning with Better Buildings Alliance is a good approach. Educating users on the tools will be important.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- 217 Million sf of participation with 30 partners. All participants receive support for best practices and operations.

- Lessons learned demonstrate that EMIS Campaign is demystifying some of the complexity/confusion that surrounds this technology:
    - Providing information back to participants on cloud-based gateway solutions.
    - Coupling with sensors and controls – interoperability
    - Identifies and asks essential questions:
        - "What are you trying to accomplish in your building?
        - "What kind of staff do you have to work with?
    - Explores the role of submeters – FDD tools usually operate on existing EMS information.
    - Campaign in conversation on next generation EMIS Technology

- I think this project has great potential to encourage more adoption of EMIS and FDD systems; however I also think that they need to provide more specifics on how they may overcome the barrier of "time/capacity to use the tools" .. This project team has provided a good set of resources to help building owners get started on sourcing and implementing these systems; more thought needs to be put into the topic of ensuring persistent use of the systems.

- To date, the savings achieved has been below potential. The interim goal for FY 2020 shows promising impact for contributing to BTO goals. Methods to increase participation should be the focus.

D. Project Integration and Collaborations

This project was rated:

1) **2.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Outreach to over 60 EMIS companies. Multiple posts to social media, partner networks and web news. Presented information at multiple national seminars.

- Effective selection of Organizing and Supporting partners covers the ecosystem of stakeholders.

- The key partners listed in the first slide are probably only a representative sample but I think it could be more complete - for example, it may be beneficial to recruit a few other partners such as the Energy Trust of Oregon, APEM (Association of Professional Energy Managers), AEE (Association of Energy Engineers) if they haven't already done so.
- Later slides mention some of the outreach and collaboration work they've done but more detail here would be helpful.

- The integration and collaboration is robust with 67 supporting partners and 5 organization partnerships.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- While risks were not specifically called out, the information provided does show a clear path to market. The infusion of minimum code requirements and a curricula and certification program will further provide validation to the program.

- Great opportunity to synthesizing what measures folks are actually implementing and identifying those best practices that will lead to routine efficient building operations.

- I think their plan to influence code requirements to incorporate minimum points (loads?) for measurement is a great idea; if they can successfully influence code to require this it will ensure implementation.
- I like that they have mentioned ongoing learning and incorporation of "lessons learned" in a few places in their presentation - I think this is an important element.
- It would be nice to see more detail on how information will be shared in the future regarding the best practice examples and evidence of savings produced by persistent use

- Recruitment efforts need to be a focus. Would a recognition program help elevate participation? What successes can be leveraged from other programs?

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- Deliverables were good and quantifiable.

- No comment.

***Average*: 2** reviewers
- Difficult to assess the value of the deliverables without actually seeing them; for example, what does the technical assistance actually look like? What has been the utilization of that assistance so far? I do think they are on the right track

- There has been a lot of promotional and educational materials developed supporting market adoption.
- The focus needs to be engaging participation. Are there other opportunities to reach targets? Maybe speaking at or setting up booths at energy conferences?

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Good emphasis has been placed on the EMIS and how to support it to the end users.

- No comment.

- Since this is a campaign I think their ideas to stimulate adoption are on the right track; as mentioned earlier though there are areas where more detail would be helpful.

- It appears that partnerships have been established to reach targets for participation. This should be a key focus.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Current success of program.
- Momentum to work towards code inclusion and curriculum.

- This Campaign will help demonstrate EMIS performance in commercial buildings and drive adoption.

- Good progress towards their goals/timeline
- Well thought out metrics to track to verify performance of the campaign

- The potential energy savings based on commercial buildings greater than 50k sf contributes greatly to BTO goals.

2) **Project Weaknesses**

- Need more details on specifics of exactly what and how the program operates.

- No comment.

- Find ways to recruit more end users of these systems; perhaps through groups like Association of Professional Energy Managers (APEM) or Association of Energy Engineers (AEE); learn from them - what are the time/capacity constraints that might prevent them from using the systems regularly. Get their input on how those constraints could be overcome.

- The actual savings to date is fairly low. Need to focus on ways to increase participation to increase market adoption and realize savings potential.

3) **Recommendations**

- Need to include website or address in presentation to allow for easy access to investigate data.

- None.

- No additional recommendations other than those mentioned in earlier questions

- Target facility operators, contractors that install equipment replacement and educate them on the usability of the tools and case studies of measured energy savings achieved.
- Consider utilities and work with them to integrate into incentive programs. This often helps overcome the first cost challenge.

Project # 22293a: Innovation Challenges: Control-Enabled LED Retrofit Kit

Presenter: Michael Myer, Pacific Northwest National Laboratory
DOE Manager: Amy Jiron

Reviewers agreed that this project supported overall BTO goals and objectives, noting that there was enormous potential for energy savings if the specification challenge was successful. One reviewer noted that a specification could help manufacturers create products that reduced the number of decision points that building managers face when looking for lighting retrofit options for commercial buildings, which could be well-received by occupants and provide building owners and managers with energy savings.

The project's approach was well received by reviewers, with reviewers praising the approach as thorough, creative, and likely to spur industry development of higher efficacy luminaire packages. Reviewers pointed to the project's referencing of similar challenges—which have been effective in the past in working to spur industry development—for guidance. Reviewers also approved of the specification development plan's consideration of technical and market barriers. One reviewer cautioned, however, that risk lay primarily with manufacturers to develop a cost-effective product that meets this specification. Two reviewers also expressed concern that the market for LED technology might be moving faster than the project, noting that while kits are currently cheaper than fixtures today, that might change in the relatively near-term future—which could undermine the cost savings the project envisions.

Reviewers generally praised the project's accomplishments, progress, and impact to date, with one reviewer noting that the team was on track and meeting milestones, and another highlighting the project's potential to affect a very large energy load if successful. Reviewers praised the team's work with stakeholders, including getting feedback from DOE's solid-state lighting team and others. Reviewers noted the importance of price points and measured results from actual installations to address owner concerns and impact market adoption.

The project's integration and collaborations were rated highly by reviewers, who praised the project team's work with existing DOE initiatives (e.g., Better Buildings and the Interior Lighting Campaign) as well as corporate partners, other federal agencies, and utility and efficiency groups. One reviewer suggested additional outreach to trade and lighting distributors or electrical contractors, who could influence lighting selections.

Reviewers noted that the project team had effectively planned future activities, including incorporating feedback and continuing work on the specification and coordinating with Next Generation Lighting Systems for demonstrations. Reviewers were pleased that the project team was considering lessons learned from previous innovation challenges. One reviewer was also pleased by the team's anticipation of barriers by front-loading work with California to determine the cost-effectiveness of kits for inclusion in utility incentive programs.

Weighted Average: 3.45 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.50 Accomplishments: 3.40 Project Collaboration: 3.60 Future Work: 3.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Working towards full scale control-enabled LED kits for the general public.

- The controlled-enabled LED retrofit kits specification fills a need for the lighting industry to develop a 'plug-and-play' option for commercial lighting that offers enhanced functionality beyond the existing TLED 'plug-and-play' option. There are many choices involved in choosing an efficient, effective and cost-effective lighting retrofit for commercial buildings. Identifying the best options from a bewildering selection of variables (efficacy, efficiency, CRI, dimmability, color tuning, ...) is very difficult for the average building owner, facility or energy manager, or lighting contractor - which is why they often settle for a TLED solution. Creating a specification and challenging manufacturers to pre-select the optimal options and combine them into a retrofit kit removes the confusion and offers a solution that optimizes the decision points. It offers 'plug-and-play' enhanced functionality to decision makers and increases the likelihood that the lighting retrofit will be well-received by building occupants and will provide building owner/operators with energy savings and minimal effort in project specification and installation.

- Project has a relatively narrow scope and focus - control enabled lighting upgrade kits; yet has a lot of potential to generate energy savings since the installed base of fluorescent and other older technology is so large.
- If the challenge does stimulate manufacturers to produce upgrade kits that overcome the barriers (first cost, high install labor costs, etc.) there is enormous potential.

- Clearly identified need / problem statement, initiative very likely to drive market to provide technology that will answer end user requirements and deliver significant overall energy savings.

- The control-enabled LED retrofit kit provides a tremendous opportunity to achieve aggressive lighting energy savings in a market with low adoption of LED technology. The energy savings potential supports BTO's goals.

B. Approach

This project was rated:
1) **3.80** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- Following the same path as the LED Parking lot lighting project. Collaborating with DOE programs to implement.

- Very thorough approach. Specification development takes into consideration:
    - Weakness of TLEDs - no ability to add controls to tubular lamps - and identifies opportunity to create an improved, cost-effective alternative
    - Labor can outpace the cost of material – innovative kit option addresses this reality
    - Lamp savings 50% - with controls 80% - adding controllability increases the potential savings on a Btu/sq ft basis
    - Considers how far to push efficacy and explores the tradeoffs
    - Looks beyond troffers.
    - Produce specifics for end users to understand end of life
    - Incorporates on-board sensors.
    - Considers installation time and required resources (staff and equipment, etc.)
    - Doesn’t address glare because it is difficult to quantify (i.e doesn't expend effort heading down a rabbit-hole unnecessarily)

- Identified barriers include: labor costs, installation method variability whether or not these barriers will be overcome by the manufacturers in response to the challenge remains to be seen. Initial comments/feedback from manufacturers seems to be positive and past challenges do seem to have been effective in influencing manufacturers.

- Approach is broadly likely to spur industry development of a higher efficacy luminaire package than it would develop without this effort likely to better satisfy end user requirements and acceptance. Nicely targeted to spur development of a product class that goes well beyond the TLED that industry might otherwise develop. Tech to market approach could potentially be augmented

- Market barriers have been identified through engagement of broad spectrum of stakeholders. Lighting performance seems to be a key barrier as well as installation costs. Performance characteristics have been well defined and a specification developed. The Innovation Challenge is a creative approach to engage manufacturers in developing a cost-effective product that meets this specification.
- Demonstration projects will provide the actual measured performance critical for building owner/operators to gain acceptance. The primary risk lies with manufacturers engaging to develop a cost-effective product for this market.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.40** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Currently drafting specification for program. Plan in place for moving to the testing phase.

- Project is on track and is meeting its milestones. Specification had been developed, reviewed by DOE SSL team, distributed to stakeholders, and is receiving great feedback from manufacturers.

- Because of the broad installed base that exists this project has the potential to affect a very large energy load.

- Lighting is second largest energy end use in commercial buildings, and easiest to target relative to lower first cost and shorter payback than HVAC. Price point (as described in presentation) will be critical in enabling this technology to capture significant market share.

- Good progress has been made. Performance specification has been developed based on feedback from broad spectrum of stakeholders.
- Demo installation to validate energy savings are yet to be completed. The measured results from actual installations will be key to addressing owner concerns, market adoption and impact relative to program performance goals.

D. Project Integration and Collaborations

This project was rated:
1) **3.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Collaboration with Better Building, Interior Lighting Campaign General Services Administration, Federal Energy Management Program, etc.

- Project is:
  - Conducting quarterly calls with BBA end-users.
  - Receiving real world feedback from Walmart
  - Developing campaign elements: information + feedback + recognition
  - Demonstrated success of kit approach when FEMP used LED retrofit guide to inform lighting retrofit decisions for FEMP managed buildings.
  - Collaborating successfully with FEMP, GPG, DLC, utility and efficiency groups

- Good collaboration and integration with other existing programs and entities (GSA, NGLS, DLC, utility efficiency groups, etc.)
- Target market and audience for awareness could/should include trade allies and lighting distributors/electrical contractors. They often influence the lighting upgrade selections and make recommendations to building owners that may not be well informed on current technology.

- Well defined approach to capturing relevant end user and manufacturing partners

- Collaboration has included broad spectrum of stakeholders and partners. Strong integration with other programs (BB, ILC, FEMP, GSA GPG, NGLS, etc.) and utility incentive programs means information will be distributed to help accelerate adoption.

E. Proposed Future Work

This project was rated **3.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Working on specification.
- Coordinating with Next General Lighting Systems for demonstrations.

- Project is anticipating barriers by front-loading work with CA to determine cost effectiveness of kits for inclusion in DSM programs. This demonstrates a high level of understanding of barriers that could minimize the effectiveness of technology acceptance and promotion through utility incentive programs.

- Next steps include incorporation of feedback; nice example of closing the loop. Also incorporates learnings from past challenges (ILC, exterior lighting challenges/specs, etc.)
- Includes a step to assess and review the success of this challenge/project and continue the learning.

- Future steps were not well defined in presentation, but appear to be well considered.

- Innovation Challenge to the manufacturers is a creative way to engage them in developing a product that meets the performance specification that has been developed. There is risk in this approach since there are no guarantees that manufacturers will respond.
- Demo installations are a critical next step so hopefully, there will be a positive response to the challenge.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- This project has clearly defined targets - spurring manufacturer innovation and offering end-users an unique and effective retrofit product that is not currently available in the market.

- Well integrated with other lighting campaigns/challenges, takes advantage of existing communication and awareness channels.

- ?

***Average*: 2** reviewers

- If the project can stay ahead of the market, this will produce a third option for owners to implement lighting upgrades.

- Primary deliverable developed to date is the performance specification. Next step is the product developed by manufacturers that meets this specification.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The emphasis is placed appropriately to develop the retrofit kit market.

- See previous comments.

- No further explanation necessary. See earlier comments.

- No comment.

- There is a tremendous amount of outreach and engagement with other DoE programs and industry programs.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Ability to fill a gap in the current market.
- Working with good partners.

- Development of this specification encourages lighting manufacturers to innovate and create new product offerings that will encourage market uptake of higher efficiency lighting retrofits. End-users are offered attractive retrofit lighting solutions that would not otherwise be available. It's a win-win for the biz case: manufactures increase sales by offering a new, attractive product and end-user install equipment that provides higher quality lighting for building occupants with higher cost savings.

- Low cost project with high potential to contribute to BTO goals!
- Comprehensive and detailed

- Project could have a significant impact in driving industry to develop and end users to adopt a better product at a competitive price relative to TLED

- The project focuses an opportunity for large energy savings in a market that has had minimal adoption of LED technologies. Strengths include the collaboration with a broad spectrum of stakeholders to understand market drivers and barriers. Integration with other programs will help accelerate adoption.

2) **Project Weaknesses**

- Is the market moving faster than this project? LED technology is moving very quickly and while kits are a bit cheaper than fixtures, for how long?
- None that I can see.
- Only weakness I can think of is that it remains to be seen if manufacturers will respond and provide cost-effective retrofit kits in time - before the whole fixture costs drop to a level where a retrofit kit may not make sense.
- Several challenges likely to inhibit adoption appear to be beyond scope of project as currently conceived. These include distribution challenge and marketing, significant challenges in a disaggregated installer base that will be on a learning curve for multiple solutions from multiple manufactures, and challenges of "future proofing" what is essentially an IT product (3 year lifecycle) with a building hardware component with a significantly longer lifecycle (up to 20 years).
- The Innovation Challenge hopes to attract manufacturer partners. This phase is still in development and these partnerships have not yet been established. Demo installations will be critical.

3) **Recommendations**

- Keep a pulse on project vs. market technology.
- Be sure the manufacturers nail down accurate estimates of kit installation time and required resources to provide Trade Allies with an accurate estimate.
- None.
- None.
- Recommend seeking other opportunities to establish partnerships with manufacturers.

Project # 22293b: Adoption Campaign: Interior Lighting Campaign

Presenter: Linda Sandahl, Pacific Northwest National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project, commenting that it was critical in driving adoption of best-in-class solutions for LED lighting in commercial buildings, and noting that the estimated savings potential of wide-scale LED lighting adoption contributed to BTO's goals. Reviewers also highly regarded the project's approach, lauding the project team for identifying successes from other LED programs and applying lessons learned to achieve this project's objectives. One reviewer remarked that, while market barriers were not clearly defined, this project's progress appeared to lend relevance to the minimal barriers. However, another reviewer noted that the first cost of LED upgrades could often be a significant barrier, and questioned whether there was opportunity to focus more on this barrier and develop potential solutions.

Reviewers assigned nearly a perfect rating to the project's accomplishments and impact, describing the project as a nicely structured collection of award programs, collateral, and tools and resources, and highlighting that the project had exceeded both its initial and adjusted goals. One reviewer recommended that the project team should consider increasing the project's long term goal, while another suggested performing some qualitative research on the level of engagement that industry partners had with awards tools and resources, in order to better assess the impact and value of these project elements.

Reviewers highlighted the project's strong list of collaborators and coordinating organizations, with one reviewer commenting that the project had a broad base of engaged partners touching the entire commercial lighting ecosystem. Another reviewer, however, encouraged the project team to also target organizations that were closer to building owners and operators, including installers, trade allies, and lighting distributors. This reviewer described the unanticipated barriers to lighting deployment that could be explored with trade allies early on—potentially avoiding increased installation costs and cost-effectiveness impacts—and also questioned whether there should be incentives for trade allies to encourage building owner participation in the campaign.

Looking forward, reviewers remarked that the project's proposed future work built nicely on the outcomes of work to date. One reviewer recommended that the project team should consider adding a closed loop feedback element to support learning, as well as a goal review/revision milestone, in case progress once again exceeded expectations. Another reviewer highlighted that efforts to promote the Controls-Enabled LED Retrofit Kit Challenge could accelerate lighting energy savings further, recommending that the project team leverage the success of the current project to assist the LED Retrofit Kit program achieve similar results.

Weighted Average: 3.70 # of Reviewers: 5
Relevance: 3.40[1] Approach: 3.40 Accomplishments: 3.90 Project Collaboration: 3.80 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Identifying products which are meeting minimum specifications.
- While lighting upgrades appear to be an easy and cost-effective savings opportunity, they still offer a number of challenges to building owners. Rapidly advancing technologies, lack of information on performance and reliability, and a complex terminology describing the technology can all contribute to general confusion about which are the best options to choose. An adoption campaign can smooth the way by providing building owners with technical information, and best practices as well as engaging manufacturers as market partners.
- Because of the amount of lighting load in commercial buildings this project has high potential to stimulate building owners and others to address energy efficiency opportunities in their buildings. The opportunity for recognition and the access to technical resources can be a strong incentive to participate.
- Interior lighting is typically second largest load in a commercial building. LED lighting plus controls represents a step change in energy performance, at a reasonable first cost and attractive payback, even in retrofit application. There is substantial uncertainty in how to select from a wide range of potential solutions, and additional concern around being an early adopter in a rapidly evolving technology space. This program is critical in driving adoption of best in class solutions.
- The estimated savings potential contributes to the BTO's goals.

B. Approach

This project was rated:
1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- While barriers are not clearly defined, the progress seems to lend relevance to the minimal barriers.
- Campaign leverages support and coordinates with other federal programs that implement high efficiency lighting. Offers a one-stop-shop for information on LED troffers, providing application information for TLEDs and LED troffers.
- First cost of the upgrades, whether new fixtures or retrofit kits, can often be a significant barrier. There may be more opportunity to focus on this barrier and develop potential solutions. Even though they do provide resources related to incentives, other creative approaches could be identified.
- Adoption campaign approach has been refined from predecessor campaigns, and is being used effectively to achieve project goals. Nice integration with other DOE programs.
- Even more than identifying market barriers, the project team identified successes from other programs and have applied them to this project. Demonstration of successful projects, access to tools and technical assistance and recognition programs are a few key examples.

C. Accomplishments/Progress/Impact

This project was rated:
1) **4.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.80** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Commitments from Target, MGM, etc. shows the volume of fixtures to be switched out. Good data will be available showing savings.

- Demonstrating that it can be done.
- Recognized a wide group and type of businesses
- Developed high efficiency troffer specification
- Calculation tool – lighting project evaluator – energy savings numbers and savings against code.
- Fact sheets – updated and repurposed
- Development of Controls-Enabled LED Retrofit Challenge Kit Specification
- Lessons learned:
    - Industry is interested and willing to participate
    - Industry is interested in recognition
    - Campaign can collect hard-to-get performance and Voice Of Customer information from campaign partners which is typically hard to obtain.

- It appears they far exceeded the initial goals for the project (by a factor of 10?) ... perhaps they should consider increasing the long term goal (2022)?

- Nicely structured award program, good collateral, tools and resources. Ability to track and consolidate adoption information that would otherwise be hard to come by is valuable. Would be good to do some qualitative research on level of engagement industry partners have with awards tools and resources to better assess impact and value.

- The project has had tremendous success demonstrated by exceeding their initial goals early and after adjusting goals even exceeding those. The energy savings impact has been readily measurable to track energy savings impact.

D. Project Integration and Collaborations

This project was rated:

1) **3.80** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.80** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Data shown supporting initiatives and awards from ILC.
- Good collaboration with many participants.

- Broad base of engaged partners touching the entire commercial lighting ecosystem.

- Good list of collaborators and organizations with whom they coordinate; perhaps other organizations that are closer to the building owners/operators should be included? Installers, trade allies, lighting distributors, etc. .. should there be incentives for them to encourage customer/building owner participation?

- With that "NASCAR" style slide of "whose who" logos....the program is clearly achieving its intent of engaging all of the key name brand players in this space. Great mix of owners, vendors and industry associations.

- Broad collaboration with other Federal programs, utilities, efficiency groups, ILC Participants and industry organizations. This broad collaboration is a contributing factor for the project success.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Good coordination with Controls-Enabled LED retrofit kit program.
- Will assist in awarding performers in the program.
- Successful approach partners with market leaders to drive adoption of HIT lighting applications.
- Future plans and next steps could include a closed loop feedback element; learn from successes, perhaps could include goal review/revision milestones with increase in goals if progress exceeds expectations?
- Builds nicely on outcomes of work to date.
- Efforts to promote the Controls-Enabled LED Retrofit Kit Challenge will accelerate the lighting energy savings further.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers
- If they can keep data current and readily accessible, then the value will be high.
- No comment.
- Good list of resources on the ILC website; specifications, technical information, incentive availability, calculation tool, etc.
- None.
- The project has been able to obtain good data on measurable results. They have also been doing a good job of sharing the information at conferences, through social media and publications.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- Emphasis is placed on improving information on lighting improvements.
- No comment.
- No additional comment required.
- None.
- The program is highly effective demonstrating sufficient emphasis has been placed on the project objectives.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Awarding top performers
- Collaboration

- Highly effective broad-based campaign that drives adoption of HIT applications.

- Strong evidence of success; good resources for building owners; access to technical assistance and recognition.

- Well-designed program to drive broad uptake of a key next gen technology. Note that value of awards is not just the value of the award to the top level end user, but to lower level project manager who delivered project, as well as serving as a "Trojan horse" to capture detailed deployment data that would otherwise not be accessible.

- The demonstrated success speaks volumes to the project's strength. The overwhelming response by exceeding project goals and the associated measured savings contribute greatly to BTO's goals.

2) **Project Weaknesses**

- Ability to vet out performers and get the info back out to end users.

- None at this time.

- Given their ability to exceed initial goals (100,000 troffers increased to 1,000,000 troffers) should they increase the long term goal (2022)?
- Incorporate goal review and revision milestones to allow for more aggressive goals based on progress.

- Could do some qualitative research to validate effectiveness of different tools

- I am unable to identify weaknesses.

3) **Recommendations**

- Provide link or address for body of work.

- Be sure to engage trade allies when considering new applications like individual troffer per cube designs. Troffers in cube farms are typically hardwired to switch in banks of multiple fixtures so adopting a troffer-per-cube switching design could increase installation costs of retrofits. These are the type of unanticipated barriers that should be explored with trade allies early on to avoid increased installation costs and cost-effectiveness impacts.

- None other than those already mentioned.

- None.

- Leverage the success of this program and assist the Controls-Enabled LED Retrofit Kit program to achieve similar success.

Project # 22294: Better Buildings Alliance Technology Solutions Team: Building Envelope

Presenter: Melissa Lapsa, Oak Ridge National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed that this project was relevant to BTO's goals and objectives. Reviewers commented on the importance of increasing building envelope efficiency, with one praising the project's estimated energy savings and another pointing to the potential short return on investment in warmer climates. Another reviewer praised the project team for ensuring that multiple perspectives were addressed.

The project's approach was generally agreed to focus on relevant and critical market barriers. Several reviewers praised the approach, calling the barrier identification and information sharing effective and valuable. One reviewer, however, questioned the approach's focus on current technologies rather than developing a vision for the building envelope of tomorrow. Several reviewers questioned the prioritization of technologies, with one arguing that decision analysis tools were highly ranked without—in this reviewer's perspective—much attention, and another reviewer suggesting that system reliability and longevity should be better incorporated into the team's approach.

Reviewers were mixed on the project's accomplishments, progress, and impact to date. While some reviewers were extremely positive about the project team's "great" efforts on developing stakeholder and market involvement, others had concerns about the progress made on the number of actual installations and associated energy savings. Another reviewer expressed confusion over the goals of the project team—was it to encourage market adoption of building envelope technologies or was it to create a building envelope solutions team. Finally, one reviewer expressed concern at the overall progress to date and web-traffic, given the current project term.

Project collaboration was generally viewed positively by reviewers, with many praising the diverse stakeholder group recruited by the project team. Specifically, reviewers praised the inclusion of trade associations, ratings organizations, and architecture and engineering firms. Several reviewers suggested that there was room for further engagement with additional groups or stakeholders.

Reviewers agreed that the project's immediate future looked well planned, but several expressed concern for longer-term outcomes. One reviewer suggested that the project team should develop specific success metrics around adoption of envelope technologies. Another suggested reaching out to the construction industry for technical and design visioning.

Weighted Average: 3.12 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.20 Accomplishments: 3.00 Project Collaboration: 3.40 Future Work: 2.80

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- By increasing building envelope technologies, the thermal gains and losses can be minimized significantly. In climates were weather tends to be more extreme, the savings can provide very short ROI.

- Understanding and improving the efficiency of building envelopes is a challenge from multiple perspectives. Creating an envelope technology solutions team is an excellent way to ensure that the various perspectives are addressed. Engaging key stakeholders before launching the Envelope Team will foster faster adoption of market-ready envelope technologies.

- It's a little bit unclear if I'm rating just the sub-project to form a building envelope technology solutions team or what I assume to be the higher level project of catalyzing the market to embrace building envelope technologies as a viable method to reduce energy consumption in commercial buildings. I'll assume it's the latter - catalyzing the market to embrace building envelope technologies as a method to reduce energy use.

- The building envelope determines the energy consumption of a building for decades. In the "onion" in the lifecycle of a building's components, none have longer lasting impact than the choices made in selecting the technologies included in the building's envelope.

- The estimated energy savings demonstrates that the potential strongly supports BTO's goals.

B. Approach

This project was rated:
1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Partnering with many different organizations, the information shared, learned and collected is very valuable. Many barriers were identified and possible solutions provided.

- Effective approach and broad-based solutions team.

- Additional barriers: Reliability, system longevity and maintenance requirements and - the length of time required to fully understand the effectiveness and reliability of new envelope technologies could be fairly long; problems may not become evident for years - or decades. How can that risk be mitigated in the work this team undertakes? Is there a way to accelerate the failure process to discover weaknesses in the technology?
- A question to the project team - the statement: "Conduct at least 2 technology team meetings" - is mentioned in a couple of places in the presentation; I would assume this team will need to meet more than twice so I assume that was just referring to an early/initial milestone - is that the case?

- The approach to identifying the "players" in shaping / influencing envelope technology decisions seems technically sound. Identification of opportunities and barriers appears a bit "rear view mirror" - it appears to capture the "state of the state" - what is of concern with the technologies of today, without any clear path to developing a vision of the envelope of tomorrow.

- The project engaged a broad spectrum of stakeholders and identified all relevant market barriers. The barriers are numerous and they are complex. The project team focused on a couple of barriers that were identified as a higher level of importance to the vast majority of stakeholders.
- However, Decision Analysis Tools was also highly ranked and I feel this could use some additional attention.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Over the past two years, several workshops, webinars, meetings, etc. have been conducted with varying partners and participation. Increased webpage activity and validating products with quantifiable savings has been presented.

- Great efforts to date developing stakeholder and market involvement and awareness.

- I'm rating questions 6 and 7 a bit lower than I might otherwise if I was more clear on the actual intent of this project - to encourage market adoption of building envelope technologies as an energy efficiency approach, or creation of the building envelope solutions team.

- Team has done a great job engaging the community of A/Es and building owners. Team appears very responsive to the needs and interests of this community, which bodes well for keeping them engaged. . Very pragmatic approach is likely to contribute to effective impact.

- A significant amount of stakeholder engagement and collaboration has occurred to raise awareness and publications and testing has been completed to provide owners with supporting information. Data on the progress made regarding number of actual installations and associated energy savings seems limited. There is good potential that market adoption will grow and this data will be collected.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- BTO, ORNL, BBA, BBC, A&E firms, Trade Associations, Rating Organizations. Diverse sampling of all key players to make a successful project.

- Large and diverse group of stakeholders recruited. Active trade association participation will be critical as program progresses.

- Architecture and engineering firm are listed as key partners; should the AIA (American Institute of Architects) be included as a key partner?
- Should energy efficiency organizations and utilities/incentive funders be included?

- Team has done a great job integrating with professional associations, as well as developing a relevant and effective tech team drawn from many of the key decision makers in the space. Good approach of ensuring that collaborators are kept up to speed.

- The project team has collaborated with a large and diverse group of stakeholders. There is room for furthering these partnerships.

E. Proposed Future Work

This project was rated **2.80** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Well laid out plan for immediate future. Some uncertainty past that. Would like to see this project continue.

- No comment at this point.

- It might be helpful to develop more specific success metrics to track projects. Currently the metrics seem to be milestone and deliverable based (create team, conduct 1 or 2 meetings; develop 1 or 2 technical resources) and less about actual adoption of envelope technologies as an energy efficiency measure.

- Path forward seems solid and well crafted. Would suggest that future strategy also reach out to the construction community, which has a great influence in both the adoption - and effective deployment of envelope technologies. Would also recommend greater research into the technical and design visioning (where is the future of active and energy producing building envelopes) and also into the needs that the construction / installation community would recommend. Note also that facades are the ultimate "beyond widget" element - they establish the daylighting parameters that artificial lighting systems depend on, the thermal performance that HVAC systems need to be sized for, and much of the IEQ that shape occupant productivity.

- There are a lot of plans for continued development of technical resources - specifications, presentations to raise awareness, develop toolkits, etc. The materials identified are broad which will help to meet the needs of different stakeholders.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers
- Increasing building envelope insulating properties will allow less waste due to thermal gains/ losses.

- No comment.

- I am rating the value of the deliverables as high but many of the deliverables are not yet available so... please keep that perspective wen using my evaluation. My rating is more about the potential than the actual quality of the deliverables.

- None.

***Average*: 1** reviewer
- I would like to see more measurement and verification data collected, compiled and published.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- The focus is placed correctly and the information being relayed demonstrates the project's success.

- No comment.

- More promotion/marketing would be helpful to increase awareness that this work is in process. Leverage the collaboration/partner organizations to spread the word.

- None.

- The project team appears to be focused on the project objectives, identification of market barriers and methods to overcome the barriers.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good partners
- Good data
- Large potential in savings opportunities

- Please see comments on Relevance.

- I agree that building envelope technologies have strong potential to save energy if the project is successful
- Good list of collaboration partners although could include others (see earlier comments)

- The building envelop shapes the performance of a building for generations. Overcoming the perceived risk of incorporating next generation solutions in the highest cost, highest visibility and longest lasting component of a building is key.

- The energy savings potential associated with this project is tremendous. The collaboration with broad spectrum of stakeholders identified market barriers and the project team has focused on the most impactful ones to increase market adoption.

2) **Project Weaknesses**

- Some methods are high cost
- Need to build more confidence in projects with end users

- No comment.

- According to the project summary slide, this project started Oct. 1 2014 - should there have been more progress by now? It appears the early work was focused on a stakeholder workshop (2015) and a webinar education series (May/June 2016) but should there be more resources available and a broader awareness of the project and team by now?
- Website traffic - listed at over 200 page views (slide 10) but that doesn't seem like very much traffic... perhaps more marketing is required?
- Are better success metrics needed?

- Generally, project will benefit from greater incorporation of future vision and construction / installer community.

- No comments.

3) **Recommendations**

- I believe this part of the market needs to be developed more. While roofing and wall construction is moving in the right direction, window technologies are lagging.
- No comment.
- None other than those already mentioned.
- None.
- I would encourage training/education for contractors as well.

Project # 22295: Developing the High Impact Technology Priority List

Presenter: Matt Guernsey, Navigant Consulting
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers highly rated this project's relevance to BTO's goals and objectives, with one reviewer noting that the "very concept" of identifying high impact technologies was clearly aligned with overall program goals.

Reviewers were split on the project's approach. Several reviewers agreed that the project "hits all major points" and was "comprehensive" in focusing on cost-effective technologies that are currently underutilized but have a high energy efficiency opportunity. Other reviewers, however, felt the project did not identify market barriers nor identify techniques or processes to overcome them. Several reviewers made comments or suggestions on alternate industry perspectives on technologies—including window tinting, lighting controls, and kitchen ventilation—for the team to consider.

Reviewers' were also split on the project's ratings for accomplishment, progress, and impact. Reviewers noted the long list of technology measures identified—exceeding the project goal of 400—and noted that the process has yielded "substantive" analysis of potential energy savings and qualitative analysis of market opportunities. One reviewer praised the project team for defining technologies that span a "broad spectrum" of sectors. Another reviewer noted, however, that they did not see any evidence of contributions towards BTO's energy reduction goals, and also that it was unclear if this was expected or if the point of the project was to identify technologies with the most potential for future contributions.

Reviewers generally agreed that the team's project integration and collaborations were strong, with many reviewers praising the diverse and comprehensive set of key stakeholders providing input on the development of the technology list. Reviewers made suggestions for improvements, however, including additional engagement with the mechanical and electrical trades as well as the design and construction community. One reviewer felt that not enough information had been provided to determine if each stakeholder group was adequately represented, nor was the reviewer able to determine the extent of the collaboration and coordination.

The project's proposed future work was rated favorably by reviewers. Reviewers generally thought that the schedule for the immediate future looked good, though one reviewer noted that longer term plans—such as deployment plan development or execution—lacked details. One reviewer noted that the team did not appear to be responding to current deployment efforts, particularly for those efforts in the lower tier of energy savings potential, and another reviewer similarly noted that the future tasks plan appeared to lack feedback loops.

Weighted Average: 2.94 # of Reviewers: 5
Relevance: 3.60[1] Approach: 2.80 Accomplishments: 3.00 Project Collaboration: 3.00 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- BTO has established strategic goals of a 30% improvement in energy use intensity (EUI) in existing buildings and a 50% improvement in new construction EUI. Identifying and prioritizing the technologies that can deliver energy efficiency cost-effectively is critical to BTO's success in meeting these strategic goals. The program is using a robust approach to screen a large number of technologies for potential inclusion in the High Impact Technology List and then to develop deployment activities that are most relevant to the technology and the market. Without this screening, time and resources would likely be wasted pursuing less promising technologies.

- Having a current, relative data base of energy efficient projects is very valuable to end users.

- The HIT Catalyst fully and effectively supports BTOs mission.

- The very concept of identifying the technologies with the highest potential is clearly aligned with the program goals. Since the BTO program has a series of phased goals for energy efficiency/reduced energy intensity it is important to provide a method to focus on the technologies with the most promise.

- This project is very broad given that it is identifying high-impact technologies that are underutilized so BTO can target resources to further deployment and achieve energy savings within the commercial sector.
- Comprehensively, this program supports BTO's project goals.

B. Approach

This project was rated:

1) **2.60** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The program is specifically designed to consider market characteristics, evaluate barriers, and work with the appropriate partners to develop and deploy the most effective deployment activities. The process is designed to evaluate changes in the market and technologies to refine the list of priority technologies and the deployment approaches that make the most sense.

- Barriers were not clearly defined in literature, but were covered during seminar. Barriers of keeping relative, up to date info is largest hurdle.

- This project hits all the major points:
    - Focus on cost effective tech, underutilized but high EE opportunities
    - Using broad-based screening of energy performance (primary energy technical savings potential) and stakeholder interest to narrow the fields
    - Periodic updating of the matrix responds to a technology space that is changing quickly and allows staff to refresh/refine deployment plan and select and execute deployment
    - Very important to include a new construction focus to identify technologies that are best implemented in NC and are typically not a good fit for retrofit applications.

- Note that my answers indicate they have not identified market barriers nor developed techniques to overcome those barriers, however, they are not yet at the point in their process where they tackle that task. Slide 15 shows that it is a future, upcoming task. It is not possible therefore to rate this project with regard to market barriers.

- The approach is less about identifying market barriers and more about identifying technologies that have the most potential impact.

- The process for identifying the technologies is comprehensive and engages a number of key stakeholders.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project has identified more than 450 technology measures for evaluation and screening relative to project goal of 400 technologies. Based on screening of energy savings and deployment readiness and key market factors, the project is close to completing the 2017 HIT List which represents the third annual technology identification, evaluation and prioritization process. The process has yielded substantive quantitative analysis of potential energy savings and qualitative analysis of market opportunities, serving as a key input into broader deployment program planning for priority technologies.
- The project team presented details on 12 candidate technologies for new construction representing an estimated primary energy technical savings potential of more than 4 quads (roughly 24% of annual commercial buildings primary energy use). This is significant relative to the BTO strategic goals for commercial new construction.

- Spreadsheet has been created, workshops conducted and annual screenings have been completed. The current list is growing and can be used.

- HIT Planning program has successfully identified, selected, and executed deployment plans for promising EE techs that needed BTO support to move towards implementation and/or commercialization.

- I didn't see any evidence of actual accomplishment/contribution to the BTO energy reduction goals described in the presentation. However, it's not clear to me if that would be expected for this project. It seems their focus is on identifying technologies with the most potential for future contribution.

- Twelve technologies have been identified over 5 market sectors (envelope, HVAC, Water heating, whole building, and lighting). Estimated energy savings potential has been identified.
- This stage is to confirm that these are the appropriate technologies to further development and deployment activities. The team has done a good job of defining technologies that span a broad spectrum of sectors.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The presenter noted the contributions of a comprehensive set of key stakeholders and the roles they play in providing input into developing a broad list of commercial building technologies for screening, contributing data to support analysis of energy savings and deployment readiness, and in the prioritization of technologies for the HIT List. Stakeholder input is sought at multiple stages of the process through workshops, an RFI, and direct communication. The list of key partners includes a comprehensive set of stakeholder types, but there wasn't enough information to determine whether each stakeholder group was adequately and equally represented or to gauge the extent of close collaboration or coordination of partners.

- Participation in the program is working well. Our presentation included inputting to varying projects and the likelihood we would pursue them.

- Integration and collaboration with stakeholders is excellent. I would encourage the HIT Catalyst Program to build stronger relationships with the mechanical and electrical trades to bring their 'boots on the ground' perspective into the conversation earlier in the project when technologies are being scored. It could help inform project design and minimize unexpected barriers that can crop up during implementation.

- It seems the design/construction community is omitted from the list of collaborators and partners. They didn't provide a lot of detail on how they actually collaborate with partners but their model shows two-way communication ... so assuming they actually do that I rate them reasonably high on this aspect. The problem of omitted collaborators (design/construction) can be addressed.

- The project team has developed a diverse set of collaborators to identify high impact technologies. Has design engineers been included in any of these groups? If not, recommend engaging this community as well. They will be recommending, designing and specifying these technologies. It is important to understand the market barriers they foresee to increase market adoption.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Plans for finalizing the 2017 HIT List and Deployment plan were laid out on a reasonable schedule through July 2017. Fewer details were provided about deployment plan development process or execution of the deployment plan. These efforts will build on past progress of the project and related BTO program efforts. One constructive question raised through the review deals with decision-making to move on from technologies that don't seem to be responding to deployment efforts, particularly those in the lower tier of energy savings potential. At what point does the program turn their attention to other technologies on the list?

- Annotated in presentation that they are still working to identify key barriers. This is positive in that they know there will be some that will need to be addressed.

- Based on program success to date and employing the existing methodology going forward, I expect HIT Catalyst to continue on as an important and effective contributor to BTOs efforts to move high-potential EE technologies forward towards commercialization. By supporting these technologies through the transition from 'great idea' to 'proven concept', HIT Catalyst is contributing to the business case by positioning technologies for development into market-ready products.

- Future tasks/plans are laid out in slides 15 and 17 but there is little detail about which key deliverables will be developed and when they will be available. There don't appear to be any feedback loops built in.

- Next steps are well defined. Risks are in RFI responses. Recommend making sure there is broad distribution of the RFI to ensure appropriate responses.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Final deliverables for the current year are not yet available. Prior year reports and materials were comprehensive and directed to the needs of BTO and stakeholders planning and implementing deployment activities for the priority technologies; I expect upcoming deliverables will be comparable. My comments are limited to deliverables related to HIT List Development and not materials targeted toward stakeholders or broader audience as part of deployment activities.

- If the challenges of keeping list current and relevant can be met, this will be a useful resource.

- Please see all previous comments.

***Average*: 2** reviewers

- As commented in several earlier questions there are no real details about their deliverables beyond the actual list of high impact technologies. It seems there should be additional detail about deliverables.

- I would like a better understanding of the basis for the savings potential. It seems like energy savings are estimated by broadly applying technologies across the commercial building sector. Based on feedback from A/E community, this might want to be tailored to appropriate building type.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- The HIT List appears to play a central role in CBI's identification and targeting of technologies for their deployment efforts.

- Emphasis is placed on creating a searchable document for many differing projects for different end users.

- I cannot see any aspect of building energy efficiency that has been left out of this process and I applaud the new focus on New Construction.

- I do believe they are on the right track and are producing a list of viable high-impact technologies.

- The project team tackled a very long list of measures and narrowed it down to a focused selection across multiple sectors. The process required utilization of resources/collaboration. The results demonstrate a focus on project objectives.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- 1. The project relies on a transparent process and stakeholder input and leverages existing tools/information sources to identify and prioritize technologies
- 2. Screening considers technical energy savings potential as well as readiness for deployment, barriers, and cost-effectiveness to develop the HIT List
- 3. Data collected in prioritization is valuable to development and implementation of most effective deployment strategies
- 4. Given CBI's role working with a broad set of stakeholders across many market segments, it is well-positioned to consider the full range of applications and benefits of candidate technologies across the commercial buildings sector

- Large list of varying projects
- Screening conducted to tailor list to each individual user

- Effective tool for identifying EE technologies and tools and providing a path for them to move from idea to proven concept.

- Strengths – they are focused on the highest payback opportunities; these should have the greatest potential to contribute to BTO goals. They have identified key stakeholder/partners and have used opportunities to gather input/feedback - including during the peer review presentation.

- From the A/E perspective see comments below:
- Dynamic tinted glass - architects are interested in transparency in building designs. Dynamic glazing allows the transparency but will block the solar radiation when it impacts occupant thermal comfort (and HVAC loads/cooling energy) and visual comfort. Manual blinds will tend to stay down so project lose out in the opportunity to use daylight and turn off electric lighting.
- Modulating kitchen ventilation - kitchen exhaust/100% makeup air consumes a lot of energy. Demand control on these systems will contribute greatly to energy savings.
- Building energy/automation systems and controls - measuring end uses and optimizing operations will contribute greatly to energy savings.
- Personal lighting controls - combining this strategy with reduction of ambient lighting will contribute to energy savings. Occupants prefer the ability to control light levels.

2) **Project Weaknesses**

- This is a solid project. It would be good to see more details about each stakeholder group participating in the process to ensure no significant players are left out and that each stakeholder group is adequately represented. More information on how partners collaborate with the project and how the wide range of partner efforts are coordinated would also be of value.

- Keeping data current
- Annual review process. Getting participation to keep data relevant.

- Would like to see incorporation of feedback from field implementation stakeholders earlier in the process where possible.

- They do not have a complete list of stakeholder partners; design/construction community is missing. There may be others missing.
- As mentioned earlier, they do not provide a lot of detail about deliverables nor when they will be available. Also don't seem to have any closed loop feedback/revision mechanisms.

- Drain-water waste heat recovery - good strategy for housing projects. Commercial office buildings may not receive enough savings based on hand washing only.
- Heat Recover RTU for water preheating - interested in feedback from A/E community. How does this impact their mechanical space locations/requirements? Water heaters are not always necessarily in penthouses adjacent to RTUs.
- Energy Recovery Ventilation Panels - engage architectural community. What does this look like? How does it integrate with desired appearance of building envelope?

3) **Recommendations**

- No further recommendations now. It will be helpful to see the final list and more details about technology screening.

- Provide link or address to webpage to allow for easy access for end users.

- Would like to see incorporation of feedback from field implementation stakeholders earlier in the process where possible.

- Address the weaknesses; provide more detail, anticipate problems and proactively develop solutions.

- Recommend engagement with the A/E community to assist with identifying project types where certain technologies are more impactful and/or appropriate.

Project # 222105: SoCal Edge

Presenter: Robert Fortunato, Los Angeles Cleantech Incubator
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to BTO's goals, commenting that addressing the particular business investment needs of property managers and owners with large real estate portfolios was important, and that "cracking the code" on how to transition from "replace in-kind" to "replace with current best in class" technologies was a core challenge facing the CBI program. However, one reviewer noted that while most project activities had an energy savings aspect to them, some activities specifically focused on water conservation, which—while important—was not really consistent with BTO's mission.

Reviewers also positively rated this project's approach, commenting that leveraging results from test bed and next-generation specification programs, and then translating these results into pilots and broader portfolio adoption, was an efficient and effective path forward. One reviewer commented that relevant barriers to the market adoption of high-performance technologies were identified and effective solutions defined. Another review agreed that barriers had been identified, but they also felt that some had been missed. Reviewers remarked that the project team's approach to soliciting participation in their program made sense for initial project stages, but they also felt that the project team should identify plans for garnering greater participation. Finally, one reviewer noted that there didn't seem to be a lot of detail in the presentation around actual project deliverables.

Reviewers were somewhat mixed on the project's progress. One reviewer exclaimed that it was "nice to see a program that is ahead of schedule, exceeding targets and under budget!" Another reviewer noted that many project partners were large, and could provide lots of data that could be passed on to other potential property owners, both in LA and across the country. A different reviewer questioned how well the project activities would work in other states with different legislation and utility companies, however, and another noted that most of the quantified energy savings appeared to be fairly small, urging the project team to find large opportunities. One reviewer noted that all the shared data was based on expected savings, expressing that actual measured savings would need to be published and shared to give building owners confidence in the value of efficiency investments.

Reviewers positively regarded the project's collaborations, with one noting that collaborations with large property owners, college campuses, energy service companies, and utilities gave the program validity and sustenance. Another reviewer lauded the project's collaboration with other federal programs (e.g. GSA's Green Proving Ground), vendors, and the local real estate and regulatory communities. One reviewer, however, felt that there were not any partners representing building owners (e.g. BOMA), nor partners representing design or construction audiences, whom could advise building owners on technologies and steer potential partners to the program.

Looking forward, one reviewer said that future plans addressed key barriers to market adoption, describing them as well-rounded. Another described that "simply continuing ongoing effort as described represent[ed] a solid blueprint for future work." Two reviewers thought that the details on future steps were a little vague, and wanted to know more about how feedback and lessons learned would be incorporated into future activities.

Weighted Average: 3.03 # of Reviewers: 5
Relevance: 3.00[1] Approach: 3.10 Accomplishments: 2.90 Project Collaboration: 3.20 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Ability to come up with projects and screen them accordingly will help end users.
- Addressing the particular business investment needs of property managers and owners with large real estate portfolios is important.
- Most projects that have an energy saving aspect to them align with the BTO program goals; however some are specifically focused on water conservation. While I agree that this is important, is it really consistent with BTO goals? There are energy savings associated with water savings but they are not likely to be the highest impact opportunities for energy savings.
- "Cracking the code" of how to transition from replace in kind to replace with current best in class technology is the core challenge that CBI is ultimately trying to tackle. Approach of leveraging results from test bed and next gen spec programs and translating those to pilots and broader portfolio adoption is an efficient and effective way to identify and place the final piece of the puzzle.
- Accelerating market adoption of best-in-class technologies will have an impact on energy and water savings that support BTO's goals.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- Uses Green Proving Grounds, DOE performance specs and Utility providers to identify best technologies. Use M & V to verify technology is performing as advertised.
- Barriers to market adoption identified and effective solutions defined.
- They have listed several obvious barriers to adoption; and they have provided reasonable detail about their plan to overcome barriers however there are some barriers they have not identified. One example related to the injected polymer solution to improve irrigation water retention - does this technology have any potential adverse impact on the environment?
- Clear and on point discussion of market barriers, LACI approach to overcome them, with good exposition of results to date illustrating effectiveness of approach. Nice to see a program that is ahead of schedule / exceeding targets and under budget!
- Market barriers have been identified. Participation seems to be through targeted partners which makes sense for initial development of materials, technical assistance, M&V guidance, results reporting.
- The project team should identify plans for garnering greater participation.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.80** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Several projects currently ongoing. Some of the partners are large and will provide a good amount of data. That data can then be passed along to other potential property owners.

- Installed 4 demonstration projects and 4 pilots underway or nearly so.

- Most of the quantified energy savings appear to be fairly small; granted it's only a few projects and the building sizes vary but they need to find large opportunities.

- LACI is doing most with its location in Los Angeles, identifying folks with big footprint, and presenting results in ways that can gain traction not just in the large real estate market that is LA, but also in projects that have national impact.

- Data shared is all based on expected savings.
- The demonstration project energy savings is much greater per gallon of water reduction than the pilot projects. The metrics for determining these savings is unclear - why would Rain Systems' pilot at CSUN save 8.3 million gallons of water and 40,238 kWh energy (206.2 gallon/kWh) while the demonstration project saves 11,649 gallons of water and 1,700 kWh (6.5 gallons/kWh)?
- Looking forward to seeing the actual measured savings results.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Collaborations with large property owners, college campuses, ESCO's, and utility companies gives the program validity and sustenance.

- Strong cohort of partners, and collaborators, including the Build Environment Cluster.

- There is evidence of collaboration with partners that they have identified however there don't appear to be any partners that represent building owners (BOMA for example) nor the design/construction audience.

- Good job working with other federal programs (such as GSA's Green Proving Ground, DOE's BTO spec programs), vendors, the local real estate community, LABBC, the local regulatory community and large real estate owners. Using incubator for tours, retaining needed subject matter expertise, and marketing savvy show that this program on the right track.

- Strong collaboration is demonstrated with key stakeholders including LABBC, portfolio property owners, utilities.
- If design engineers have not been part of technology showcases, strongly encourage outreach to this market sector as well. They will advise owners on these technologies and share publications of demonstrated savings, engage experts for technical assistance, and possibly steer potential partners to the program.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Future steps seemed a little vague to me. Some of the points presented were general in nature and theoretical. Would have liked to see some better specifics.

- Developing procurement process at the organizational level – pilots to portfolios.

- They provide a fair amount of detail in the project plan on slide 17, however there doesn't seem to be any mention of a feedback loop to allow for improvement along the way. It's likely they will receive feedback from several different actives and milestones and there should be a way to incorporate what they learn.

- Presentation could have provided more specifics on next steps for greater feedback; overall however, the program appears to be very effectively engaged to leverage the regulatory environment in Los Angeles (energy reporting) and simply continuing ongoing effort as described represent a solid blueprint for future work.

- Future work planned addresses key barriers to market adoption. It is a well-rounded plan.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- The project appears to be working well at the current time. Branching it out to other localities may present a challenge to the program.

- None

***Average*: 3** reviewers
- No comment.

- There are some interesting products/technologies presented that I plan to investigate myself however as mentioned earlier is there too much emphasis on water savings vs. energy savings?
- Also there didn't seem to be a lot of detail around the actual deliverables. There are hints in the project plan but not a lot of specifics.

- Actual measured savings will be critical. These results should be published and shared to give owner's confidence on what they can expect for their projects.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- The different companies participating show the deployment is effective. The target areas were identified and applied to the correct partners.

- No comment.

- This is a "qualified" yes... if the intent for this project was to give equal consideration to water conservation (in addition to energy) then I would answer yes; however if the intended scope is energy savings then I would answer No.

- None

- The broad stakeholders engaged and diverse partnerships demonstrate that sufficient emphasis is being placed on project objectives.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good metrics
- Double screening of projects
- Good partners and communication

- Strong cohort of project partners and collaborators.

- Good details; good examples of market introduction strategies and some ideas on overcoming barriers (rebates/incentives for example)

- "Pilot to portfolio" is the key "last mile" to all of the work flowing from bench level development of innovative technology through test bed and demonstration programs. LACCI appears well on the way to "cracking the code" needed to achieve this outcome.

- Identifying partners that have a potential to scale-up installations of the technologies is a great way to accelerate market adoption. These partners are also leaders in the market and will steer others to acceptance of these technologies.

2) **Project Weaknesses**

- Only minor weakness I could see is the general comments about future work.

- Would like to see more evidence of ability to scale to multiple sites or an analysis of the barriers.

- No feedback loop; some key stakeholder partners omitted. Too much emphasis on water savings vs. energy savings (?)

- None identified.

- The design engineers and installation contractors should also be engaged. Oftentimes they are at touch-points with potential owners and they can convince acceptance or steer owners away due to uncertainties. Making sure they have the information to encourage acceptance may help overcome another market barrier that has not been identified.

3) **Recommendations**

- Providing website address or link in presentation would be helpful.
- While this work is being performed in California, I wonder how it will work in other states with different legislation and utility companies.

- Focus on implementing strategies to demonstrate that these on-ramp technologies can be taken to scale.
- Ensure they are leveraging opportunities to incorporate what is learned along the way. Ensure the results will contribute in a meaningful way to BTO goals for energy reduction.
- None
- Refer to previous comments. I have no additional recommendations.

Project # 32486: New Air and Water Resistive Barrier Technologies for Commercial Buildings

Presenter: Diana Hun, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers agreed that this project supported overall BTO goals and objectives, with reviewers calling the project outcomes "critical for health[y], efficient structure[s]," with a "high potential to generate significant energy savings." Reviewers cautioned that overcoming installation barriers would be key to realizing potential energy savings, with several reviewers arguing that this aspect of the work needed to be given more prominence.

Reviewers were mixed on the project's approach, offering different feedback on how the project should adjust to focus on and address market barriers. There was disagreement among reviewers as to the project scope, with some arguing it was too narrow for overcoming adoption barriers and others arguing it was too broad to achieve targeted results and demonstrations. Several reviewers liked the field testing and data collection methodology, approving of efforts to reduce variability and collect data on product specific partners. Three reviewers felt that the project did not focus enough on identifying market barriers like ease of installation, training, or product cost. The project's manufacturing partnership was praised, with reviewers arguing that manufacturing partners could help overcome market barriers with information gained from the project.

The project's accomplishments were rated well by reviewers, with one reviewer positively remarking on the demonstrated energy savings to date and the potential value to participating partners and the broader industry. Two reviewers commented on the lessons learned from demonstrations and how they would inform adoption going forward, with one cautioning that it was unclear how significantly technology adoption would impact BTO's program goals. Another reviewer praised the plan to share testing results with partner programs such as Better Buildings and GSA's Green Proving Grounds, to help distribute information to building owners and operators.

Reviewers were split on the project's integration and collaboration with stakeholders. While several reviewers praising the project's partnership with 3M and its minimization of delays, others worried that additional manufacturers should be included to get broader market representation. One reviewer praised the logic model of project objectives and several reviewers praised the broader focus on training installers on new technologies as a means to achieving market adoption and energy savings.

Reviewers generally did not rate the project's proposed future work highly, pointing to a lack of detail provided on future plans. One reviewer recommended reaching out to contractors and installers to help them understand energy saving impacts associated with the new technology, as well as the ease of installation to encourage them to support the technology.

Weighted Average: 2.78 # of Reviewers: 5
Relevance: 3.40[1] Approach: 2.60 Accomplishments: 3.00 Project Collaboration: 2.70 Future Work: 2.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Keeping unwanted air and moisture intrusion from buildings is critical for a healthy, efficient structure.
- Work to demonstrate and document improved envelope technologies' performance and ease of installation should accelerate market adoption. Problem statement indicated that the performance of air barrier technologies are highly dependent on the installer - identifying and solving installation barriers could be given more prominence.
- High potential to generate significant energy savings - IF barriers are overcome. And if end performance is confirmed to be significant improvement over competing/existing technologies.
- Broad problem statement wasn't as clearly articulated as it could have been; since I am less familiar with this market space, hard for me to fill in.
- Based on the estimated energy savings in existing building retrofit and new construction buildings, this project supports BTO's goals.
- This also supports achieving the more stringent energy and high performing green building standards.

B. Approach

This project was rated:

1) **2.80** for the degree to which it focuses on critical market barriers, and
2) **2.40** for the degree to which the approach addresses the market barriers identified.

- Different products applied to test buildings and data was collected on each one. All other variables were held constant providing good data on product specific properties.
- Good approach field testing 3Ms products. As a major manufacturer, they should be open to feedback on ways to improve installation, likely through additional contractor training. Identical test facilities in proximity is a major plus as is data collection from existing buildings.
- I don't think they have put enough through into the likely barriers to adoption. Also I don't see much detail on how cost will compare to existing technologies. They do mention faster installation time but not product cost.
- Although in principle I believe this appears to have a good handle on a needed material with a broad market space, the presentation seems to indicate a project plan that did not clearly characterize what the market opportunities and barriers are at the outset, and has in fact identified these market forces only as "lessons learned".
- Data gathering on actual installations will help determine leakage rates which can then be incorporated into energy modeling analysis to estimate energy saving impacts.
- Leveraging the Emerging Technologies program, market barriers (such as ease of installation and training) can be addressed by the key manufacturing partner.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Data provided in each case showed performance of materials used and an increase in performance over the baseline model. Energy reduction shown to be between 40 - 65%.

- Good progress. Learning that construction industry appears reluctant to install tech that hasn't been in market for 5 years and that one barrier doesn't fit all will inform market adoption efforts going forward.

- This is a new technology and is still being evaluated/tested so difficult to say if it contribute significantly to the BTO program goals.

- Good approach to documenting results; seems likely to be of value to participating manufacturer, and potentially to broader industry. Unclear what next steps would be to really driving future uptake / development of this industry space.

- Challenges with identifying demonstration projects and timelines for collecting data.

D. Project Integration and Collaborations

This project was rated:

1) **2.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.80** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Manufacturer, builders, installers, etc. for real life projects in two locations. Working through 3M, contractors educated, presentations, videos.

- Good collaboration. 3M's test coordination minimized delays from erratic schedules /owners.

- It seems the primary (only?) partner is 3M the manufacturer of the new technology. Perhaps this is the intent of this project - to work directly with the manufacturer to evaluate a new technology (?) .. it seems it would be useful to include other entities that don't compete with 3M in the evaluation to assure objectivity.
- In slide #3 target market/audience is not very specific; I would think the target market should align closely with (be the same as?) that stated in the building technologies solutions team project (Lapsa)

- Appears to be a good collaboration with 3M the manufacturing partner, but characterization of the broader market channel (other manufactures, contractors, end users) less well defined.

- The logic model of project objectives was well planned. Integration and collaboration with the key manufacturer enabled the manufacturer to focus on training installers. Adoption of new technologies was identified as a market barrier. Training installers on new technologies will be critical to the achieving market adoption.

E. Proposed Future Work

This project was rated **2.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- One project showed the potential barriers of installing the product over existing cladding. Other demonstration projects will show real world performance of the products.
- No comment.
- They detail the follow up work that will be done at test facilities and demonstration projects; mainly performance data analysis from tests, but no real detail on other future milestones/tasks other than the final report and posting to the team website.
- Unclear what next steps for broader development/ deployment of this technology are.
- Recommend conducting an outreach to contractors/installers so they understand the energy savings impacts associated with the new technology as well as ease of installation. This might encourage support for the technology.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer
- If the product can be applied correctly, the data shows there is significant energy savings.

***Average*: 4** reviewers
- No comment.
- As mentioned earlier; detail is lacking in terms of future work and eventual deliverables.
- None.
- Projects have been identified, construction is underway and testing is planned.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- Data shows the focus is being placed in the right area for this stage of the project. Eventually, training installers will be largest focus of efforts.
- No comment.
- This project is narrow in scope; the research and testing underway does seem relevant and applicable; however the project does have weaknesses that should be addressed. See earlier comments.
- None.
- Testing results will be shared with partner programs, BB and GSA GPG which will help to distribute information to building owners/operators.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good data
- Strong manufacturer partner

- Project yields useful technical information for commercial building construction market that can be shared on the BB Envelope website.

- Since building envelopes can be a significant factor in determining energy use in commercial buildings this is a good area for research.
- Faster installation time and less complexity in installation (primerless) could be useful in improving reliability and eliminating/reducing installation errors.

- Less familiar with what opportunity and need for this technology are - but M&V plan, data analysis and lessons learned were well defined.

- The energy savings opportunities is high and supports BTO's goals.
- Developing case studies with actual measured data provides industry with the information needed to accelerate market adoption.

2) **Project Weaknesses**

- Cost
- Installation is critical to success of product

- Project scope may have been too broad. A narrower scope might have yielded increased data/insights for the builder/designer stakeholders.

- Slide #4 implies (mid-term outcome) that new air barriers might be integrated into existing buildings as well as new buildings. It is not realistic to think they might be a retrofit item in existing buildings.
- Not a viable solution for masonry facade because of potential for change to freeze/thaw cycles and possible for damage to facade
- There's a risk the product will not be much more effective than existing technologies; that won't be known until full testing complete and data available for analysis.

- Market opportunity not well defined; M&V objectives not organized around overcoming potential barriers identified at outset.

- More should be done to overcome the barrier associated with installers being reluctant to adopt new technologies. Recommend including an outreach/training program with contractors/installers in addition to the demo installations. It seems like this was in the scope of the manufacturer, but based on lessons learned, this still seems to be a major market barrier.

3) **Recommendations**

- None.

- No comment.

- None.

- None.
- Refer to previous comments.

Residential Buildings Integration
Building America

Project # 1112: Building Science Advisor

Presenter: Roderick Jackson, Oark Ridge National Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project, noting that it directly addresses the concerns stated by builders about the moisture durability of efficient envelopes, and also that it aligned with Building America's Research-to-Market Plan. One reviewer commented that the project directly aligns with BTO's mission and goals for improving the efficiency of residential buildings through use of an integrated building systems approach, though other reviewers questioned how far the project goes to address Building America's 60% EUI reduction target.

Reviewers felt generally positively about the project approach, though with some reservation. On the positive side, one reviewer commented that critical market barriers were identified and prioritized following outreach to the building community, and that the BSA tool directly addressed these barriers. Similarly, another reviewer remarked that the project enjoyed a strong team, great industry collaboration and engagement, and a solid technical base in building physics. More critically, one reviewer noted the lack of project cost share, while others commented that the tool stopped short of helping users understand some key aspects of moisture performance, and also that no attention was being given to how to build trust among homebuilders in the results of the tool. In part to address these issues, one reviewer recommended asking builders directly what it would take for them to rely on this tool for design and specification decisions. Another reviewer recommended consideration of an open-source platform for the tool, to provide flexible options for sustaining the software once this project is complete.

Reviewers were mixed on the project's progress and accomplishments. One reviewer felt that the program was on track with its interim market goal and demonstrated clear alignment with stated program performance goals. Conversely, another reviewer felt it was unclear whether the project was contributing to BTO's 60% EUI goal given that the project had no goal in terms of energy savings potential. One reviewer thought the presentation could have been clearer about the status of the project plan and schedule, but noted that the presentation did convey that BSA was already having a positive impact in the industry.

Reviewers were generally positive about the project's collaboration and engagement with industry, and felt that project staff had enlisted an appropriate expert panel to drive development of software tool. One reviewer noted that the project team appeared to have good connections with builders who would utilize the tool, while another remarked that ongoing stakeholder collaboration was recognized as essential and was factored into the project plan. One reviewer highlighted a potential need to reach out to key stakeholders from the siding industry, while another reviewer highlighted the importance of manufacturer engagement, given that potential conflicts if the BSA's recommendations for a particular product diverged from manufacturers' recommendations.

Several reviewers expressed confidence about the project's future plans. One noted that a soft rollout and beta testing of the software tool was smart and effective and would help guide future work and outcomes, while another commented that the project's plans to continuously update and monitor the tool would be essential to its success. One reviewer expressed concern that no information was presented on how the tool will ultimately seek to garner trust in the homebuilder community. Another reviewer recommended that the BSA should be cross-linked with other BTO-supported software, so that users are aware of other available building energy software tools.

Weighted Average: 3.16 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.40 Accomplishments: 2.90 Project Collaboration: 3.30 Future Work: 3.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project is directly aligned with BTO RBI mission and goals for improving the energy efficiency of residential buildings through use of an integrated building systems approach. The BSA tool is unique in the industry as a more user friendly avenue to parametrically identify and select high R-value wall assemblies early in a design process and provide more certainty to the users regarding expected energy and moisture performance. Directly addresses builder responses to surveys regarding top challenges in Energy Efficiency.

- Code as well as voluntary above-code programs are striving for (and realizing) high energy savings due in large part to reduce air leakage in buildings. But some know consequences is reduced moisture management. Therefore, how can we have our cake (low-e buildings) and eat it too (not rot them down)? This project includes BTO goals and collaborating with strong industry professionals.

- I think this is valuable but I am not sure how far it goes to address the BA 60% EUI reduction target. Builders do not need to go much higher than 2015 IECC levels, in terms of wall R-value, to deliver zero energy ready homes.

- Project directly addresses the concerns stated by builders about the moisture durability of efficient envelopes.

- This project aligns with the DOE High Performance envelope moisture migration and durability initiative.

B. Approach

This project was rated:
1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- Through outreach to the building community, critical market barriers are identified and prioritized. The top priorities of the market research speak to industry concerns regarding moisture performance and durability of high-R value assemblies. Without confidence in these assemblies, the market is loath to experiment on actual buildings. The BSA tool directly addresses the barriers identified by the market research and are easily translatable into the market. However, the tool stops short of helping users understand some key aspects of moisture performance - namely that of the resiliency of the assemblies. By resiliency, I mean how sensitive an assembly is to moisture - can it easily dry out or will water be trapped in a location where opportunities for drying are limited. No building is perfect and users of the tool need to be warned or somehow otherwise appreciate the value of the results from a perspective of when an assembly gets wet, not if it gets wet. I understand that modeling the moisture performance of assemblies includes some assumed amount of moisture intrusion or air leakage condensation in appropriate climates, but the effect of these wetting mechanisms can't be downplayed or underestimated if the BSA tool is truly to be useful for the long term.

- Strong team, great industry collaborators, solid technical base in building physics, and engaged with industry and professionals. But no cost share?
- (Slide 13) What is the assumed indoor RH for the calculation? Can it be changed?

- I think the tool itself will be useful, both as for education and even selection. However, the issue is not just what builders know but what they can trust. Builders will need to know why they should believe the results of the tool. This is a community that needs proof of performance in real world applications, like they build in, to have trust. A simple thumbs up from ORNL or DOE is not enough. Also, the real concern here is liability. Moisture is builders #1 concern when it comes to liability. Let's say they rely on this tool for a

recommendation, but the wall develops moisture, fails and results in huge costs for the builder and homeowner. Is ORNL on the hook? If they disclaim all liability for the tool's recommendations, will that engender the trust builders' require to use it? None of this is addressed.

- The approach will lead to an easy-to-use tool by builders and architects that will give a go/no-go indication of the performance of an assembly given a particular climate.

- A big barrier is communicating the necessary building methods to the mainstream contractor. In the US we don't require contractor technical training, or ongoing technical training to maintain a contractor's license. Many residential contractors have never had any formal building science training. We can't expect them to know how to build high performance envelopes. A simple to use and understand building envelop "how to" tool is essential to move these construction methods into the mainstream.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Program is on track with its interim market goal and demonstrates clear alignment with stated program performance goals. I am impressed with how far the tool has come in one year and look forward to seeing the beta version implemented. It will be important to vet assemblies, especially masonry veneer based assemblies, to make sure walls that shouldn't be built, such as masonry veneers without at least a 1" cavity behind them, convey such information to the user, or walls with fiber cement panel siding shown without the drainage cavity behind the panel that is required by the manufacturer in certain climate/exposure zones.

- Could have been clearer and included a visual, grid-based breakdown of tasks for the project plan and schedule. But based on presentation, you have already had and are having a positive impact in the industry.

- Hard to say. No goal in terms of energy savings potential. I do think the project is doing what it claims to do, but how this supports the 60% EUI goal is unclear.

- Software tool is in developmental stage. It promises to provide a tool that will directly address one of BA's goals. Usability appears good, but it will be interesting to see how the end users will take to the tool.

- Good concept. Roderick mentioned the beta version release was coming soon. The feedback to this beta version will help guide future work and outcomes.
- Additionally, my recommendation is to consider an open source platform. Similar to what DOE is doing with the OpenStudio platform. Open source allows for better future flexibility options. What is the exit strategy for this software platform? Do DOE along with Roderick and team want to be the gatekeepers for updates and maintenance? In this era of budget uncertainty we need to be thoughtful of long term software strategy so it can live beyond our limited budget support.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.20** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- I scored this section with 3's only because it seems there may need to be some key siding industry players added, e.g., fiber cement, masonry, vinyl siding. The remaining key stakeholders identified clearly relate back to initial market studies that led to the creation of this project, ie, closes the loop on market study,

planning, action taken, reviewing/feedback, and finalizing the outcome. Ongoing collaboration is recognized as essential and is planned and ongoing.

- Please see previous comments.

- No comments here.

- Project staff has enlisted an expert panel to drive development of software tool. Team appears to have good connections with builders who will utilize the tool.

- I expect the learnings from other DOE envelop projects will funnel into this data base. I hope the wall system choices will be representative of the entire market. For example, will it incorporate rock wool CI options and the various different SIP panel configurations and methods?
- One potential issue is how the tool will demonstrate the different wall construction methods in relation to the manufacturers' recommendations. Will the user enter the manufacturers' recommendation wall construction design and see what the tool result is or does the tool recommend best options with construction methods? The point I am making is what if the "tool"-recommended construction method does not follow the manufacturer recommended installation practice. Is this a potential issue, I don't know.

E. Proposed Future Work

This project was rated **3.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- A soft rollout approach and beta testing is smart and effective. Such tools require continuous updating and monitoring, which is also planned. Should include in plan regular check-ins with construction industry users and manufacturers, but not to the detriment of the building science that backs all of the information produced.

- Sounds great...looking forward to taking it for a test drive and sharing with clients.

- There is no reference to how the tool will ultimately seek to garner builder trust. There is a pilot period, but this specific issue is not addressed.

- Work builds on history of outstanding work at ORNL on building assemblies. Work will translate from paper reports to a software tool that provides actionable information.

- The upcoming beta release and product testing feedback will provide the information needed to direct the best path forward. The product concept definitely addresses a market need to empower the mainstream contractor with the correct envelope building methodology to reduce risk and improve building envelope energy performance.
- This product should be cross linked with BEopt so the user is aware of other building energy software tools which are available and supported by DOE.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 5** reviewers
- The BSA tool represents a departure from expert-only analysis tools like WUFI, to a tool for everyone. This is a big step for a lot of people used to "building it the way we always have."

- See previous comments.

- The project does address a critical need and interest area for the target audience.

- Project would result in an easy-to-use software tool that addresses a key concern of builders, namely moisture tolerant envelope assemblies.

- This is dependent on the beta release results.

***Average*: 0** reviewers
- N/A

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers
- The BSA tool directly addresses RBI goals and market research that limits adoption of high R-value assemblies. The deployment activity directly addresses these limitations and is directly tied to using the decades of building science research and knowledge that has been developed nationally and internationally.

- Thanks for you work on this value tool. Looking forward to seeing it up close and using it with clients.

- No comment.

- Same as previous...addressing one of the key areas of concern by builders.

- None.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project's strengths include the following:
    - 1) Building Science based tool
    - 2) User friendly
    - 3) Results easily interpreted
    - 4) Nothing like it exists in the market and has the potential to help transform the industry's comfort level with high R-value assemblies.

- Please see other comments.

- I think the technical backing is good. The tool appears user friendly and accessible, which will increase likelihood of use. What I question is whether this will be an interesting learning tool or something that really drives design and specification decisions.

- Yielding a tool that will provide clear information to key stakeholders who need the information.
- Addresses a critical issue facing the building industry in developing high performance homes.
- Tool seems to be intuitive.

- See other comments.

2) **Project Weaknesses**

- Project weaknesses include the following:
    - 1) I believe the potential exists for users to underestimate or under appreciate the moisture tolerance/resilience of assemblies. After they receive their results, they need to be guided toward information upon which the results are based that will give them the best chance of success.
    - 2) Assemblies need to be vetted so that assemblies that shouldn't ever be built or contravene manufacturer installation requirements are flagged at some early point in the process so the user isn't wasting time inputting an assembly that should never be built in the first place.
    - 3) Manufacturers can help with item 2 above and may need to be more involved with the project.

- Provide more information on cost share. Increase cost share to be more in line with other winning Teams. Having a visual, grid-based breakdown of tasks for the project plan and schedule would be helpful to understand more about what you've accomplished and what's to come.

- Already done.

- No major weaknesses.
- There is still a risk in that the tool is at an early stage.
- Hopefully the tool will be integrated with other tools so that it doesn't provide more confusion to building professionals who have access to multiple software options.

- The weaknesses will become apparent from testing feedback on the beta release.

3) **Recommendations**

- At some point, the user needs to be made aware that the BSA tool is a guide, and that in order to achieve the expected performance, the whole building, or whole building system needs to be taken into account and they may/likely will need expert help in determine how best to achieve the desired end results. High R-value assemblies are by their nature generally highly sensitive to moisture; the industry as a whole has not caught up with the science, so there are a lot of builders out there who are going to need a lot of help. Hopefully they will be willing to accept it.

- Suggest that you reach out to the Architecture/Designer and Homeowner markets to help increase the understanding and demand (pull) of this stuff into future homes.

- Asking builders directly what it will take for them to rely on this tool for design and spec decisions and then incorporating those findings into the project plan. Without trust, this is just a handy tool not a game changer.

- None.

- None.

Project # 11119: Healthy Efficient Homes

Presenter: Brett Singer, Lawrence Berkeley National Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project was needed, with one commenting that the project was poised to produce "useful and heretofore non-existent rating criteria for the effectiveness of range hoods." They felt that the project took a holistic approach to indoor air quality (IAQ), which has been identified as a major technical challenge in residential buildings and is therefore relevant to BTO goals.

Overall, reviewers agreed with the project's approach, noting that the project reflected a strong team, great industry collaborators, a solid technical base in building physics, and solid funding, and also that the project team had "demonstrated a keen awareness of the issues and crafted its approach to carefully [and] scientifically address the issues." One reviewer further commented that the project's focus on critical IAQ issues was notable for a topic area that still required much research. However, another reviewer felt that—because the presentation provided an overview of multiple projects—information on the approach was too high-level and not specific enough.

One reviewer felt that the project was making good progress, showed strong technical work, and was already having a positive impact in the industry, noting in particular that the feedback loop established with ASHRAE 62.2 was a good project component that would help guide the needed updates to ASHRAE standards. Another reviewer agreed that the project was promising and making demonstrable progress towards its goals, but was concerned that "end results [would] require a complex and coordinated effort to get buy in….from manufacturers and [the] building industry." A third reviewer felt that there seemed to be a lot of different activities taking place, and that it was not completely clear from the presentation what accomplishments had been achieved from the work and what impact was being had.

One reviewer thought that the project had a good mix of partners—including manufacturers, utilities, code bodies, and housing authorities—and had demonstrated a willingness and ability to engage the relevant communities in constructive ways. Several reviewers, however, were less confident about the project's collaboration and engagement, with one noting that it was not clear how much collaboration the project was having with manufacturers of equipment or other researchers.

One reviewer thought that, given the project team's industry contacts, previous papers, and project plan, this project had a strong track record that would carry forward. However, another felt "down on the future of project," caveating that that this was a reflection of the state of the industry rather than a reflection on the work completed to date. A third reviewer noted that, while the project seemed to be involved in a lot of topics that covered critical IAQ issue, future plans—and the ultimate goal of the effort—were not entirely clear. Another cautioned that the project did not have as clear a path to homebuilders and contractors as some other Building America projects.

Weighted Average: 3.38 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.50 Accomplishments: 3.25 Project Collaboration: 3.50 Future Work: 3.25

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project (review criteria and evaluation of range hood effectiveness and an idea of what a "healthy" home is) is certainly needed, and is poised to produce useful and heretofore non-existent rating criteria for the effectiveness of range hoods. Confidence in the effectiveness of range hoods and source pollutant removal has long been a black hole in the whole ventilation debate. The project is expected to lead to outcomes that will change how range hood devices are manufactured, coupled with how such devices will be integrated into the type and characteristics of the home in which it will be installed. While expected to lead to positive outcomes in the ventilation debate and change manufacturing practices, it is not wholly clear that the outcomes will lead to more energy efficient buildings. Market understanding and wholesale adoption will be key.

- Code as well as voluntary above-code programs are striving for (and realizing) high energy savings due in large part to reduce air leakage in buildings. But a known consequence is reduced IAQ. Therefore, how can we have our cake (low-e buildings) and eat it too (not get sick from them)? This project includes BTO goals and real field testing to collect data to inform the conversation.

- Project is one of the few in the Building America program that provide a holistic approach to Indoor Air Quality, which has been identified as one of the major technical challenges in residential by the program.

- This was an overview of several IAQ projects. IAQ is relevant to DOE goals. The individual projects touch on different areas. The optimal IAQ solution is a systems solution. In these studies IAQ and RH have an intersection point for occupant health, ventilation energy efficiency, and more appropriate standards.

B. Approach

This project was rated:

1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.50** for the degree to which the approach addresses the market barriers identified.

- The project represents a massive, complex, and comprehensive undertaking in the face of a lot of entrenched positions within the industry. Keeping its focus on building science principles and robust research methods, as well as strong community outreach and partnerships, the project team has demonstrated a keen awareness of the issues and crafted its approach to carefully scientifically address the issues.

- Strong team, great industry collaborators, solid technical base in building physics, engaged with industry and professionals, and solid funding.

- Team is focusing on critical IAQ issues. Much of their work is going towards standards work and peer-reviewed papers. Approach is solid, particularly for this topic area that still requires much research.

- We received an overview of projects. All high level and nothing very specific.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.25** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Promising work, and demonstrable progress towards goals, but ultimate end results will require a complex and coordinated effort to get buy in/adoption of program from manufacturers and building industry. Will likely need to incorporate results into EnergyStar framework or some similar framework to seed adoption/market readiness.

- Based on presentation, you have already had and are having a positive impact in the industry.

- There seem to be a lot of different activities taking place, from the development of a test method for evaluating range hoods to the assorted activities with standards. It was not completely clear from the presentation, though, what clear accomplishments have been achieved from the work. There are lots of different things going on, but the impact of all of those efforts was not made clear.

- The feedback loop to ASHRAE 62.2 is a good component of this project. This will help guide the needed updates to ASHRAE standards.

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The visibility and high impactful nature of the project requires a high degree of industry input. The project team has demonstrated a willingness and ability to engage the relevant communities in constructive ways.

- Yes, whether the manufacturers are choosing to improve their products is another thing.

- Project team appears to collaborate with SDO's such as ASHRAE and ASTM. It was not clear how much collaboration they have with manufacturers of equipment or other researchers.

- These projects have a good mix of key partners. Included are manufacturers, utilities, code body, and housing authorities.

E. Proposed Future Work

This project was rated **3.25** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The rating is not a reflection of the work so much as it is a reflection of the state of the industry. The project has spurred many related projects, the success of which is all ultimately tied to each other. With a generally unsophisticated marketplace, raising the bar through standards and codes may be the only reasonable path to achieving healthy efficient homes that contain the right equipment to deliver on the potential this project's outcomes represent.

- Given industry contacts, previous papers and project plan, this project has a strong track record.

- They seem to be involved in a lot of topics that cover the critical area of indoor air quality. Their plan for the future was not entirely clear to this reviewer; what is the ultimate goal of this effort? I believe that it is valuable work, but the presentation made it seem a bit scattered.

- This reviewer really likes the proposed capture efficiency labeling. Recently I bought a (Unnamed) microwave/range hood combo unit. The ventilation capture is AWFUL and the IAQ suffers as a result. As a consumer I fully support a ranking system for ventilation capture.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- The deliverables clearly have the potential to drastically change the kitchen exhaust ventilation market, as well as spur additional development for smart ventilation technologies.

- See previous comments.

- Test methods for range hoods could prove quite valuable.
- IAQ valuation metrics are critical; industry currently doesn't have a good way to describe IAQ.
- Work as part of ASHRAE and ASTM standards provides one potential avenue for application of research results.

***Average*: 1** reviewer
- None.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Healthy indoor environments and energy efficient, air tight construction are the future of buildings, and in many sectors of the country the future is here. The research programs within this grouping shine a much needed light on key research and deployment activities within the residential construction market that have been lagging in good building science applied research for far too long. This research goes a long way in closing that gap.

- I think this has already been said. Thanks for your team's great work on this project, but don't get cocky from this review score.

- Addressing key area of need identified by BA program, Indoor Air Quality.

- See earlier comments.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- 1) Comprehensive in its scope.
- 2) Currently influencing codes and standards development
- 3) Will very likely lead to a new rating system and new construction methods relating to range hoods and their integration within the whole house system.
- 4) Promising developments for taking advantage of smart ventilation technologies.

- Please see other comments.

- Addressing a critical need of the residential building industry.
- Strong interaction with standards bodies.
- Technical work appears to be very sound.

- Well planned projects with good target outcomes that will advance DOE IAQ initiatives.

2) **Project Weaknesses**

- You don't know what you don't know: in other words, it will be hard to tell where the next pocket of resistance will be to the broad changes the results of the project logically lead to. The unsophisticated nature of the industry will require a painstakingly plain and simple approach to help them feel like the results were all their ideas and not government interference in "the marketplace" or "their lives". Sorry to be crass, but these are the times we live in, perhaps have always lived in, but need to be awake to it now more than ever. The point is we need to be mindful of shoving things down people's throats and instead have compassion for fear that changes cause and work to minimize that fear.

- It would be a shame to measure and document challenges and problems with existing components in houses and not be able to inform or test out improved designs (e.g. exhaust hoods with different intake configurations/ locations, or?) in this funding phase or future funding opportunities.

- Does not have as clear a path to the practitioner as some other BA projects.
- Efforts do not seem entirely cohesive to solve the IAQ problem...what is the problem to be solved?

- When the presentation concluded, this reviewer was a bit confused whether this presentation covered two or three projects. That needed to be conveyed up front on the first slide. Clearly delineate how many projects are being discussed. Brett is very knowledgeable and conveys a lot of information, but the information he is discussing does not always align with the projects he is covering. He needs to frame the projects a bit more to align his presentation discussion with the actual project.

3) **Recommendations**

- None

- Not for this phase of the project...but for the future. So now what? I think this project should apply for additional funding to act on these findings and help design improved controls and components.

- None

- None

Project # 11150a: Durability of Windows in Walls with Continuous Insulation (CI)

Presenter: Vladimir Kochkin, Home Innovation Research Labs
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project, remarking that the project focused on a significant barrier impeding residential energy efficiency—namely understanding how to safely install windows in walls with continuous insulation (CI). One reviewer commented that overcoming any barriers to implementing continuous insulation would greatly encourage CI uptake, and therefore fit clearly within BTO's goals.

Reviewers strongly agreed with this project's approach, commenting that the project demonstrated a strong understanding of the players involved and the barriers they faced, and that the project was narrowly focused on key issues and should lead to the development of effective solutions. As one word of caution, one reviewer encouraged the project team to more clearly define "unacceptable performance" in windows installed in walls with CI, to make it easier to measure success. One reviewer also recommended considering longer-term testing to assess robustness of installation guidelines to expansion/contraction and other envelope movement over time. Another reviewer expressed concern that the approach would only address lab testing, encouraging the project team to also target field installation issues and to consider the complete wall package, including finished siding materials and trim details.

Though this project was relatively new, reviewers agreed the project team had progressed appropriately, and reviewers felt confident that the project would ultimately have an impact by encouraging the construction of high R-value walls. One reviewer commented that project outputs and the project goal were clearly stated.

Several reviewers felt the project featured collaboration with appropriate industry partners, including the builders and window manufacturers that would implement the solutions that were developed. One reviewer expressed concern over the fact that the project—as described—engaged only with foam CI manufacturers, counselling the project team to focus on protocols that supported a level playing field across all product types, including mineral-wool CI. Another reviewer recommended that the project team coordinate with other Building America teams working on envelope issues, particularly ORNL.

Reviewers agreed that proposed future work appeared closely aligned with the achievement of performance goals for window manufacturers and the BTO community, with reviewers commenting that these plans were logical, results driven, and would result in an impactful end product. Some concerns were raised around those project elements that reviewers felt were missing, including field testing potential solutions as well as engaging with CI manufacturers beyond foam.

Weighted Average: 3.31 # of Reviewers: 5
Relevance: 3.40[1] Approach: 3.70 Accomplishments: 3.10 Project Collaboration: 3.00 Future Work: 3.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Understanding how to safely install windows in walls with continuous insulation is critical to achieving BTO RBI program goals.

- Great topic and industry challenge, but for this project:
    - From Slide 4…(key issues: ...concern that in certain installation configurations and exposure conditions it can lead to unacceptable performance.) what kind of "unacceptable performance" are you referring to (e.g. structural, air leakage, moisture, etc.)? If the problem is not clearly identified, how do we know if we are successful at addressing it?
    - In addition to lab-based testing installation details, suggest also doing some field-based installation details?

- Wall R-values really cannot be driven upward without CI, so this project focuses on a significant barrier which impedes residential energy efficiency.

- High-performance envelopes of the future will very likely involve continuous exterior insulation to help achieve BTO's goals of savings in both new and existing housing. Overcoming any barriers to implementing this insulation, such as ways to install windows, would greatly encourage uptake of this building approach.

- This project fits with the BTO goal of developing high performance building envelopes. The CI method is an anticipated mainstream approach to low energy building energy envelope construction.

B. Approach

This project was rated:

1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.80** for the degree to which the approach addresses the market barriers identified.

- Narrowly focused issue with wide participation from all players leads to a focused and effective approach at address the problem.

- Again, I think this may only achieve a "good" rating if it only addresses a lab approach. But it can achieve an "outstanding" rating if it also targets the field installation details.

- I think the approach demonstrates a strong understanding of the actual barriers, players and how to overcome them.

- This project would result in easy-to-use guidelines by builders. While there are guidelines already in place for installing windows in a moisture tolerant manner, they tend to be rather complex and involved, and it's not clear that they are followed as rigorously as needed. The proposed approach would overcome the key barrier to builders installing more continuous insulation, namely how to efficiently install windows while minimizing the risk of moisture damage.

- Window installation on CI clad structures is a major issue. Window manufactures prefer direct wood frame mounting. This project will address the issues of window mounting on CI clad homes. Good solid approach.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Accomplishments to date are good given where the project is at this time. Finalizing draft evaluation protocol is critical, as well as subsequent test results.

- Has industry also provided comments regarding finished siding materials and trim details? If the whole wall assembly including the finish package is not discussed and included in the SWOT analysis, how is this research going to drive people to adopt it in the field?

- They have shown good progress with the draft protocol, developed with key stakeholders.

- The project is relatively new, but it appears that the team has progressed appropriately by putting together an advisory board to identify the windows to be investigated and by developing an initial test plan. It is expected that the project will have impact in encouraging high R-value walls.

- This is a relatively new project. The project goal is clearly stated and the project outputs are clear.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Collaboration and integration of appropriate industry partners appears to be in place.

- Yes, you have access to many industry players in different climate zones of the US.

- This was hard to score. I feel they identified most key stakeholders and appear to have worked well with them. However, the project is focused on CI but only engaged foam CI manufacturers. While relatively small today, mineral wool CI has a foothold in the US residential market, and is strong in commercial. As CI in residential becomes more common mineral wool could make inroads. It is unclear to me whether the project outcomes are specific to foam CI or extend to other types of CI, such as mineral wool. DOE should focus on protocols that support a level playing field across product types.

- Project team is well connected to the builders and window manufacturers that would implement the solutions that they develop.
- Team should be sure to integrate with other BA teams working on envelope issues, particularly ORNL.

- Key partners are appropriate for this project.

E. Proposed Future Work

This project was rated **3.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Proposed future work appears closely aligned with achieving performance goals of window manufacturers and the DOE community.

- See previous comments. Also Project Plan and Schedule on Slide 13 does not provide any additional clarification on field test.

- Plan is fine, but there is no mention of mineral wool or other CI products. Before project completion, the project team should engage with other CI manufacturers, or at a minimum determine if the protocol is limited to foam or more all-encompassing.

- Future work would involve a thorough set of tests and then development of guidance for the window installation industry. It appears that this future work would result in an impactful product.

- On the final presentation slide seven points are presented. These points are logical and results driven. Good structure.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- See answers to previous questions.

- Done

- Deliverable should be clear guidance for use by builders.

***Average*: 2** reviewers
- I would place it in between Average and High.

- None.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- See answers to previous questions.

- Key identified areas are receiving sufficient emphasis, but there are other areas that need more (already discussed in previous comments).

- Project will address key questions raised by builders in terms of developing a window installation over a high R-value wall that does not put the home at risk of failure.

- See earlier comments.

***No*: 1** reviewer
- As noted before, I think having a field testing/evaluation/knowledge transfer component of this project would take it from good to great.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project strength comes from window manufacturer and construction industry partners getting together to address a problem unique to CI installations.

- Solid team, access to great lab equipment, large bank of possible partners and cost share.

- Strong focus on barriers, key actors and needs to overcome them.

- Addressing a key barrier that is getting in the way of higher R-value envelopes.
- Good ties with industry.
- Logical path to accomplish a key output, namely standard installation guidance.

- There is a definite market need for resolving window attachment when using with CI cladding. The engagement with the window manufactures is key to mutual agreement to solutions. The resulting of guidance documents and tech notes are tangible solution oriented products that builders can reference to guide high performance envelope construction.

2) **Project Weaknesses**

- Project weakness may lie in entrenched interests. Will need to make sure all parties are open and respectful of positions and use science and testing to mete out concerns.

- See previous comments on missed opportunities if only limited to lab setting or if not also factoring in the finished materials used around the windows.

- Main weakness is possible exclusion of certain types of CI from the project.

- No major weaknesses. Team should be mindful of the fact that guidelines that are proposed will be adopted by many builders; they should be mindful to consider all alternatives so as not to eliminate potential good installation practices.

- One item that is not mentioned is CI insulation with 1/4 to 1/2 inch air gap construction methods. This type of construction needs to be addressed in the window attachment guide.

3) **Recommendations**

- None.

- See previous comments.

- Already done.

- Consider longer term testing to assess robustness of installation guidelines to expansion/contraction and other envelope movement over time.

- None.

Project # 11150b: Aerosol Sealing in New Construction

Presenter: David Bohac, Center for Energy and Environment
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project, noting that (1) air sealing is key to high performance housing, (2) the project fits squarely into Building America's focus on improve building envelope performance, and (3) it directly impacts the largest source of energy loss in residential construction: infiltration. One reviewer highlighted that successful completion will have a direct impact on saving energy in buildings.

Several reviewers agreed that the project team was implementing a sound approach to assessing whether the techniques under investigation would be effective at addressing air leakage, noting that the project benefited from a strong team with solid knowledge of building science, an innovative product, and good cost share. One reviewer highlighted that cost effectiveness was not highlighted in the presentation and was not noted in the next steps and future plans section, commenting that cost is a key component for market adoption and therefore should be a component of the study. Another reviewer flagged potential unintended consequences that the project team should consider, including that (1) the project's narrow focus on one technology could lead to an over-reliance on aerosol sealing and (2) the possibility that the process could encourage poor quality framing and carpentry. One reviewer recommended implementing some sort of tracer system in a completed home to see where air was flowing.

In terms of progress, reviewers acknowledged that it was early in the project cycle, and that there were not much field-result information to determine project accomplishments and impact. Notwithstanding this fact, reviewers commented that the project looked to be well on its way, that the team had demonstrated the viability of the approach, and that there was no reason to think that results could not be extended to other climates.

Reviewers noted that project properly integrated previous, related research, commenting also that the project team appeared to be well-positioned with the primary vendor of the sealing solution and builders in Minnesota, and was working to build relationships with builders in California and elsewhere nationwide. One reviewer highlighted that it was not completely clear which trade would take on the work in question, or whether it would require introduction of a new trade into the building process. This reviewer recommended that the project team continue to develop a network of builders who might be interested in the technology.

Looking forward, several reviewers noted that future work seemed appropriate, with one expressing appreciation for the project's iterative process, which was allowing the project team to "work out the [technology's] kinks." Some technical and market-oriented questions were raised, however (e.g., would moisture data be collected if the product was installed post drywall? are there other players in the market besides Aerosol?). Reviewers also had a few recommendations, including that the project team should (1) investigate the technology in a more humid climate, (2) perform cost analysis; (3) develop feedback guides or other mechanisms to improve the application process, and (4) follow-up after a few years to reassess tightness, comfort, and durability.

Weighted Average: 3.00 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 3.00 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Air sealing is key to high performance housing and achieving BTO RBI program goals.

- Positives: creative material/ application, importance of air sealing (connected to codes, above-code programs, and often associated with improved energy efficiency)
- Negatives: is this a new "airtight drywall approach" and the related missed opportunities, does this reduce moisture resiliency of wall, doesn't address convective loops from holes in sheathing or chases, air tightness is still not directly correlated to energy savings.

- Project directly impacts the largest energy loss in residential construction, the loss of conditioned air via infiltration. Successful completion will have a direct impact on saving energy in buildings.

- This project fits with improved envelope performance. Air sealing to reduce infiltration is an important component in achieving high performance building envelopes.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project approach is narrowly focused on one technology to limit the need for other air sealing steps/technologies. This could lead to an over-reliance on aerosol sealing and leave a few other larger holes that could cause problems in the future if they aren't also dealt with by other means.

- As noted on https://energy.gov/energysaver/air-sealing-new-home-construction: "However, Simple Caulk and Seal is less comprehensive than Airtight Drywall Approach, and may miss some critical points inside building cavities that become inaccessible after the drywall is installed."
- Is this product going to encourage poor quality framing and carpentry and not encourage details to be fixed during the process?
- On slide 6 ("Assess current sealing methods....and develop two approaches for each"), will this evaluation also look at moisture/ durability performance over time of wall assemblies depending on the location of the cracks (for 2 climate zones)?
- If this cannot be used in MN winters, but other products can, isn't that a big market threat?

- Air sealing is a labor intensive process that is more art than science. Doing it well requires a good deal of supervision. This approach could help automate the process and result in a more effective result.

- The approach is sound. Project study results show good efficacy. This project should help advance the application to production builders. The cost effectiveness of this method was not highlighted and is not noted in the next steps and future plans section. Cost is a key component for market adoption. It should a component of the study results.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project looks to be well on its way. I look forward to future reports on progress and lessons learned from contractor engagement.

- Bummer on the timing of the project and MN winters.

- Team has demonstrated the viability of this approach in a limited set of climates. There is no reason to think that the results could not be extended to other areas of the country considering that much of the work has taken place in one of the country's more extreme climates. It's not clear whether this approach could exacerbate any moisture issues in high R envelopes; would the aerosol particles settle in places that allow currents to deposit moisture in places that might be cold and susceptible to moisture problems?

- Early in the project cycle. Not much field result information is available to determine project accomplishments and impact.

D. Project Integration and Collaborations

This project was rated:

1) **3.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project integration and collaboration with previous research appears to be on track. Extending existing knowledge base of duct sealing into air sealing of homes is novel and could really make a difference.

- Sounds good, looking forward to hearing more about it.

- Project team appears to be well-positioned with the primary vendor of the sealing solution and builders in Minnesota; it is working to build relationships with builders in California and some of the large builders in the US. It's not completely clear which trade would take on this work, or whether it would require introduction of a new trade in the building process. Team should continue to build up the network of builders who might be interested in this technology.

- This is not a complicated project. The basic concept is demonstrating a spray whole home sealer. The project team is appropriate for the project type and desired outcomes.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- I appreciate the recognition of the need for an iterative process as the project participants and proponents work out the kinks.

- Is hind-sight 20/20? Why start in MN and not CA given the temperature limitations of the product?

- If the product is installed post drywall, is moisture monitoring (on cracks of exterior sheathing) going to be part of the data collection? If the product is installed pre insulation, will this limit the product to a certain ceiling configuration (non-vented attic)?

- Team will broaden its scope beyond Minnesota to tackle housing in California. It would be good to tackle a more humid climate. Work is starting to get to more details of how the process would work. It's still an exploratory effort, but one that could have great impact.

- The approach and future work seem appropriate. Lacking are:
  - cost analysis
  - mention of feedback guides, documents or other mechanisms to the manufacturer or users to improve the application process.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- Project has the potential to save a lot of time and money in the air sealing process of buildings.

- Deliverable would be a clear approach for builders that will help them more effectively air seal buildings.

***Average*: 2** reviewers
- I'd go between Average and High based on previous comments.

- No comment.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Yes, but I would like to see some emphasis also on the holes that are left after aerosol sealing and an assessment of the potential damage from air leakage condensation at those locations.

- Just a bummer that the timing of winter through things off so much with MN being the first location before CA.
- Looking to hear how this installation process compares to the builders existing air sealing process for code/ above code program targets.

- Team is currently in research stage, but it is engaging builders to best understand their needs. It is expected that, if the approach proves successful, the team can refocus future activities to outreach.

- No comment.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project has real promise in the area of improving overall airtightness of buildings cost effectively.

- Strong team, solid knowledge in building science, innovative product and good cost share.

- Interesting approach that could decrease the cost to air seal a home and could decrease the variability in the air sealing process. Could overcome the lack of skilled labor needed to achieve a tight home.
- Project has already demonstrated great promise; the team has implemented a sound approach to assessing whether the technique will be effective.

- *No Comment*

2) **Project Weaknesses**

- Cost (in both time and money) are key weaknesses until sorted out. Unintended consequences should also be seriously considered.

- Please see previous comments.

- No major weaknesses.
- Approach may need to be verified over multiple seasons to see if air sealing approach is effective as buildings expand and contract.
- Approach should be more broadly tested, particularly in humid climates to see if any adverse effects occur.

- See earlier comments on cost.

3) **Recommendations**

- None.

- Nothing additional.

- Could be valuable to implement some sort of tracer system in a completed home to see where air is flowing.
- Follow-up a few years down the road would be valuable to reassess tightness and to ask about any comfort or durability issues that have arisen.
- It's good that the team is working with builders to best understand the sequencing of the operation, and also to identify cleanup issues.

- Are there other players in the market besides Aerosol? If so, will there products and methods work similar to this product, or do we need to differentiate the products that work from those that don't work?

Project # 11150c: Monitoring of Unvented Roofs with Diffusion Vents & Interior Vapor Control in a Cold Climate

Presenter: Kohta Ueno, Building Science Corporation
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers were very positive about the relevance of this project, noting that the research was in direct alignment with BTO's goal of developing moisture-managed, high R-value envelopes and could significantly impact energy consumption, comfort, and durability in residential buildings. One reviewer noted that the project reflected a great, forward-thinking idea, but was concerned that it would ultimately have low impact due to limited market demand.

Reviewers highly rated the project's approach, noting that it was sound; vetted by industry partners; and built on a strong team, solid building science fundamentals, a great track record for field data collection, and good cost share. In particular, one reviewer lauded the project's rigorous scientific approach to testing various installation methods. The approach was not without criticism, however. One reviewer questioned why the building industry was not focusing on air sealing ceilings, burying ducts, and leaving attics ventilated. Another reviewer recommended the project team consider the effect of water leaks, as well as the effect of this venting technique on shingle life.

Reviewers were pleased with the progress made to date, given that it was early in the study, commenting that the study plan was solid, that target outcomes were realistic and appropriate, and that it appeared the project was already producing some actionable results.

Reviewers described this project as well-coordinated and integrated, and that it was building on years of field experience and research. Reviewers lauded the project team's connections with key building insulation manufacturers, as well as the team's understanding of the importance of connecting with code developing organizations. One reviewer remained unsure about the types of collaborations that were being developed with builders.

Looking forward, reviewers remarked that the project's proposed future work addressed the largest critical barriers to implementation of the project's roof assembly, and that the project's three-year runtime was sufficient. One reviewer commented that the formulation of building code language was a good target deliverable for the project, but another questioned why the project was not also testing an externally-ventilated DVR (e.g. tile, metal).

Weighted Average: 3.69 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.63 Accomplishments: 3.75 Project Collaboration: 3.75 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Research is in direct alignment with DOE goal of developing moisture managed high R-value envelopes.
- Great, forward thinking idea, but low impact, at approx. 4% or 40,000 units/year.
- Project directly addresses issues related to heating and cooling losses that occur when ductwork and equipment are placed in unconditioned spaces. By providing builders confidence in a lower cost method for creating conditioned attics, the project could significantly impact energy consumption, comfort, and durability of residential buildings.
- BSC performed previous successful studies for vented and unvented roof moisture and mold risk. This study expands on this work and is very relevant for high performance insulated ceiling structures.

B. Approach

This project was rated:

1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.75** for the degree to which the approach addresses the market barriers identified.

- Approach is sound and vetted by industry partners. The only other variable one might consider is the effect of a leak, but at that point, the owner should really be looking for a new roof due to age, or in the case of new roof, looking for the contractor to repair, assuming it is not an air leakage condensation leak manifesting on the interior. The effect on shingle life is also a consideration that is missing.
- Strong team, solid building science knowledge, great track record for field data collection, good cost share.
- Project team has identified the higher costs of spray foam as a market barrier as well as the reluctance of builders to adopt a solution that they may perceive as risky. Additionally, the team acknowledges the barrier that the building codes may present and plan to bring any potential solutions to the code development process.
- Very solid approach, similar in set up to prior studies.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.75** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is in its infancy, but is up and running and appears to be producing some actionable results already.
- I think given its previous research to influence this project, it is well positioned.
- Project is still in its early stages, but the team has developed a seemingly appropriate experimental effort that will assess the performance of a variety of ways to insulate rooflines. Project builds on previous work through experiments in a test hut in climate zone 5a tests will occur over a sufficiently long period of time to assess performance.
- Early in study, but study plan is solid and target outcomes are realistic and appropriate.

D. Project Integration and Collaborations

This project was rated:

1) **3.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Well-coordinated and integrated project building on years of anecdotal evidence, now to be backed up by research.

- CZ 2A research already shared at Buildings XIII Conference. Looking forward to hearing about this CZ research when it comes out.

- Project team has connections with key building insulation manufacturers that can promote these solutions. Team understands the importance of connecting with code developing organizations.
- Not sure what types of collaborations are being had with builders; also, results should inform other BA teams.

- Project integration includes a number of insulation manufacturers. Very good.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Proposed future work addresses the largest critical barriers to implementation of this type or roof assembly.

- I like how you're numerically tracking indoor RH options.
- Why not also test an externally ventilated DVR (e.g. tile, metal) in CZ 5A?

- Team will be monitoring test huts for 3 winters, which should provide sufficient data to assess performance. Team will then work with formulating approach into code language.

- Project is running for three years. That is sufficient time for issues to develop and be identified. Formulation of building code language is a good target deliverable for the project.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- See previous answers.

- Guidance on cost-effective ways to construct conditioned attics. Can crawl spaces be done as well?

- Basing this on the good results from prior studies.

***Average*: 1** reviewer

- High value information for a low impact technology.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- See answers to previous questions.
- Thanks for your research. Looking forward to hearing more data when it come in.
- Easy to use guidance will result for builders, and overcoming code barriers is important in enabling the moisture tolerant, high R-value approach.
- None.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project's strength lies in its rigorous scientific approach and the variety of installation methods available to test.
- Taking previous experience to the next phase.
- See also previous comments.
- Addressing a critical problem with a solution that could be more amenable to builders than current approaches.
- Well-developed experiment.
- Good thoughts to overcome critical barrier of building codes.
- It's a good project. It effectively addresses moisture and mold issues across several different construction and insulation methods

2) **Project Weaknesses**

- Project weaknesses include not addressing the effect on shingle life and what happens in case of a leak.
- Why don't we air seal the ceiling, bury the duct, and leave the attic ventilated. Focus more on getting this documented, streamlined, and low-cost.
- No major weaknesses.
- As noted in presentation, there may be a need to do an interim visual assessment, which may or may not disrupt the experiment.
- No major weaknesses noted.

3) **Recommendations**

- None.
- See previous comments.
- Not sure what will be done should dramatic problems in one or more of the installations occur in first or second year.

- Assess whether the bays have any interaction with each other.
- None.

Project # 11150d: Physics-based Interval Data Model to Automate & Scale Home Energy Performance Evaluations

Presenter: Kurt Roth, Fraunhofer Center for Sustainable Energy Systems
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers strongly agreed on the relevance of this project, noting that it aligned with BTO's goals by directly addressing heating and cooling energy consumption in existing homes, and also that it was a concrete step in the use and application of residential energy data generated by IOT devices—in this case connected thermostats (CTs). One reviewer commented that they thought the relevance of the project *idea* was outstanding, but that they had concerns about the project's achievability and measurability; this reviewer questioned how the project would know that the quality of the audits and retrofits were dependable enough to use to validate the models, as well as how the baseline quality of existing HVAC systems would be verified.

Reviewers were generally positive about this project's approach, but they raised numerous concerns, including that (1) the full landscape of barriers was not yet defined or discovered; (2) data being collected and reported by CTs was of unknown quality and type; and (3) this project may not be different enough from existing high-bill data to motivate homeowners, utilities, and/or renters to take action. One reviewer flagged that a number of efforts were underway to develop gray box models of homes for similar purposes, expressing hope that the project team had fully evaluated these efforts, especially those led by universities.

Reviewers agreed that it was too early in the project to have significant accomplishments to report, but noted that the project appeared to be on track and that a logical technical plan has been laid out. Reviewers also felt that the project team's key partners were appropriate for this work, highlighting in particular that the project had great utility partners while also receiving strong interest from others in the market. One reviewer emphasized that the complexity of the project required significant collaboration, but noted that the project team appeared to understand this complexity and was well-prepared to deal with it.

Reviewers were mixed on the project's proposed future work, commenting more on what they felt was missing from the plan than on what was included. One reviewer noted that the project plan appeared solid, but also felt that it was not clear how the timing of different project stages would work. This reviewer specifically questioned whether CTs would have to be installed before the peak of heating season, and also whether there would be enough time to fully assess what retrofit measures were be most valuable. Two reviewers recommended adding heat pumps and other HVAC technologies to the evaluation, referencing that some CTs have been shown to increase heat pump energy use after CT installation. Another reviewer recommended focusing on activities that demonstrated a "win-win" for the stakeholders involved, first demonstrating success on an activity-by-activity basis and then aggregating these individual wins to better demonstrate a path to the project's broader objectives.

Weighted Average: 3.00 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.00 Accomplishments: 2.88 Project Collaboration: 3.38 Future Work: 2.75

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project is directly aligned with BTO RBI program goals.

- I think the idea relevance and team are outstanding, and I also have questions and concerns about the relevance and details of the field verification/ validation. (Specific to BTO Goals of achievable and measurable) How do you know that the quality of the audits and retrofits are dependable enough to use to validate the models? Is the project going to be using the NREL Guidelines for Home Energy Upgrades for retrofit standardization of audits, work, QC and QA? Or other vetted specifications? Are the retrofits going to be performed on the same shaped and configured homes? How will you know the starting/ baseline quality of the existing HVAC system? Is it going to be part of the audit?

- Project directly addresses heating and cooling energy consumption in existing homes. This end use is a significant one that is being addressed by BTO. Therefore, this project is relevant in addressing a key area of energy savings across the building stock.

- This project has relevance on several levels:
    - It's a concrete step in the use and application of residential energy IOT device-generated data
    - The analyzed data provides new opportunities to:
        - Profile home with poor UA values in order to target weatherization. Huge economic savings potential for utility weatherization programs.
        - Profile homes with poorly operating HVAC systems. Another good utility program opportunity. For both new construction installs with a smart thermostat (QA/QC) and upgrade/repair potential to generate EE savings.
        - Investigate residential control applications in the IOT space. The project, if successful, establishes a concrete opportunity to establish a value proposition.

B. Approach

This project was rated:

1) **3.00** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project is in its very early stages. Some critical barriers are beginning to crystalize, but the full landscape of barriers remains to be defined or discovered.

- How is this going to be different enough from existing high bill data analysis (e.g. 2 times national average EUI, or 40k kWh/year, or 13 kWh/sqft EUI used in SC Help My House and NC Upgrade to $ave) to motivate partner (home owner, utility, renter) to act and have a large impact?

- This project will help utility driven retrofit programs target their marketing efforts towards those homes with the greatest potential for energy savings. Convincing homeowners to make improvements to their homes is frequently cited as the biggest challenge for the HPC industry; anything that could help overcome that barrier is welcome.
- There is a concern that the project will only utilize communicating thermostats installed by the utilities (to which the efficiency program would have access). I am not sure how the utility programs work in the area to be evaluated, but my current area only has such thermostats when the customer opts in to the program. One would expect that those homeowners that opt in are already motivated to reduce energy consumption, so there is question whether the effort would identify homes that truly have opportunities for energy consumption, yet the homeowners don't have the time to think about the possibilities. Also, this project would not necessarily make retrofits any easier; it may provide an opportunity to prove that the retrofit was successful given before and after data.

- BPA is interested in applications for IOT thermostat generated data. We have ongoing discussions on this topic with EPRI, VEIC, and others. We are very interested in the results and lessons learned produced thru this project.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.75** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Project is in its early stage. Too early to have significant accomplishments to report, but appears to be on track.

- Project is newly awarded.
- Project has clear and achievable milestones.

- Project is still in its early stages, yet the team seems to be well on its way towards meeting its goals. It appears that a logical technical plan has been laid out. This reviewer is somewhat aware of a number of efforts at building gray box models of homes for purposes similar to these based on reviewing papers for the BuildSys conference, so it is hoped that the project team has fully evaluated work being done, especially by universities.

- This work targets home EUI reduction, utility program cost effectiveness and IOT device data value proposition.

D. Project Integration and Collaborations

This project was rated:

1) **3.25** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- This is a complex project with will require significant collaboration. Early indications are that the project team understands this complexity and are well-prepared to deal with it.

- As mentioned, this is a great topic of current high interest, the project team has great utility partners while also getting strong interest from other market players.

- Team has wisely joined forces with three utilities. These partners will be some of the only ones with access to the necessary data to make use of the knowledge gained in the effort. Also, they would be the ones who could most benefit from the findings.

- The Key Partners are appropriate for this work.

E. Proposed Future Work

This project was rated **2.75** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Project is in its very early stages. The potential certainly exists with the growing use of connected thermostats. There are now datasets being captured that heretofore were difficult to come by. The ability to mine this data for targeted ECMs has transformational potential.

- We have already seen some substantial factory setting challenges to this CT that have made heat pump energy usage worse after installation. Therefore, we think it is wise and critical to include other HVAC technologies to this effort.
- As mentioned before, I have concerns on the accuracy and validation of retrofit work that will then be critical to the usability of the models.

- Project plan appears solid. Further development of the models will occur in the near future. There will be some uncertainty in recruiting the 80 homes to participate in the project. Findings should be valuable for this climate; it is not clear how timing will work, whether they must have the CTs installed during the peak of heating season. Will they have enough time to fully assess what retrofit measures will be most valuable?

- New project and still early in the project timeline. The goals are good
- Looking forward I see immense opportunity in understanding what can be done with data from devices and equipment. In the future, there will be an intersection of the electric utility, manufacturers, the free market (product providers) and the customers. This space, is currently fragmented, but is very valuable when viewed in the aggregate. The "top-down" approach is daunting so if DOE, BPA and others can coalesce on small wins, then that will help build the roadmap to where the connected device space could potentially end up: Our focus forward should:
- Demonstrate projects with a "win-win" scenario for the stakeholders involved
- Work with disparate pieces to demonstrate success at that level and then aggregating induvial wins into an aggregate to better demonstrate a path to a larger end-goal.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer
- This needs to be done. IOT and device level data is a transformative market trend and we need to begin working on projects that advance our goals in this space.

***Average*: 3** reviewers
- Project is in its early stages. Nothing produced thus far is above average, or beyond what would be expected at this early stage. I look forward to future reports on progress.

- I would put this in the Above Average category.
- How is this "silver bullet" going to be different from other approaches?

- It should aid utilities in marketing efforts; it remains to be seen whether it will truly increase the number of homes that are retrofitted. It is worth the effort to study.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Ultimately, the team knows where it is going, so appropriate emphasis is expected to continually be applied.

- Yes, but as mentioned before, I can foresee some field related problems that could be devastating to the accuracy of the models.
- Great idea. Looking forward to the progress reports.

- Good stakeholder engagement, correctly trying to tackle modeling, then field test. Appropriate approach.

- See earlier comments.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project's strength lies in its potential to increase uptake of ECMs and the associated energy savings that goes along with that. It also takes advantage of the "internet of things" phenomena in a way to harness that information to produce real energy savings.

- In addition to the previous comments, this team has strong technical and building physics experience.

- Addresses the critical issue of space heating and cooling for existing residential.
- Seeks to overcome a critical barrier in implementing energy retrofits, namely convincing homeowners that a significant investment and potential inconvenience could save them money.

- See earlier comments.

2) **Project Weaknesses**

- Project's main weakness lies in the unknown quality and type of data being collected and reported by CTs and the lack of an internationally or nationally accepted standard for such devices. However, I believe there is enough time and room within the program to rely on partners and stakeholders to agree on a set of data.

- Are the field tasks going to be as reliable and dependable as the other tasks (e.g. modeling, analytics, etc.)
- How is this project different from the existing remote, electronic evaluations performed?

- It is not clear that the approach could be applied to a large amount of houses given the need for communicating thermostats; at this point, I don't believe that there are a great deal of such devices to which a program would have access.
- Results will help in targeting marketing; not sure whether it will help convince homeowners.

- See earlier comments.

3) **Recommendations**

- None.

- In future funding phase, add heat pumps to the effort.

- None other than already stated.

- Whatever the outcome this project lays a good foundation for what use cases and how we can analyze thermostat data. We will get there, this project may be fully successful or only partially successful, but either way the time, money and effort will be valuable.

Project # 11150e: Development of the Industry's First Smart Range Hood

Presenter: Mike Moore, Newport Partners
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers were mixed on the relevance of this project to BTO's goals. They agreed that the project was addressing the question of how to increase building tightness for code and above-code programs, which is relevant to BTO's goals. However, several reviewers questioned the direct link between point-source exhaust ventilation and the goal of saving energy by addressing indoor air quality (IAQ) concerns in air-tight homes; reviewers were not convinced that better, more effective, customer-friendly range hoods would make builders feel more confident building tighter homes. One reviewer also felt that the project's ultimate impact would be to improve IAQ rather than produce energy savings, and therefore that the project would be better framed in IAQ terms.

Reviewers positively rated the project's approach, commenting that the approach was sound; the presenter did a good job of conveying the overall project scope, intent, and intended results; and the project did a good job of identifying marketing barriers and structuring a plan to address them. One reviewer expressed support for the development of sensor and control technologies to advance the effectiveness of smart range hoods, but also cautioned that addressing ongoing maintenance and commissioning issues would also be critical. Another reviewer questioned whether a simple interlock with the stove controls could be a better approach. One reviewer recommended expanding the amount of lab testing for early prototypes, to prevent any big surprises from popping up in 2019.

Reviewers acknowledged that the project was in its very early stages, but felt that it was off to a strong start, appeared on track, and that its work to date demonstrated good execution and delivery on an overall solid project plan. Reviewers also noted that the project had strong partners, was well connected to the range hood and ventilation ecosystem, and had developed key collaborations with other Building America teams with expertise in the area (i.e., LBNL). One reviewer lauded the project's planned engagement of the ASHRAE Standard 62.2 committee, while another expressed concern that end-user stakeholders—and their input—were noticeably absent.

Looking forward, reviewers were somewhat mixed on the project's future plans. One reviewer commented that the project timeline and associated deliverables appeared logical, but another remarked that the project plan and schedule appeared very ambitious.

Weighted Average: 3.18 # of Reviewers: 5
Relevance: 2.80[1] Approach: 3.40 Accomplishments: 3.00 Project Collaboration: 3.30 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.80** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Smart range hood and saving energy in air tight houses are not directly linked. Certainly air tight houses need point source exhaust ventilation, but it is a system issue.

- Yes to BTO Goals (clear, ambitious, achievable, measurable, relatable).
- Component is very important to support increased building tightness for code and above-code programs.

- The premise of the project is that builders resist air tightness requirements over IAQ concerns. This is true. The project extends this premise to assume that range hoods, and cooking-related IAQ issues, are a part, and in fact a significant part, of this builder resistance to tight homes. I am not certain this is true, and what's more, no data is provided to support this position. This could be answered by a simple question to builders "if there were better, more effective, more customer-friendly range hoods would you feel more confident building tighter homes?" Until this question is answered, I feel the foundation of this project is shaky.

- While the project is important in the sense that it should lead to better IAQ in tightly built homes, it won't in and of itself have any marked effect on energy consumption, except for increasing it. That's not a knock, but the impact should be rephrased to focus on improved IAQ rather than energy savings.

- This range hood ventilation project, thru sensor technology, targets:
    - To reduce indoor cooking generated air pollution.
    - To optimize mechanical range hood ventilation.
- This range hood project dovetails with other DOE investments to create a systems view and approach to optimize indoor IAQ and RH, while reducing EUI.

B. Approach

This project was rated:

1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- Sensor controls and technology, in my view, will be the limiting factor in the long term effectiveness of smart range hoods. I support development of such, but ongoing maintenance and commissioning will likely be critical, if not absolutely necessary. Another jobs program, now the HVAC contractor can add smart range hood maintenance to his list of services. I haven't been happy with my smart refrigerator . . . food for thought

- Benefits of kitchen exhaust is totally dependent on being turned on. If auto function is available, then impacts and benefits from technology could be great.

- The project did a good job of identifying marketing barriers and structuring a plan to address them.

- Team has identified the technical issues with fans that cause users to not use them.
- Team has developed partnerships with leading hood manufacturers.
- Team recognizes the challenges in place due to Standard 62.2 requirements.

- Project started in October 2016. New project. The approach is sound and the presenter did a good job of conveying the overall project scope, intent and intended results.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Project is in very early stages and is off to a strong start.
- Just been awarded, but has strong project partner.
- This is early stage but it seems on track so far.
- Project is still in its very early stages, so few conclusions can be presented regarding the progress to date. The approach at this time seems appropriate. If successful, the project should improve IAQ in tight homes.
- Project is in the early execution with much of the initial project focus towards sensors and sensor control. The team is also working in conjunction with ASHRAE to allow this type of automatic control approach. The work to date demonstrates good execution and delivery on an overall solid project plan.

D. Project Integration and Collaborations

This project was rated:

1) **3.40** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.20** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project proponent is well-connected to the range hood and ventilation ecosystem.
- Looks great...LBNL and major manufacturer.
- The work with key manufacturers is good, however end users are absent. I am concerned about developing a project divorced from end users input.
- Team has developed key collaborations with (a) other BA team with expertise in the area (LBL) and (b) leading manufacturers of the products. They also plan to engage the 62.2 committee to explore any necessary changes in the standard.
- There are 2 identified key partners. Newport partners and Broan. In the body of the presentation they indicated LBNL as a collaborator. From the presentation, and early accomplishments, my impression is that this is a good team. I think there is an opportunity to include bit more depth and breadth in with one or two additional key partners. But, if they can accomplish the work, then this may not be that big of an issue. Sometimes a long list of key partnerships are more project window dressing than providing actual value.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Project is in early stages. Project plan is logical and anticipated to achieve desired outcomes.
- This looks like a very ambitious Project Plan and Schedule...please describe more about how you can achieve it.

- Plan does seem to address the market barriers.

- Not too many details are available at this time, but it appears that the current plan is adequate. There will be risks in identifying the sensing methods that are appropriate given the vast amount of pollutants of interest. It is expected, though, that a few key parameters will be identified to minimize both false negatives and false positives.

- The project timeline and associated deliverables appear to be logical with a solid project progression path.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- See comments on + and -.

- DOE is funding several IAQ studies. The results of these different studies need to cross pollinate in order to create a systems approach to regulations, IAQ solutions, EUI improvements and consumer satisfaction.

***Average*: 3** reviewers
- Deliverables are what I would expect at this early stage of the project.

- Early stage, so far things are looking good.

- Should be a solid contribution for improving IAQ; not clear how popular the resulting product would be.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Project is highly focused.

- No comment.

- Good mix of product development, engagement with standards organizations, and direct involvement with product manufacturers.

- None.

***No*: 1** reviewer
- As mentioned before, I am concerned that the timing of the lab time may not be the best for developing and testing out prototypes at different milestones to keep on this schedule.
- Thanks for your research, looking forward to hearing updates.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project strength lies in its narrow focus on developing the technology to support adoption of smart range hoods. Project collaborators are also a strength.

- Valuable and unique strategy (automatic) to address an impactful task (kitchen ventilation).
- Strong team and partners. Great timing with LBNL.

- I think the project did a good job of outlining market barriers and key performance objectives needed. The technical element is strong.

- Aims to make ventilation easy. Easy is always good for residential applications.
- Good collaborations have been developed.

- In low load homes automated cooking ventilation control that optimizes ventilation run time to IAQ is a good project goal.

2) **Project Weaknesses**

- Weakness lies in the sensor technology available to pull off desired operational characteristics for the life of the range hood and the possible need to change ASHRAE 62-2.

- See previous comments on time frame.

- What is missing is a real understanding of whether or not this will meaningfully address the concerns it seeks to. If it doesn't, it really does not meaningfully support BTO's programmatic energy savings goals.

- There is a bit of risk in terms of identifying sensing mechanisms.
- Questions about how the project might address long-term performance of these devices.
- Not clear about the market for these devices; would people be willing to spend the extra money to install these?

- Overall this appears to be a solid project. No major weaknesses identified.

3) **Recommendations**

- None.

- Try to add more later on lab testing to earlier prototypes to not lose time or get big surprises in 2019 (e.g. add high level M3.3 to M3.1, then beta test M4.2 and M4.3).

- None.

- Could a simple interlock with the stove controls be a better approach, perhaps wireless to eliminate any need for communications wiring between the two?
- Examine sensor technology for commercial kitchens for ideas about best approaches.

- None.

Project # 11150f: Affordable Solid Panel "Perfect Wall" System

Presenter: Pat Huelman, University of Minnesota
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers agreed overall that this project was relevant to BTO's goals, noting that it meshed with Building America's focus on moisture-tolerant, high R-value building envelopes and that it addressed one of the largest sources of energy use in the home (i.e., space heating and cooling). One reviewer expressed a strong liking of this project, but also had a hard time viewing "a new way to build buildings" as a critical tool for meeting BTO's goals. One reviewer questioned why the project appeared to focus on only 10% of the market (i.e., affordable housing), though another reviewer expected that the new wall system would impact more than just affordable units.

The project's approach was well-regarded by reviewers. One noted that the project was laser focused on the success of new construction practices, while another remarked that the plan to build 23 homes would provide a large enough sample to validate the project's findings. Some concerns were raised on the approach, including about how the project would be leveraged for impact beyond the local test markets, as well as whether the planned performance testing included moisture issues in addition to air leakage and energy use.

Acknowledged to still be in its early stages, one reviewer believed the project to be well on its way to accomplishing its goals, while another thought it was too early to tell if the project was on track. Other reviewers reiterated their concerns over the project approach in the context of the project's ultimate impact: will the project be scalable, and what will be the impact of the new wall technology on moisture and comfort issues?

Overall, reviewers were pleased with the project's collaborations, with one noting that the project's design and implementation were made possible only through close collaboration with a cross-section of market actors. One reviewer expressed interest in seeing more collaboration at the national level—in order to better leverage the project's findings after completion—while another wanted to see more collaboration with other Building America project teams working on envelope issues.

Looking forward, reviewers felt that the proposed future work for the project was appropriate, given that the only way to overcome builder reticence around a new technology was to do actual installations. One reviewer did express concerns that the project plan felt geographically limited, recommending greater emphasis on sharing lessons learned more broadly.

Weighted Average: 3.22 # of Reviewers: 5
Relevance: 3.40[1] Approach: 3.20 Accomplishments: 3.30 Project Collaboration: 3.10 Future Work: 3.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- I wanted to rate this 4, but I don't view a new way to build buildings as "critical" to meeting BTO goals. That being said, I love this project.

- This project addresses the BTO Goals (clear, ambitious, achievable, measurable, and relatable).
- And this technology has the potential to impact more than just affordable housing.

- It is relevant to BTO goals but I question a project that seems to only focus on 10% of the market.

- Project addresses largest energy use in homes, space heating and cooling.
- Focus is on new homes.
- Meshes with BA goal of promoting moisture tolerant, high R-value envelopes.

- It fits with the high performance building envelope goal defined by BTO. This project appears to represent a new building envelope system. I am not familiar with this system. It's not SIP or CI on conventional framing. I also didn't get the impression it was post and beam. This project is designed to demonstrate this new framing/insulation system and quantify:
    - Required labor skill level
    - Ease of construction
    - Thermal performance
    - Cost
    - other

B. Approach

This project was rated:
1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Project is laser focused on what makes this new construction type successful and how to build it successfully. A masterful demonstration.

- Yes, these are valuable markets (non-profit and for-profit).
- Yes, demand for YER homes is growing.
- But growing concerns of moisture management and ventilation in code and YER homes. Does your "test plan for performance" include moisture or just overall house tightness and energy?

- I think it addresses the barriers but maybe underplays them. It seems like it is really looking to address a local market. The question is how this project will be leveraged beyond the local area. I am less clear on that.

- Much has been written about the "Perfect Wall" and its ability to provide a high R-value wall that is durable. This approach will aim to implement this wall in a cost-effective manner for the affordable housing market. It also promises to increase the likelihood that the wall assembly would meet the definition of the perfect wall as opposed to one that is built purely on-site.

- Project started in July 2016. New project. The approach is to build 23 homes. This is a large enough sample to provide a good study to validate the project goals and intended results.
- Note to the speaker. My impression is that he was unaware of the timetable and the presentation did not focus on nor cover the key points that needed to be conveyed to the audience. They did not do a good job of providing a good overview. This presentation issue does not reduce the value of the project.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Project accomplishments are impressive and growing. The importance of keep with the design parameters that make this type of construction work cannot be overstated and can potentially have a significant effect on production housing.

- Congrats on completion of 11 houses already. Glad you are building upon previous work. But what are those 11 houses showing besides selling quickly? How is the energy, moisture, comfort performance? Where the same builders/ developer involved in those houses?

- They seem to have had good success. It just comes back to scalability.

- Project is still in its early stages, but the team appears to be well on its way to accomplishing its goals. If successful, the team could have great impact by enabling builders to more confidently build durable walls with high R-values, not to mention building them at lower cost.

- Project is in the home design phase and selection of contractors. Too early to tell if this project is on track to meet the desired goals.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Truly smart and thoughtful project designed to address many of the problems facing production of high performance homes. This level of thoughtfulness is only possible with close collaboration of industry partners.

- Based on the energy, moisture, comfort performance of the previous 11 houses, please elaborate on the "energy monitoring protocol" and how it relates to these prototype houses.
- Per slide 6, if "Builders, contractors, inspectors understand the system.", why are there so many milestones focused on this same audience (construction docs, process documentation, builder training)? (Do these milestones need project funding to be critical to the existing knowledge base?) Are the construction documents going to align with previous Building America funding on fastening schedule recommendation for externally insulated buildings?

- I think the local collaboration is good, but how could they do more to collaborate on a national level? What about SIPA? NAHB even? This is a small project focused on transforming how homes are built, a big goal. Finding ways to leverage the findings is critical for it to be a good use of DOE funds.

- Team has currently engaged with a number of local builders that will try out the system. Have built relations with Habitat for Humanity and other affordable housing developers. Seems like an appropriate approach at present, but team will need to develop a plan to better engage a broader audience if successful. Additionally, it's not clear what sort of collaborations would be needed with other BA teams such as those at ORNL and BSC.

- There are 7 key partners including builders, raters, developers, manufacturers, and habitat for humanity. This is a good cross sectional mix of market actors.

E. Proposed Future Work

This project was rated **3.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Can't wait to see future homes built. Can I participate?
- See previous comments.
- Needs to be a much greater emphasis on sharing lessons learned more broadly. This feels very geographically limited.
- The key market barrier here is convincing builders that these systems are cost effective and that they work for an extended period of time. The only way to overcome that barrier is to do actual installations, which is the plan for this project.
- The outlined future steps presented in the presentation are good. Included is a market delivery and acceptance analysis, which if done right is critical when proposing new framing/building systems into the construction market that has historically been very slow to adopt change. However, this is a price conscious industry and a lower cost method will attract interest. The presentation briefly covered issues regarding electrical, plumbing and other trade work that is typically placed in the frame wall cavity. Maybe the proposed baseboard chase will be acceptable to the market. I don't know.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers
- See previous answers.
- See previous comments.
- Project would result in cost-effective method to construct what theoretically should be very durable walls. Will result in demonstrations in real conditions, which should give builders the confidence that they need.
- None.

***Average*: 1** reviewer
- They are fine, just limited.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- See previous answers.
- No comments.
- Key activity here is demonstration, which is vital to overcoming the major barriers to constructing high R-value walls.

- See earlier comments.

***No*: 1** reviewer
- As mentioned before, would like to see more information and description about energy monitoring protocol.
- Great research topic. Look forward to hearing more in updates.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project's strength lies in its packaged approach, use of one contractor for the exterior enclosure, and commitment to optimized house plans that work for this type of construction. It is also very strong on building science, perhaps the most important strength.

- This project addresses the BTO Goals (clear, ambitious, achievable, measurable, and relatable).
- And this technology has the potential to impact more than just affordable housing.
- This project has a solid track record with previous 11 homes

- Good direct outcomes.

- Addresses a key challenge as documented by BTO and the BA program.
- Will directly tackle some key barriers to implementing durable high R-value envelope assemblies, namely cost-effectiveness and demonstrating (hopefully) that the walls do not suffer from moisture damage.
- Initial test set will take place in a very challenging environment.

- This project is as worthwhile investment to investigate a new high performance building envelope construction method. The results of this study should determine if this is a worthwhile and market ready method of construction.

2) **Project Weaknesses**

- Weakness lies in its limited application to certain optimized house plans. Another weakness could be that it requires learning an entirely new way of building homes, but it seems like that hurdle is surmounted rather easily.

- Based on the energy, moisture, comfort performance of the previous 11 houses, please elaborate on the "energy monitoring protocol" and how it relates to these prototype houses.
- Per slide 6, if "Builders, contractors, inspectors understand the system.", why are there so many milestones focused on this same audience (construction docs, process documentation, builder training)? (Do these milestones need project funding to be critical to the existing knowledge base?) Are the construction documents going to align with previous Building America funding on fastening schedule recommendation for externally insulated buildings?

- More focus on scale is needed

- It is a bit risky implementing this novel approach for a set of 23 homes; I certainly hope that no problems are found that would put the team at risk. Kudos to the homeowners and builders for taking the chance!
- Wasn't quite clear how the homes would be monitored, and what would constitute success? Will there be visual inspections, long term data collection with sensors embedded in walls?

- One item that I can think of is a structural analysis. Can this be method be used in areas with high snow loads, earthquake or other requirements. Will this be a limiting factor to national scale rollout?

3) **Recommendations**

- None.
- None.
- None.
- Develop rigorous approach to assessing performance of assemblies.
- None.

Project # 11150g: Performance-Based IQ & Optimized Ventilation

Presenter: Sydney Roberts, Southface Energy Institute
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed on this project's relevance to BTO's goals, with one reviewer commenting that the project would directly address the challenge of ensuring good indoor air quality (IAQ) as homes become more energy efficient. Another reviewer pointed out that while the project looked to reduce energy use intensity while optimizing relative humidity and IAQ in homes, the project was focused more on non-energy benefits than energy savings.

Reviewers similarly agreed on the project's approach, commenting that the approach appeared to be sound and on track. One reviewer was particularly taken with the fact that the approach addressed fundamental questions about IAQ; this reviewer described the project's work as "the kind of baseline, fundamental work DOE should be most focused on." Another reviewer was not quite as satisfied, feeling that it was not clear whether the project's primary intention was to develop new IAQ sensors or to test approaches to evaluate IAQ sensors.

When considering progress and accomplishment, reviewers acknowledged that the project was in its early stages, noting that much work remained. One reviewer thought that the results were good and should be shared broadly among all Building American teams doing IAQ work, but another said that it was yet clear what had been accomplished given the expenditures to date. One reviewer felt that the project could have great impact if it was successful, but also that it would be tough for the project to meet all of its goals.

Reviewers felt that the project benefited from a stable of strong, knowledgeable, and impactful partners, with good representation from different players across the value chain. One reviewer felt that the project was drawing upon these partners' work to advance the project's own efforts.

Looking forward, reviewers expressed some uncertainty over the future work that was proposed. One reviewer thought the proposed work was logical, though they acknowledged that much remained to be discovered as the project progressed (i.e. regarding sensor requirements, longevity, etc.). Another reviewer expressed that it was not clear if or how the project team would identify what needed to be measured in order to establish performance requirements for IAQ sensors. Reviewers offered numerous recommendations, including that the project team should:

- think more about how IAQ sensors can be placed in a home to best control the ventilation system;
- replicate the study in additional climate zones and with exhaust-only ventilation in the southeast; and
- develop a dissemination strategy to maximize the exposure of key findings.

Weighted Average: 3.10 # of Reviewers: 5
Relevance: 3.40[1] Approach: 3.20 Accomplishments: 2.90 Project Collaboration: 3.50 Future Work: 2.80

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.40** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project is in very early stages. Goals align with BTO goals, assuming the assumptions that improved control of IAQ by measuring pollutants and operating systems based on these measurements hold true.
- Great idea and can have a lot of impact.
- None.
- Project would directly address BTO's stated challenge of ensuring good IAQ as homes get more energy efficient. Development of new IAQ sensors for effectively controlling ventilation is a holy grail in terms of optimizing energy consumption in relation to IEQ.
- This ventilation project targets to reduce EUI and optimize RH and IAQ control in homes.

B. Approach

This project was rated:
1) **3.20** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- Project is in early stages. Approach appears to be on track and sound, but remains to be vigorously tested.
- Sure, may not include exhaust ventilation in this funding phase, but looks like a great start for the funding dollars allotted.
- Strong cost share.
- What I most like about the approach is it addressed really fundamental questions: how well do we understand IAQ? How can we really measure it? As I sat through numerous RBI and Building America presentations on IAQ I was struck by a focus on solutions to problems we cannot yet define terribly well. This is the kind of baseline, fundamental work DOE should be most focused on.
- The development of IAQ sensors would greatly assist in developing optimized ventilation systems and generally in ensuring adequate, if not beneficial, IAQ.
- Not quite clear whether the primary intention is to develop new IAQ sensors or test approaches to assess IAQ sensors. While latter seems important, there seems to be a lot of work needed still on the former.
- Project started in October 2016. New project. The approach is to establish performance rather than prescriptive ventilation requirements. This should result in better IAQ, RH control, and ventilation energy reduction.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.60** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Much work remains, but progress is evident and appears likely to achieve goals.
- Recently funded project, but has a strong team and clear strategy.

- I think the results are good and should be shared broadly among all other DOE grant recipients doing IAQ work.

- Project is still in its early stages, but it is not quite clear what has been accomplished given the expenditures indicated.
- If successful, the project could have great impact, but it will be tough to get to that stage.

- Project is in the early execution and vendor engagement phase.

D. Project Integration and Collaborations

This project was rated:

1) **3.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Drawing upon work conducted by LBNL and other partners, this project aims to move these efforts forward and rely on the support and participation experts involved in related efforts.

- Strong, knowledgeable, impactful partners.

- I think the project team is strong. It has numerous actors across the value chain, including end users (builders/architects).

- Project team has developed a large list of collaborators, ranging from researchers (LBL), builders, equipment makers, and control manufacturers.

- There are 10 key partners. It appears that there is a good representation from different players.

E. Proposed Future Work

This project was rated **2.80** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Proposed future work is logical. Much remains to be discovered once the team gets into the meat of sensor requirements, longevity, etc.

- Looking forward to hearing results from milestones.

- The test home approach is needed, real-world results are all builders care about.

- It's not clear how the team will be able to establish performance requirements for IAQ sensors when not many exist, and it's not even clear what needs to be measured. Perhaps that is the focus of the project, but it wasn't apparent to this reviewer. Considering the huge array of key pollutants of interest, it appears that establishing such performance requirements would have a low likelihood of success. I hope that I am proven wrong.

- I like the approach and proposed project outcomes and support the research to further moving towards a performance based (SMART) ventilation standard.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers

- A huge market barrier for achieving cost effective ventilation for ever-tighter homes has been low cost, reliable sensors. The V in HVAC is becoming more important in today's code and above-code programs, so this is very good timing to establish, test and collect data on industry recommended protocols.
- Understanding where sensor tech stands is critical.

***Average*: 3** reviewers

- About what I would expect at this early stage of the project. Looking forward to hearing more in the future.
- If successful, the project could assist in improving ventilation efficiency and eliminating over-ventilation.
- No comment.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 5** reviewers

- Project is well focused.
- Great research idea. Looking forward to hearing more in updates.
- None.
- While significant work has taken place in developing such sensors, the fact that they do not yet exist indicates that more research is necessary to enable better ventilation control.
- No comment.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project's strength is related to an optimistic view of the ability to use sensors to feed back into HVAC controls to improve IAQ and reduce or optimize equipment run time.
- Please see previous comments.
- Strong collaboration, good focus on answering baseline questions and then validating work in the field.
- Addressing a critical issue in the Building America program.
- If successful, the project could lead to key techniques for better controlling house ventilation.
- See earlier comments.

2) **Project Weaknesses**

- Hopefully, control technology is at a state where it can be harnessed to achieve the project's goals.
- This focuses more on non-energy benefits than energy benefits and savings.
- None come to mind.
- Many research efforts have been undertaken to develop better IAQ sensors, but the shear breadth of the contaminants of interest make this endeavor extremely challenging.
- See earlier comments.

3) **Recommendations**

- None.
- Get ready to replicate this study 1) in additional climate zones and 2) with exhaust only ventilation in the southeast.
- Make sure results get seen by everyone you can.
- Need to think a bit more about how such sensors would be placed in a home to best control the ventilation system, as is the ultimate goal of the effort.
- None.

Project # 11150h: Ventilation Integrated Comfort Systems

Presenter: Robb Aldrich, Steven Winter Associates
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers strongly agreed on this project's relevance to BTO's goals, remarking that it would produce real, field-tested data to inform efforts to reduce air leakage in homes without reducing indoor air quality (IAQ), while also addressing affordability issues with heat/energy recovery ventilation (H/ERV) systems. According to one reviewer, this project had the potential to greatly impact energy use *and* help shift the market towards mechanical systems that address latent and sensible loads separately.

Reviewers acknowledged that the project was in its early stages, but also felt that the project plan appeared sound and on track. Reviewers also commented that the project team's work to identify market barriers was solid, and was buoyed by the project team's engagement with market actors to learn what was needed. One reviewer felt that working with a single manufacturer provided an opportunity to seed a competitive market with a new product, but another reviewer thought that working with a single manufacturer risked benefiting one manufacturer rather than the industry as a whole.

Reviewers acknowledged that it was still early in the project, but they did comment that the project's work to date was promising and that the project team appeared to have set the stage for significant impact. One reviewer was concerned, however, that potential equipment cost savings were not being evaluated against a comparable low-energy system. Another reviewer expressed a similar concern, flagging that a project weakness might lie in the cost of the new equipment if the market did not fully appreciate what was being delivered.

Reviewers agreed that project integration and collaboration was appropriate—covering equipment manufacturers, builders, and end users—and was expected to help avoid pitfalls and make sure that the project team fully understood the market barriers that needed to be overcome. One reviewer recommended getting feedback on the project plan from LBNL and/or members of the ASHRAE 62.2 committee.

Looking forward, reviewers commented that the project team appeared to have a strong grasp of technical and market needs, as well as a plan in place to address these needs. Some questions were raised, however, around if and how the project would continue without funding, and also around how and where the findings of the research would be shared. One reviewer suggested performing demonstrations in an occupied home earlier in the process, in order to get quick feedback on size, sounds, smell, vibrations, etc.

Weighted Average: 3.16 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.40 Accomplishments: 3.00 Project Collaboration: 3.20 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Good relevance to BTO goals and the making of HRV/ERV systems more affordable.

- Code as well as voluntary above-code programs are striving for (and realizing) high energy savings due in large part to reduce air leakage in buildings. But a known consequence is reduced IAQ. Therefore, how can we have our cake (low-e buildings) and eat it too (not get sick from them)? This project includes BTO goals and real field testing to collect data to inform the conversation.

- This project has the potential to impact a huge amount of energy use. It also speak to a seminal change occurring in the housing industry, shifting to mechanicals that can address latent and sensible separately.

- Project will assist in ensuring adequate indoor air quality in homes that have very low heating and cooling loads. By easing the installation of a balanced ventilation approach that will enable the use of energy or heat recovery, the project should have dramatic impacts in saving energy in certain climates while promoting good IAQ.

- This project has relevance on several levels:
    - It's addressing an HVAC heat pump market need. The DHP family of heat pump products are not cost effective and sized small enough for low load homes and smaller spaces such as apartments or multifamily units. A small heat pump unit will address this market space
    - Combining ventilation and HVAC operation into a single unit can produce several benefits:
        - Single mechanical system for an installation;
        - Single mechanical system for maintenance. Not separate HVAC, IAQ Ventilation and RH equipment;
        - Provides energy efficient low load HVAC HP equipment that currently does not exist on the market.

B. Approach

This project was rated:

1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- Project is in its early stages. Approach appears to be sound and on track to produce desired deliverables. Work to identify barriers is solid at this stage of the project.

- Yes, having more V in HVAC is a big interest and growing industry need. But there is also significant discussion to disconnect V from H/C, especially in low-load homes. This proposal is unclear to me if and how this ventilation design satisfies some target while also allowing the H/C system to meet a target set point. Umm, how is this have "solutions for homes with a high latent load (high moisture)"?

- The project team demonstrates a strong understanding of market barriers. They did this by actually engaging with market actors to learn what the need. This is only partly a technical challenge, a lot of it is marketing, understanding what different actors need from the tech, both from a functionality and cost standpoint. The team recognizes this.

- Project team has identified critical barriers to installing efficient ventilation systems, namely the cost and the difficulty in routing dedicated ductwork. Additionally, the team noted the challenge in heating and cooling system selection for efficient homes, that being that manufacturers of the equipment don't seem keen to make such low-load equipment. This approach could encourage manufacturers to make products that have a higher value to the builder yet meet low heating and cooling loads. The other major barrier that

would be addressed would be the cost and complexity of a separate balanced ventilation system. The team appears to be well engaged with key stakeholders to best understand these barriers.

- Project started in August 2016. New project. Good approach outlined and they appear to be partnered with an engaged manufacturer. By working with the manufacturer, this creates the opportunity to seed the market with a new HVAC product. It's a competitive market and other manufacturers will follow. Leveraging the market is a good strategy to multiply the impact of limited research dollars.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.80** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Early stages of project are showing promising progress. Looking forward to future reports.

- Again with minimum details on the V functionality of the system, it is hard to say how this might compete with other technology or combinations of technology already in the marketplace.

- Only 6 months in it is hard to judge

- The project is still in its early stages, but the team appears to have set the stage for having significant impact. They have spent the time to date gathering feedback from builders. The intention is to construct a first prototype shortly and test it in a laboratory setting in the upcoming months. It is conceivable that successful execution would lead to a viable product.

- The identified market need is real and relevant. Good strategy to select a major manufacturer who can successfully bring the product to market. This leverages market competition to entice other manufacturers to develop market products for the low load space.

D. Project Integration and Collaborations

This project was rated:

1) **3.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.20** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project integration and collaboration is appropriate and expected to help avoid pitfalls and minefields.

- This sounds more like a federally funded project to benefit one manufacturer than an investment to benefit the whole industry.

- I think you would strengthen your project team if you can get feedback from LBNL and/or members of the ASHRAE 62.2 working committee.

- Though a small team, the PI indicated they have broader contacts, in particular with end users, which have proven beneficial.

- Project team appears to collaborate with key stakeholders: Equipment makers and builders. These folks have already helped guide the effort.

- Three identified key partners are sufficient for this project.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Future work depends on size of units and how much can be crammed into a small space and still function properly. With such constraints often come novel solutions. Looking forward to future updates.

- Will this continue without funding?
- How and where will the findings from this R&D be shared?

- Strong grasp of technical and market needs and the plan to address them is solid.

- No major concerns. The team has not given great details about their plans, perhaps because of their intent to file a provisional patent. They did indicate a go/no-go decision prior to installation of second prototype in an unoccupied building.

- Built into this is a go/no decision. Always like to see milestones in a project. Presenter did a good job of providing the overall project landscape and proposed future work.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 2** reviewers
- If successful, the project will create a path for a product that really drives at a core customer need.

- Project would assist builders by providing an easy-to-install and commission HVAC system for residences.

***Average*: 3** reviewers
- What I would expect at this early stage of the project. Deliverables at this stage are critical to next stages and should be treated as such.

- Don't see how this is different from other technologies.
- Don't see how the ventilation can satisfy the target (without over or under ventilating) while the H/A satisfies its target.
- I don't think the equipment cost savings are comparing against a comparable low-energy system.

- At this time the reviewer can't predict if the prototype will be sufficiently developed for the manufacturer to continue moving the product into the market. The goal is to get early commercialization products into the market to kick start development and roll out of low load HVAC equipment.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- Project is highly focused.

- No comment.

- The project is mostly focused on research at this stage, but some consideration is given to deployment by the team's partnerships. Further efforts would be needed at end of this project to further the deployment goals.

- See earlier comments.

***No*: 1** reviewer

- How is this different from other technologies?
- How is this product going to comply with ASHRAE 62.2?
- Good research idea. Looking forward to hearing more in progress reports.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project strength includes the potential to radically change the landscape and cost of installing HRV/ERV, which are recognized as essential for low load homes. Equipment manufacturers are also on board with helping to solve problem.

- Creative idea/ option and strong industry partner.

- Good focus on technical and market needs, what customers need to make the work result into a viable product.

- Packaged ventilation/heating/cooling unit would greatly assist builders and directly addresses the key market barrier.
- Successful project completion should lead to a product that is very viable on the market.

- See earlier comments.

2) **Project Weaknesses**

- Weakness may lie in the cost of the new equipment and the market not fully appreciating what is being delivered. Major educational campaigns will be needed to keep builders from doing what the default to.

- Please see previous comments.
- How is this different from other package or combined technologies?

- None come to mind.

- No major weaknesses. The project is an R&D one; it would be expected that follow-on work would be needed to further demonstrate the viability of this solution and to confirm that it is providing the necessary ventilation rates as well as heating and cooling capacity.

- No major weaknesses identified.

3) **Recommendations**

- None.

- See previous comments.
- Would suggest adding demonstration in occupied home to first Q7 (to get quick feedback on size, sounds, smell, vibrations, etc.) before waiting until Q12.

- None.

- There were some concerns raised by builders when discussing balanced ventilation systems about envelope penetrations. There was no information given in the presentation about the penetrations needed for this device. I trust that the project team will consider those challenges.

- None.

Project # 12201: High Performance Building Envelope Assemblies

Presenter: Vladimir Kochkin, Home Innovation Research Labs
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers strongly agreed that the three projects covered in this presentation were directly relevant to BTO's program goals and objectives, noting that each project explored a different approach to the construction of high performance building envelopes, as well as each approach's moisture implications.

In all instances, reviewers commented on the various projects' strong partners, knowledgeable teams, and good cost share. Several reviewers remarked that each of the projects seemed well structured and focused on the solutions needed for mainstream market adoption, having addressed market barriers from the perspective of builders and tested concepts in different climate zones to help alleviate builders' concerns. The only noted deficit in the project approaches centered on questions about how research results would be shared. Reviewers unanimously agreed that the projects were well coordinated and integrated with previous BTO and Building America work, and also that collaborations were strong. One reviewer remarked that "it [was] hard to imagine a project team could be better integrated with builders and materials suppliers than HIRL."

Reviewers generally agreed on the progress being made on the various projects, with one reviewer commenting that accomplishments to date appeared impressive. One reviewer affirmed that the project teams had completed some impressive tasks based on the various project plans, but wanted more detail on realized impacts and accomplishments. Recognizing that the projects were coming to a close, one reviewer noted that the only future work that remained was to publicize and educate builders on the techniques developed. Another hoped to see a follow up report next year demonstrating how well the results of the research program were being adopted. One reviewer hoped that—because ORNL was a partner—all learnings from the different projects would feed into the building envelope moisture risk software tool that ORNL was developing as part of another Building America project.

Weighted Average: 3.55 # of Reviewers: 4
Relevance: 4.00[1] Approach: 3.75 Accomplishments: 3.50 Project Collaboration: 3.63 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The three projects that are the focus of this project are directly relevant to BTO RBI program goals and objectives, representing builder approaches to solving constructability issues.

- Building code and above-code programs have been increasing the insulation requirements of walls, floors and ceilings. How those surfaces are insulated can vary. But the moisture consequences of increased insulation levels are of high interest. This funding explores different approaches as well as the moisture implications of each.

- Project has addressed heating and cooling loads in buildings, the primary energy consumer, by focusing on construction approaches for high R-value walls and roofs.

- All four projects relate to the high performance building envelope goals.

B. Approach

This project was rated:
1) **3.75** for the degree to which it focuses on critical market barriers, and
2) **3.75** for the degree to which the approach addresses the market barriers identified.

- The project presents market barriers from the perspective of the builder community. Projects have been selected in a wide range of climate zones, which is good to prove out concepts and modeling exercises in different zones. EP&B walls portion of project directly address constructability issues to create an easily adoptable system that is gaining acceptance rapidly. Attic retrofit project is also especially promising and the approaches demonstrated are easily reproducible.

- Strong partners, knowledgeable team and good cost share.
- But, how are you going to share the research results? How are you going to "improve level of confidence for builders using high-R wall solutions" and "accelerate adoption of high performance homes"? Be more boastful on specifically how you have or are going to share the results.

- A key market barrier to high R-value envelopes is reluctance on the part of builders to novel solutions because of the risk of moisture damage and structural strength reductions. These demonstrations over extended periods of time in different climate zones are critical to helping alleviate those concerns.

- I like how the presenter states on the first slide that this is four distinct projects and lists them as a, b, c, d. This makes it a lot easier to follow the presentation and the transitions between projects. All four projects, seem well structured and are focused towards requirements and solutions needed for mainstream market adoption.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Accomplishments are impressive to date. The icing on the cake will be to see more widespread adoption of high performance homes, led by the effort of the project proponent and supported by industry/manufacturers. Especially promising would be support across the country for adoption of 2012/2015 I-codes.

- You have accomplished some good tasks on your project plans.
- But you've glossed over the measured/experienced/realized impacts and accomplishments. Have you achieved some of the principles on slide 2?

- Project has collected difficult-to-acquire data over longs periods of time on different options for high R-value opaque wall components. Such tests are quite valuable because of the difficulty in conducting them.

- Three projects really stand out to me:
    - Moisture performance of high r wall systems
        - This is great information to feed back into the ORNL software.
    - Extended plate and beam wall system
        - This building system will appeal to builders. It's simple, quick and they don't have to change much to current framing methods to incorporate a CI solution.
    - Durability of windows and walls with continuous insulation
        - This is an issue. This industry facing building group is collaborating with window manufactures to find workable solutions/recommendations. This enhances its potential acceptance by builders.

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The projects are well coordinated and integrated with previous BTO RBI and BA work. Collaborations are strong and as expected for a construction industry based research organization.

- You have strong "Key Partners" on each project...some overlap (which can be valuable from a systems interaction approach) and some are new (which can be helpful to get new perspectives and voices).

- It's hard to imagine a project team could be better integrated with builders and materials suppliers than HIRL. They have worked with numerous builders across the country as part of this project.

- Good cross discipline team.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- The project contributes much to counter concerns regarding high R-value wall assemblies and is tackling novel approaches to insulating attics above the sheathing. A follow up report next year demonstrating how well the results of the research program are being adopted would be push this rating higher.

- Wish you could have provided more interim progress reports or circulated them more often to more audiences.

- Project has come to a close; the only future work that appears to be left is to publicize the approaches and educate builders on the techniques.

- I want to bring up an issue that I don't see addressed in any of the current continuous insulation (CI) studies. Should we consider fire issues from burning plastic foam? There is an increased health hazard of

burning XPS/EPS CI insulated homes? The off gassing of toxins produced from a burning foam clad home may present both firefighters and neighbors with elevated health risks. In our quest for energy savings are we overlooking fire safety and the potential home fire toxin release health risk? It may be that insurance companies will give premium reductions to CI homes insulated with mineral wool board over foam. Should we be looking at this? Include insurance in the stakeholder conversations?

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Deliverables are highly valuable in that they come from and are geared toward the builder community.
- Addresses a critical issue facing home builders. Addresses a key goal stated by the BA program.
- See earlier comments.

***Average*: 1** reviewer

- I think the value of the information is huge, but has it been delivered via tech sheets or other mechanisms?
- Who has received them? How have they adjusted their products?

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 3** reviewers

- The research project is focused on addressing barriers to high R-value assemblies and roof retrofit applications that can have benefits all across the country.
- Addressed durability issues with high R-value walls. Engaging well with builders; should continue to determine appropriate outreach mechanisms to reach even more builders.
- None.

***No*: 1** reviewer

- As mentioned before, I think the deployment side of the project could be improved and integrated more into the next steps.
- This is very interesting research, looking forward to hearing more about the details.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project strengths lie in demonstrated changes in the marketplace and development and adoption of a new, non-proprietary exterior wall assembly with insulating sheathing. Successful use of nailbase insulation for attic rehabs is also in important step.
- Please see previous comments.
- Addressed key challenge in high R-value assemblies, namely showing ways that it can be done reliably.
- Excellent integration with the builder community.
- All solid projects that are focused on advanced envelope demonstration and market adoption.

2) **Project Weaknesses**

- Weaknesses lie in the extent to which the advancements championed by the research will be adopted in the marketplace.

- No more than those already shared.
- How are the EP&B panels working out on the jobsite? Is there racking or fastener weakening from flexing before raising up over subfloor?

- Not clear what next steps are planned to publicize the results to the builders. Ensure that results are integrated with Building America's solution center, ORNL tool under development, and other BA mechanisms for outreach.

- No major weaknesses identified.

3) **Recommendations**

- None.

- No additional ones.

- None.

- Since ORNL is a partner, I will assume all learnings from this project will feed into the building envelope moisture risk software tool.

Project # 12202: Partnership for Improved Residential Construction

Presenter: Eric Martin, University of Central Florida
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, with one commenting that the project aligned with BTO's objectives related to indoor air quality (IAQ), and another remarking that controlling relative humidity in low-load homes (without requiring as much supplemental dehumidification) was critical to achieving BTO's energy-saving goals.

Looking at its approach, reviewers commented that the project did a good job of identifying industry challenges and opportunities and drilling down on the key market issue: how to address latent and sensible loads in new, tighter, better-insulated homes. One reviewer lauded the project for focusing on the use of equipment available today to implement optimized ventilation strategies. However, another remarked that manufacturers would not be able to just build and sell products that utilized these strategies; this reviewer counseled the project team to consider how their findings would impact the world of regulated HVAC products, recommending that they consider how to engage BTO's appliance standards team and other standards bodies.

In terms of accomplishments, one reviewer described the project as being at the forefront of our understanding of mechanical ventilation and occupant comfort in newer housing. Another described the results of the project as providing actionable data that manufacturers were already using to adjust their equipment. Other reviewers were more muted, commenting that while the project team had engaged in preliminary efforts to translate key findings into impacts, these efforts were still at an early stage. One reviewer expressed a desire to see performance data from more extreme environmental conditions, while another wanted to see data generated by more homes from the same region in order to validate findings.

Reviewers felt positively about the project's collaborations, describing the project as having great relationships with industry partners looking to take advantage of the data being produced and commercialize the findings. One reviewer felt that the project's cost share appeared low, however. Another reviewer believed the project's connection with builders was not entirely clear, which this reviewer found surprising given that builders were often the ones selecting HVAC systems for new homes.

Looking forward, some reviewers felt that future plans indicated a strong understanding of what would drive market actors to develop products and functionality that reflect research findings. However, others thought that while a fair amount of work had been undertaken on the experimental effort, it was not entirely clear what types of outputs were intended after the data collection period ended. One reviewer pointedly recommended that the project team find an appropriate mechanism to present the detailed research results to correct audiences, while another felt strongly that this project—along with the other Building America projects focused on IAQ—should "cross pollinate" for greater impact.

Weighted Average: 3.37 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.50 Accomplishments: 3.20 Project Collaboration: 3.60 Future Work: 3.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project's relevance to BTO program goals is critical. Field testing and implementation of systems to maintain RH <60% for low load homes without or with less reliance on supplemental dehumidification is critical to achieving energy MYPP energy saving goals.

- Yes, I think these technologies (HVAC systems) have a significant influence on the BTO Goals, and this project does a very good job quickly summarizing industry challenges/opportunities, impact potentials and navigating between the two.

- Addresses the key market issue of how to address latent/sensible in new tighter, better insulated homes.

- This project addresses approaches to decrease space conditioning energy consumption while improving control of the humidity. The focus is on humid climates, both hot humid and the Pacific Northwest. There is also effort on optimal ventilation strategies, which will also decrease energy consumption while improving the indoor environment.

- This presentation is an overview of several different in home demonstrations. Each different home focused on RH control and/or IAQ solutions. This project aligns with the DOE IAQ focus.

B. Approach

This project was rated:
1) **3.60** for the degree to which it focuses on critical market barriers, and
2) **3.40** for the degree to which the approach addresses the market barriers identified.

- The approach is directly targeted at equipment available in the marketplace advertising certain beneficial performance characteristics for new and existing low load homes in humid climates. The focus on optimized ventilation strategies for such homes is critical to delivering healthy IAQ and realizing energy savings. The project tests systems actually being used and controls currently available in the market.

- Achieving HVAC targets in low-load homes in FL is a great and challenging location to satisfy. Wish you could share ventilation data from more extreme environmental conditions than FL in October or April or Washington State.

- The project indicates a strong grasp of the barriers, both from an occupant, technical and value chain standpoint.

- With the building codes requiring tighter envelopes with higher R-values, builders are forced to consider alternative heating and cooling technologies if they do not want to risk unhappy homeowners. Makers of equipment that can better handle latent loads would benefit from objective data on the performance of their equipment in real homes; this project is providing such data.

- The work focuses on different elements of IAQ thru several different demonstration homes. The presentation gave an overview of the different projects. At a high level it appears that there will be some good results. This reviewer thinks some projects homes will present better value than others. However, taken as a whole, the project results seem solid.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.40** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The results of the project are providing actionable data manufacturers are using to adjust their equipment to perform as advertised. In addition, the projects have demonstrated achievable energy savings through the use of smart ventilation technologies.

- What have you seen so far (in addition to Aug-Oct data)?
- On slide 15, aren't geographical locations for 1 and 2 different? Did you perform the same tests in both geographic locations for validation?

- Results have been interesting and should inform new thinking about comfort, products and relevant standards and code requirements. This project is at the forefront of advancing our understanding of mechanical ventilation and occupant comfort in new housing.

- The project addresses 2 key focus areas of the Building America program: thermal comfort with low-load equipment, and improved IAQ. The focus of the work on the humid climates is key, as these locations have the greatest issues with moisture management. There are some preliminary efforts into having an impact with the work (most promising include work with manufacturers and efforts with Std. 62.2), but those efforts are still at an early stage.

- Project will be complete in July 2017.

D. Project Integration and Collaborations

This project was rated:

1) **3.60** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.60** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Great collaboration with industry partners willing to play along and take advantage of the data being produced.

- Strong, knowledgeable partners.
- Cost share seems low.
- What are the energy/savings/RH/comfort findings from the 6 Habitat Homes?

- Very strong core team, capable of commercializing findings across relevant market actors.

- Project has connections with Habitat for Humanity affiliates, manufacturers of the small-duct high-velocity and multi-split systems. Connections with builders was stated but is not quite as clear. One would think that finding a way to present the research results to those selecting HVAC systems for new homes will be important. Ventilation work is focusing on making changes through standard 62.2.

- Different partners apply to different project homes. For individual home projects, I can't determine if there was sufficient integration and collaboration. As a whole across all projects, the identified key partners represent a solid team.

E. Proposed Future Work

This project was rated **3.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Industry participation in continuing to improve their equipment to meet stated performance characteristics is promising, but not guaranteed. Looking forward to further research and market innovations this project will spur.

- On slide 17, are you just simulating "energy and RH set points < 60%"? Any chance to get actual numbers from a real house and also get comfort feedback?

- Future plans indicate a strong understanding of what will drive market actors to develop products and functionality that reflects research findings.

- Project is in its latter stages and is focused on completing data collection. A fair amount of work has been undertaken up to this point to lead to the experimental effort. It is not entirely clear what types of outputs are intended after the data collection period ends; I would expect that reports are set to be written, but how will these results be put to best use?

- There are a number of IAQ projects reviewed in the PEER review. Individually, each of these projects have value. However they should cross pollinate with each other. For example there are learnings from several of these projects focusing on updating ASHRAE 62.2 performance standards. For this topic the learnings should be compiled and brought to ASHRAE in total and not separately. That may be part of the T2M plan, but it is not apparent in any of the individual projects. Maybe that is a focus for a future IAQ project?

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers

- Previous responses to questions address this.

- No comment.

- The issues addressed are key for builders; I rate as between high/average since I am not sure how the data will best be presented to those making decisions about space conditioning and ventilating systems.

***Average*: 2** reviewers

- I would give it only average value if actual results are only from one home in each climate.
- I would score it high value if able to get 6 or more homes (co-located) worth of real data.

- Different home studies have different project out comes. Overall there is value from the different studies to inform ASHRAE and code bodies and opportunities for manufacturers to improve HVAC equipment operation.

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- Previous responses address this.

- No further comment.

- As noted previously, the topic is of great importance to the program.

- No comment.

***No*: 1** reviewer
- As mentioned before, would like to see more than 1 homes worth of field data (as well as min 1 year) before simulations are compared/updated/used.
- Very relevant research topic. Looking forward to hearing more results in progress reports.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The strength of the project lies in its application in real world scenarios and its use of available off the shelf technologies. The information and data produced is highly valuable and leaves much for future work to build on.

- Please see previous comments.

- Good team, strong results from the field, good plan to turn them into market changes.

- Addresses a critical issue of finding ways to assure thermal comfort in low-load homes, particularly in humid climates.
- Creating valuable data for two types of heating systems that show promise for improved moisture management.
- Investigating alternative ventilation strategies, a topic that appears to be giving the builder community a good deal of challenges.

- None.

2) **Project Weaknesses**

- Manufacturer's willingness to take the data to heart and make changes to their equipment is an uncontrollable weakness, but at least they now can't say they don't have the information they need to be able to move forward in some fashion.

- Nothing more than what's already shared.

- Only consideration would be how to engage AHRI and DOE BTO appliance standards staff. A questioner raised the issue of test procedures and the commenter said they would use Energy Star. HVAC systems are federally regulated products, which means DOE test procedure requirements impact innovation. Manufacturers just can't build products that reflect these data and start selling. The team needs to consider how their findings impact the world of regulated HVAC products.

- No major weaknesses; the only point is that it will be important for the investigators to find an appropriate mechanism to present the detailed research results to the correct audience.

- None.

3) **Recommendations**

- None.

- See previous comments.

- None.

- There would be value in using the results of the research on the SDHV and mini-split systems to feed into test method development to give appropriate credit for moisture management instead of solely looking at SEER.

- None.

Project # 12203: Integrated Design: A High Performance Solution for Affordable Housing

Presenter: Jordan Dentz, The Levy Partnerships Inc.
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed on this project's relevance to BTO, noting that the demonstrated ability to improve energy efficiency in production and site-built homes (1) was directly relevant to BTO's goals, (2) aligned with Building America's high performance envelope strategy and EUI reduction targets, and (3) was unique in its focus on manufactured housing. One reviewer felt the project's key idea was not new, however, commenting further that the project was not sufficiently clear on *how* it was meeting BTO's goals (e.g., what are the modeled energy savings? how are the impacts from this project going to be different from existing, non-federally funded projects? what are key findings found so far?).

Reviewers were mixed on the project's approach. One reviewer commented that the approach focused on much-needed improvements to manufactured and affordable housing, which could lead to significant energy efficiency gains. Another reviewer thought some of the project deliverables appropriate, specifically highlighting the planned guidelines for affordable housing construction, which could reduce reliance on skilled trades and maximize use of lower skilled volunteers. A serious concern flagged by most reviewers was the project's approach to addressing cost in a price-sensitive market. Reviewers also raised concerns about the potential impact of occupant behavior on some of the innovations being developed, as well as whether this project was duplicating the effort of non-federally funded projects in NC and VT.

Looking at the project's progress and accomplishments, one reviewer felt that the project had demonstrated remarkable progress to this point, primarily around issues of technical feasibility and constructability. Another reviewer expressed their expectation that the results of the project would lead directly to changes in manufactured home design. Questions lingered for some reviewers, however, including questions around projected energy savings, preliminary measured savings, and affordability and price comparisons.

Collaboration is one area where reviewers thought that the project excelled. One reviewer remarked that the project's integration and collaboration was "a model for similar projects," while another commented that the project team appeared well connected to a range of manufactured home builders, equipment manufacturers, and building material suppliers. One of the only concerns noted by reviewers focused on what would happen to these relationships once the project's federal funding was exhausted.

Looking forward, reviewers were relatively comfortable with the project's proposed future work. One reviewer was encouraged by the project team's intention to extend its testing to occupied homes, noting that such testing would be important to better understand if any unforeseen behaviors would negate proposed solutions. Another reviewer commented that planned outreach to housing manufacturers was logical. A third reviewer remarked that the project's potential was exceedingly attractive, but cautioned that the affordability hurdle remained present and could limit the project effectiveness.

Weighted Average: 2.96 # of Reviewers: 4
Relevance: 3.00[1] Approach: 2.63 Accomplishments: 2.88 Project Collaboration: 3.63 Future Work: 3.00

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Similar to UCF project, this project is focused on a specific and rather large segment of the housing market, for both low income market rate housing in the form of single level manufactured housing, and H4H, which represents site built construction for low income families. The demonstrated ability to improve energy efficiency in production homes and site built homes is directly relevant to BTO goals and is unique in its focus on manufactured housing.

- Great idea and market segment, but not new and not clear on meeting BTO Goals:
    - clear: what are the modeled energy savings? Why/how are the building components chosen and selected? How is this effort different from Catawba Habitat in NC or VerMOD project in VT?
    - ambitious audience, but how are the impacts from this project going to be different from the existing non-federally funded projects in NC and VT?
    - achievable: what are the modeled or projected energy savings, now? What are the findings from the unoccupied home? "Affordable" for whom?
    - measurable progress can be assessed. But what have you found? Are slides 9 and 10 from the unoccupied home?
    - relatable is not clear.

- With a not-insignificant market share, manufactured housing represents a good opportunity for improving the energy efficiency and IEQ for many Americans. Developing efficient envelope and equipment options is the goal for this project. Manufactured housing promises good quality control, so development of effective approaches should lead to real world savings.

- This project aligns with the high performance envelop and reduction in EUI targets.

B. Approach

This project was rated:

1) **2.75** for the degree to which it focuses on critical market barriers, and
2) **2.50** for the degree to which the approach addresses the market barriers identified.

- The approach squarely focuses on much needed improvements to manufactured housing and improvements to H4H housing that will lead to significant energy efficiency gains. The challenge will be deliver the low load homes at a price point attractive to typical buyers of manufactured housing. The project notes that a key issue is affordability and assurance that the project ultimately aims to meet this challenge, but not much was reported on this issue at this time. I look forward to future updates regarding progress towards meeting the affordability metric.

- How is this project different from similar houses already built by Catawba Habitat for Humanity in NC and VerMOD in VT (that are also not federally funded)? This may be an expensive way to relearn the findings.

- Team appreciates the key issue of cost in the manufactured housing sector, so they are seeking options that will not change the first cost of the homes to a great extent. Options are appropriate given the constraints of the manufactured housing profile.

- The Habitat for Humanity approach seems reasonable. The focus to provide guidelines that reduce reliance on skilled trades and maximize use of lower skilled volunteers is appropriate.
- For manufactured homes, there are market barriers that are not well addressed in the presentation. We did high performance manufactured home demonstrations in the Pacific Northwest. From a constructability and energy performance perspective, the project was successful. The biggest barrier for these homes is acceptance in the market. It is a very price sensitive market. Manufacturers have to sell a reasonable

volume to justify inventory and production costs associated with high performance. Hurdling this market barrier is key to a T2M transformation.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project has demonstrated remarkable progress thus far and is rated on that progress. Future work and results corroborating expected savings and performance will push this rating higher.

- As mentioned before, what are the projected energy savings of the house(s), what are the measured savings, affordable for whom, what is the price comparison?

- Team has collected very good data in a test house in Alabama. They are extending this work to other climates, in particular in a test house in New Jersey. Results will lead directly to changes in manufactured home design through the team's collaborations with a range of builders.

- The technical feasibility and constructability is demonstrated.

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project integration and collaboration is a model for similar projects. The focus on manufactured housing and H4H likely contributed to the development of a strong, wide, and varied alliance of partners - the market impact is potentially large and garners a lot of attention.

- Yes, there is a very strong team and broad group of collaborators. But what happens after the federal funding? And how is this project going to be different from the other two mentioned before.

- Team appears to be well connected to a range of builders of manufactured homes. Additionally, they seem to be tied in well with equipment manufacturers and building material suppliers who can help implement the envelope and equipment solutions proposed.

- There are a lot of key partners involved in this. My big question is still marketability and sales potential for high performance manufactured homes. The successful entry of these homes into the market is yet to be proven.

E. Proposed Future Work

This project was rated **3.00** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Project potential is exceedingly attractive; however, the affordability hurdle remains that could limit the project effectiveness/adoption.

- See previous comments.

- Much of experimental effort has taken place in test homes. The team will extend this effort to occupied homes for a 1 year period. That phase will be important to best understand if any unforeseen behaviors would negate some of the proposed solutions. Effort will then transition to outreach to manufacturers. Seems like a logical approach.

- Speaker outlined some good next steps:
  - increased effort to work with manufacturers.
  - delivery of guidelines.
  - financing and business plans.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- See previous answers.

- Products will be clear actionable guidance for the manufactured home and affordable housing sector.

- Good project. High performance manufactured homes are a desirable product from the EE point of view.

***Average*: 1** reviewer
- See previous comments.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- See answers to previous questions.

- Team has struck a good balance between R&D and outreach to stakeholders.

- No comment.

***No*: 0** reviewers
- Please provide more clarity on how this is going to meet all 5 BTO goals.
- Thank you. Great topic. Look forward to hearing more through progress reports.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project strengths include the broad stakeholder participation and projects built and currently being monitored. Focus on manufactured housing and H4H is also a strength in reaching the lower end of the housing market, as well as reaching the H4H volunteers and the housing types they represent.

- Strong team, broad collaborators, impactful target market.

- Developing clear guidance that has a strong likelihood of decreasing space conditioning loads in manufactured housing while improving thermal comfort.
- Team is well connected to the key stakeholders that will implement the solutions.

- See prior comments.

2) **Project Weaknesses**

- Affordability is the main weakness at this point. Looking forward to seeing how it turns out.
- Please see previous comments
- No major weaknesses observed.
- Increased cost of a high performance unit may create a market entry barrier. How will that issue be addressed?

3) **Recommendations**

- None.
- Look up lessons learned and details chosen for two existing reference homes mentioned.
- It will be interesting to see how occupants impact the effectiveness of transfer fans. Will they turn them off? Will they place furniture in locations that will restrict the airflow?
- None.

Project # 12204: Energy Savings with Acceptable Indoor Air Quality Through Improved Air Flow Control in Residential Retrofit

Presenter: Ryan Kerr, Gas Technology Institute
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed on this project's relevance to BTO's energy savings goals and indoor air quality (IAQ) objectives, by directly addressing how much builders can reduce unwanted airflow across the envelope without affecting IAQ. One reviewer liked that the project's focus was squarely on improving IAQ while reducing energy use, and believed the project's approach could be quite successful at achieving both goals. Another reviewer liked the idea of positioning this project as "weatherization commissioning," because if all weatherization projects were commissioned as this project sets out to demonstrate, substantial additional energy savings and IAQ improvements could be realized.

It was not clear for one reviewer—given all the variations in homes, homeowner behaviors, IAQ contaminants, ventilation strategies, etc.—whether the project was meant to be a proof-of-concept study or if its intent was to achieve statistical significance. Another reviewer commented that it remained to be seen whether the study would produce clear guidance for a range of home performance contractors, or whether there would be enough statistical noise in the results to confuse key findings. Along the same lines, a third reviewer expressed that because they did not fully understand whether the study was looking at particular interventions versus a suite of interventions, they were unable to comment on how impactful, achievable, measurable, or relatable the project could and would be.

When evaluating the project's progress and potential impact, some reviewers thought the resulting data would be very valuable, and further commented that the project was on track to produce actionable information. One reviewer noted that the project was about half way through its funding cycle, but substantial experimental work had not yet started. However, another reviewer believed that project delays appeared to have occurred for good reason: to fine tune the experimental plan. Given the delays, one reviewer expressed concern about whether the "before" and "after" measurements would occur over sufficient periods of time to allow the impact of retrofit measures to be easily gleaned from the data.

The project's collaboration with a range of stakeholders was well regarded. Reviewers commented that the project team was well-connected across industry, regional energy efficiency alliances, and local performance contractors, while also commending the project for drawing from and building upon previous BTO research. One reviewer expressed hope that the project's lessons learned could be extended to other regions of the country, and considered whether more interaction with national organization (e.g., BPI) would have value.

Looking forward, reviewers noted that future work would focus on implementing the study design in selected homes, commenting that this proposed work was built on a solid project plan and would benefit from the strong field research experience of the project team. One reviewer expressed hope that the study would result in clear findings, while another commented that it would be important for study results to be combined with—and considered alongside—the results of other Building America projects focused on IAQ.

Weighted Average: 3.18 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.25 Accomplishments: 2.75 Project Collaboration: 3.63 Future Work: 3.75

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project certainly aligns with BTO MYPP goals to reduce energy use. By focusing on home performance contractors, the pool of qualified (and motivated) participants is certainly reduced. While I like and appreciate the focus on improving air flows and ventilation effectiveness in homes, I guess I am surprised this sort of research doesn't already exist given that weatherization programs have been in place for some 30+ years. Nonetheless, the tools available today are certainly different than 30+ years ago and so a research program like this is relevant to today's BTO MYPP goals.

- The benefits and industry challenge are clear and valuable.
- But what makes up the "intervention/treatment" and "tools"? Unclear so unable to comment on BTO Goals of impactful, achievable, measurable and relatable.

- Project directly attacks the question of how much can we get away with reducing unwanted airflow across the envelope without affecting IAQ. In some ways it sets a limit to how much we can gain from improvements in envelope airtightness.

- Project is relevant to DOE IAQ and energy saving goals.

B. Approach

This project was rated:
1) **3.50** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- The project's focus is squarely pointed at IAQ and ventilation effectiveness while reducing energy use, which are often at odds. By outlining and measuring IAQ surrogates and providing clear guidance on what measures to be implemented, how they are to be monitored, I believe the project can be quite successful at achieving both IAQ and energy savings goals.

- +: Partnering with 1) performance contractor to get consistency and economies of scale, 2) GTI and MEEA for lessons learned and large impact from findings, 3) UIUC/ICRT and NCHH for subject matter expertise in field and training.
- Concern: Related to slide 7, with all the variations in homes, homeowner behaviors, IAQ contaminants, ventilation strategies, etc. is this meant to be a proof of concept study or achieve statistical significance?

- A critical barrier to tighter envelopes in the retrofit arena is the risk to IAQ. This project will feed information to home performance contractors to help them in safely tightening envelopes.
- It's not completely clear whether or not the study will result in a go/no-go situation for contractors. Will it be able to evaluate a range of different techniques and assess which ones are most effective at reducing energy consumption with minimal impact on IAQ? Or, will it simply give a yes-no answer to the complete suite that is being used in the study? If the answer is no, will there be any guidance that results? If the answer is yes, we don't have an idea of the optimal solution.

- This project has a similar theme to other IAQ projects in the portfolio. The approach is to optimize the systematic management of airflow without compromising IAQ. Project seeks to identify target indicators for IAQ quality and then optimize ventilation based on the target indicators.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.75** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is well on track to producing actionable data. Will be important to maintain partner contractor training and engagement.

- In light of slide 17 project plan and schedule, we're about half way through project funding cycle, do you think milestones will be reached?

- Project has fallen behind a bit, so substantial experimental work has not yet started. Delays appear to be for good reason, to better fine tune the experimental plan.
- The plan was not presented here; it is hoped that before and after measurements will occur over sufficient periods of time that the impact of retrofit measures will be easy to glean from the data.
- The resulting data will be very valuable; this reviewer is not aware of any such thorough studies.

- On the Purpose and Objectives slide and listed under Impact of Project are near, medium and long term goals. All very good.

D. Project Integration and Collaborations

This project was rated:

1) **3.50** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project team is well-connected across the industry, regional energy efficiency alliances, and local performance contractors. Project draws upon previous research from the BTO RBI program and builds on that foundation.

- See previous comments.

- Team appears to have reached out to some key institutions, including the Midwest Energy Efficiency Alliance and a local Home Performance Contractor. It is hoped that the lessons learned can be extend to other regions of the country. Would better interaction with BPI have value?

- Project integration description appears solid as does the Partners, Subcontractors and Collaborators

E. Proposed Future Work

This project was rated **3.75** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Proposed future work is in the implementation stages. Because human health effects are part of the program, institutional review board review has helped to strengthen program. Looking forward to seeing results next year.

- Solid project plan and schedule.
- Strong field research track record.

- Future Work will focus on implementing the study in selected homes. Given the effort on the experimental plan, it is anticipated that the results will provide clear findings. While the plan has not been presented in great detail, it is hoped that it will result in clear guidance on what works and what does not work. It is hoped that the metrics for success are clear.

- The outcomes are good. But these outcomes by themselves won't result in ASHRAE or other entities adopting IAQ demand ventilation. The work results from this project need to funnel into all the other IAQ project results. Collectively the body of knowledge resulting from the different studies should provide the needed information and research validation to implement a systems solution

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- I like the idea of positioning this project as weatherization commissioning. We know weatherization works and that a lot of weatherization projects take place every year. If they were all commissioned as this project sets out to demonstrate, substantial additional energy savings and IAQ improvements can be realized.

- With more clarifications than task restructuring, this project will be very valuable to the industry and BTOs goals.

- If the project is successful, the deliverable of guidance to HPC's would be very valuable in helping them reduce the energy consumption of existing homes to a safe limit. There wouldn't be as much lost opportunity to ensure good IAQ.

***Average*: 1** reviewer
- Good project to identify IAQ parameters with a focus to correlate to infiltration source. It's a component of a larger system approach to optimize ventilation energy use and IAQ.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- The relationship between energy savings and IAQ are at the heart of this project and directly emphasize that one can be achieved along with the other; they need not necessarily conflict.

- It may have had a slow (and valuable) start, but looking forward to hearing more findings in progress reports.

- Project is more focused on R&D, but it seems like there is sufficient outreach. Team will need to find best ways to translate results to a wide range of potential users.

- None.

***No*: 0** reviewers
- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Project strengths are that it builds on current home performance contractor model to focus delivery of energy saving and improved IAQ through an established/existing pipeline. It is a very cost effective

program given the number of test subjects sought out and potential for energy saved (similar in scale to other programs presented). A strength is that it is really just a system commissioning/optimization project that will ultimately demonstrate that value of commissioning for weatherization programs. Lastly, choosing subjects that are already participating in a home performance program should lead to high participation rates and good data collection.

- Please see previous comments.
- And, this research focuses on (house tightness and IAQ of) the existing homes industry, which isn't getting as much attention as new construction.

- Addresses a key issue in reducing energy consumption in housing, namely how to reduce infiltration losses without putting occupants at risk.
- The data collected will be very valuable; such rich data are not common in the field.

- Good building block project highlighting IAQ target contaminants to potential infiltration sources. This will improve the body of knowledge for IAQ control.

2) **Project Weaknesses**

- Project weakness might include contractor follow through.

- See previous comments.

- It remains to be seen whether the study can result in clear guidance for a range of home performance contractors, or whether there will be so much noise in the results to confuse the key findings.

- None identified.

3) **Recommendations**

- None.

- No additional comments.

- No further recommendations.

- None.

Project # 12205: A "Plug and Play" Air Delivery System for Low Load Homes

Presenter: Ari Rapport, IBACOS
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, though with some reservations. One reviewer described the project's focus on alleviating the problems of comfort, indoor quality, and air distribution in low-load homes as supportive of BTO goals. Another reviewer described the project as having "truly transformative potential" that could "revolution[ize] HVAC duct systems." One reviewer was concerned, however, that the project assumed the existence of a low-load home rather than attempting to facilitate the development of low-load homes, referring to this as a chicken-and-egg problem.

In terms of approach, one reviewer remarked that the project had enough value to justify moving the concept forward, while another noted that critical barriers had been identified and that additional work was planned to address these barriers, though only *after* the DOE project was complete. One reviewer described the project's technical approach as sound, though they raised several specific, technical concerns about things like return ducting, integration with existing air handlers, and how the technology differed from existing commercial products. One reviewer felt that conducting a market survey of comparable air distribution systems in Europe could have improved the project plan. Another was interested in whether the new approach could be used to overcome certain ventilation system challenges, specifically citing the problems associated with routing dedicated ductwork for ventilation.

Reviewers generally agreed that the project demonstrated good progress on technical matters, but several reviewers felt the technology was still not market ready. Several reviewers commented that field demonstrations would be necessary to validate the air delivery system's simulated impacts and confirm acceptable non-energy performance (e.g. comfort, IAQ, sound, aesthetics, and cost). Given its departure from conventional approaches, one reviewer emphasized the need to convince builders to adopt the new technology if the technology was to have an impact.

Reviewers identified strengths in the project's collaborations, but overall felt that numerous deficits persisted. One reviewer felt that collaborations continued to grow throughout project implementation, and expressed positive expectations for the future. Another reviewer lauded the project team's intention to address potential code barriers by working with standards and codes organizations. However, other reviewers expressed skepticism. One reviewer questioned whether relevant groups identified in the presentation were active or *potential* collaborators and another reviewer lamented the lack of outreach to mechanical contractors. One reviewer encouraged collaboration with Building America's Ventilation Integrated Comfort System (VICS) project team, describing potential opportunities to leverage value from both projects in a combined system.

Overall, reviewers were not impressed with the project's proposed future work. One reviewer felt that proposed work was promising, but cautioned that potential stumbling blocks persisted and that broader stakeholder collaboration would be needed. Another reviewer reinforced this idea, noting that finding partners willing to explore the project's novel approach would be a key challenge. One reviewer felt that proposed activities "required work"—noting that the presenter offered some bold statements about growth without laying out a clear plan—while another reviewer described the project's technology-to-market transition as "weak."

Weighted Average: 2.79 # of Reviewers: 5
Relevance: 3.00[1] Approach: 3.30 Accomplishments: 2.80 Project Collaboration: 2.30 Future Work: 2.20

[1] Score not included in weighted average.

A. Relevance

This project was rated **3.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project assumes a low load home, rather than being created to facilitate the creation of low load homes. Sort of a chicken and egg problem, but ultimately the project aims to alleviate problems of air/comfort/IAQ distribution in low load homes, so in that regard it is relevant and supports BTO goals. It is certainly designed to fill a gap in residential HVAC system design and delivery that, absent the emergence of low load homes, likely would not be there to be filled.

- Yes, this research appears to comply with BTO goals.
- But have questions about this specific component (ducts alone) researched as critical to meet these goals.

- This is a project that has truly transformative potential and could go a long way to address BTO goals by revolutionizing HVAC duct systems. It is a ways off, but the potential is significant.

- Project addresses challenges of thermal comfort in low-load homes given low air flow rates, and it also could lead to easier and less costly ways to run ducting in conditioned space. Both of these features are important as program's efforts drive down heating and cooling loads.

- I like the concept of plug and a play ventilation piping system for low load homes. I have seen a similar system utilized in European passive home ventilation projects. Low load homes provide the market opportunity to move from a sheet metal duct system to a smaller diameter plug and play system. Our current method of duct system installation suffers from a lot of issues and there is a definite market opportunity to introduce "Plug and Play" duct systems. This could help move the HVAC duct industry to the next level functionality and performance.

B. Approach

This project was rated:
1) **3.40** for the degree to which it focuses on critical market barriers, and
2) **3.20** for the degree to which the approach addresses the market barriers identified.

- Project critical barriers are identified and additional work is planned to address these barriers in later phases of the project, after the DOE funded portion of the project is complete.

- Heating, cooling, humidity control, mixing, circulation, IAQ, etc. are still critical components in homes. Therefore this is valuable industry research from a 30k foot view. How that is done with tighter code and above-code homes are the focus of much research and conversation. Drilling down more into specifics, how is this technology going to make impacts like PEX piping has? Do these small diameter ducts integrate with existing air handlers and grills/registers? Do these have negative impacts on IAQ (e.g. outgassing; separate from fire rating)?
- How does this product differ from existing Zehnder ComfoTubes?

- Technical approach was sound, but there are some open questions, e.g. return ducting. If you need to do conventional returns, what does that do from a labor standpoint? This is a big feasibility question.

- This project's approach is clever; the analogy to PEX plumbing systems is an excellent way to demonstrate that point. The team is keenly aware of key barriers, including the cost of installing ductwork, the resistance from builders for putting ducts in conditioned space, and the lack of a labor force with the substantial skills to do a good job with duct installation.

- There are a number of improvements this system can offer:
  - Reduced duct leakage.
  - Improved duct system planning and implementation thru a better sizing tool and uniform duct system parts.
  - Improved comfort thru optimized delivery.
  - Improved energy performance.
- This project has merit and value to justify the DOE investment to move the concept forward.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.60** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project accomplishments since last year are good to see and appear on the verge of becoming commercially viable. That being said, reasonably good size hurdles remain to the ultimate adoption of this system as a viable alternative to current air delivery systems. Good progress has certainly been made, and the case for the further development of the system is clear and cogent. It will require adoption by a relatively large market segment to see it take off as PEX plumbing has. Take the time to get it right.

- See some good progress with model/simulation and potential market impact from new technology, but don't see strong evidence that this technology has demonstrated promise in at least one actual home (for comfort, IAQ, energy, sound, aesthetics, cost). Does this plug and play perform like the models indicate it 'should'?

- Progress is significant so far, actual field work needed.

- Project has been in an R&D phase. The team has developed a very strong experimental design to assess a variety of issues, and the result is very promising. The challenge now is to convince builders to adopt this approach, as it appears to be a large departure from conventional practice. But, the PEX example shows that it can be done. The team has demonstrated some key lessons learned to date.

- The project is complete. Some good progress was made, but my impression is that this is not yet ready for market adoption. There are still some open issues that need to be resolved, including fire code acceptance and a solid T2M plan. Does DOE have a T2M market plan for this technology? These issues should have been better addressed in the project results. It seems to hang with no solid path forward.

D. Project Integration and Collaborations

This project was rated:

1) **2.20** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **2.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Collaborations and integration has been building throughout the project lifespan. Significant momentum exists to propel the project to the commercialization stage, at which time broader market collaboration and penetration will likely be achieved, consistent with project estimates.

- You have identified relevant groups, but are they active collaborators or on the list to reach out to for hopeful engagement?
- Is the brief reference to Housing Innovation Alliance, on slide 2, use for vagueness and non-commitment or to save space with all active members of HIA?

- The project team is limited. Big question to me is the trades. Need to get mechanical contractors involved. This is a huge gap.

- Team has mostly been focused on its laboratory tests but has built relationships with builders who might demonstrate this approach. It will be interesting to see if anyone is willing to give this a shot.
- I particularly liked the team's appreciation of potential barriers in the building codes and their plans to address those with work through the standards and codes organizations.

- First I did not see any market survey of other comparable systems from Europe before embarking on this project. I suspect there may be a body of work already done in this space. Some upfront leg work could have resulted in a much better project plan and outcome. The key partners should have identified European companies that are working in this space and then leverage their experience and expertise.
- On a different note. This might be a good fit with the Ventilation Integrated Comfort System (VICS) project. There may be an opportunity to leverage the value from each of these projects into a combined single solution (HVAC, ventilation, and duct) system.

E. Proposed Future Work

This project was rated **2.20** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Proposed future work is promising, but there are several components and parameters that remain to be determined, any one of which could be a significant stumbling block. Careful attention to each step will be required to make sure nothing falls through the cracks. Broader stakeholder/collaboration may be needed.

- See previous comments, especially regarding the investment needed to compete with existing product approved in more strict European market.

- I think the future focus needs work. There are some bold statements about growth, which I agree is possible, but the project needs to lay out a path to get there. This includes engaging the trades, pilot homes as well as other items they do mention like code bodies.

- Project is mostly done at this point, just pending final reports. The challenge will be in finding partners willing to explore this possibility.

- I don't see a strong finish to this project. Again the T2M transition is weak.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 3** reviewers
- Novel system designed to transform the residential air delivery market for a large subset of homes.

- No comment.

- Deliverables are clear findings from an R&D effort. It expands the toolbox for builders should they continue to run into thermal comfort challenges in low load homes.

***Average*: 2** reviewers
- I think the value could be just average if a key outcome is to R&D small diameter ducts for this valuable market opportunity.
- Or I think the value could be high if the outcome is to validate small diameter ducts for this valuable market opportunity, and if a material choice is determined in the process than that can be icing on the cake.

- See earlier comments.

***Low*: 0** reviewers
- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers
- See answers to previous questions.
- No comment.
- Project is definitely one that is more R&D, so the focus has been rightly put on that as opposed to deployment. Some work is going on with deployment, but more will be needed for this approach to have an impact on the market.
- See earlier comments.

***No*: 1** reviewer
- I think this is a really creative idea. I think your next steps would be stronger if you had at least one proof of concept real house to reference.
- Looking forward to reading final report.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project's strength is in its simplicity, its ease of installation, and effectiveness for low load homes. It is consistent with results from the UCF study.
- See previous comments.
- Huge potential, strong technical component with data to support there is a real opportunity.
- Innovative approach to solving the thermal comfort concerns with low load equipment.
- Team has conducted solid experiments that help identify the key issues.
- Concept is great. Project Plan and execution are ok. Why wasn't a market survey done to identify and leverage other systems learnings rather than recreating and testing basic system design, which now leaves a weak T2M transition plan.

2) **Project Weaknesses**

- Weaknesses lie in the fact that several installation details and guidelines for appropriate use and installation remain to be ironed out.
- See previous comments.
- Need more trade collaboration and a focus on field testing.
- Not necessarily a weakness, but it will be interesting to see if the team is able to find partners willing to test this approach in a real home.
- See earlier comments.

3) **Recommendations**

- None.

- None to add.
- Provide additional recommendations and lessons learned for supply plenum to go with these ducts and any air handler

- None.

- Could this approach be used to overcome challenges with balanced ventilation systems, namely the problem in routing dedicated ductwork for ventilation?

- See earlier comments.

Project # 14119: Intelligent Residential Comfort Control Applications

Presenter: Cheryn Metzger, Pacific Northwest National Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Most reviewers agreed on the potential relevance of this project to BTO's goals, though with some skepticism or hesitance. One reviewer felt that, because the project had so far operated without market input, market actors would need to be engaged to confirm the project's relevance. Another reviewer thought the project was relevant for existing homes, but would not have measurable impacts for new construction. A third reviewer remarked that the subject of the project was closely connected to BTO's goals, but expressed that "outlining value propositions and connecting market actors [was] not DOE's role."

Several reviewers saw merit in the project's approach. However, one cautioned that relevant technologies change so fast that current gaps may be obsolete in a year or two, highlighting that the project team would need to remain flexible to adapt, adopt, and integrate new technologies into the study. Another reviewer flagged the importance of having clear and consistent partners, so that the end product was not disconnected from installer and manufacturer feedback. A third reviewer remarked that if the research focused only on pushing new technologies into the marketplace, and not also on pulling new technologies from the consumer side, then the project's impact would be muted.

Reviewers felt that it was too early to gauge accomplishments, but one reviewer did laud the project team for building structure around the Internet of Things (IOT) topic. Another reinforced that the potential for impact exists, though with the caveat that market engagement over the next year would determine whether potential impacts would likely be realized. Other reviewers were not so optimistic, with one commenting that they did not foresee this project having an impact in the HVAC community, while another questioned some of the presented energy savings projections.

Reviewers agreed that the project team had not yet engaged in meaningful collaboration. One reviewer was unsure whether the project team had identified key stakeholders, while another felt the project had no partners at all, describing BTO as "operating in a vacuum." One reviewer was somewhat optimistic about future opportunities for collaboration, noting that stakeholders had yet to be engaged *primarily* due to the early scoping stage of the project, and that outreach was planned for the project's next phase.

Reviewers were mixed on the project's proposed future work. One reviewer described the planned market outreach as very relevant, impactful, and scalable, but several reviewers expected that some target stakeholders—particularly builders and architects—might not find great value in the initially-planned deliverables. Given these doubts, one reviewer recommended that the project team focus on "win opportunities," (i.e., demonstrating one win at a time to slowly build out the value propositions and show that ideas can move from concept to actual practice).

Weighted Average: 2.20 # of Reviewers: 5
Relevance: 2.60[1] Approach: 2.40 Accomplishments: 2.20 Project Collaboration: 1.70 Future Work: 2.60

[1] Score not included in weighted average.

A. Relevance

This project was rated **2.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project is highly focused/targeted on comfort system controls, rather than whole building or system improvements. This is not necessarily a bad thing, as targeted efforts such as this can lead to broader holistic system changes. The project is in its early stages yet and outreach to the market has yet to begin. This is essentially the tip of the iceberg for the project. In future updates I would like to see progress in engaging the market and getting confirmation from the market of the project's relevance to them and to BTO/RBI program goals.

- Yes I think this is relevant and addresses BTO's goals for the existing homes industry, but I don't think this will have nearly as many measurable impacts for the new construction market as H/AC systems (and therefore t-stat) become a lower and lower part of the overall energy pie as building shell efficiencies continue to rise.

- The subject generally is closely connected to BTO goals. However, I think this is not an appropriate project for DOE BTO to engage in. It is also clear to me it stems from a misunderstanding of the market. A DOE rep, when asked about the origin of the project, said it came from the fact that manufacturers are not sufficiently focused on this area. Having worked for an HVAC OEM, on a team focused on this issue, I know this to be untrue. The issue is not one of technology development, or even cost for deployment, it is about figuring out the value proposition, across the chain, and who pays and who benefits. This is a marketplace issue that DOE is not situated to solve. All the tech is there, the HVAC industry is scrambling to see who can be the first to monetize it. If this were about fundamental tech, communication protocols, standards, some baseline issues, DOE would have a role. But outlining the value proposition and connecting the market actors is not DOE's role.

- This project is in the early stages; it doesn't address the key focus areas of moisture tolerant envelopes, IAQ, and HVAC for low loads. That fact is ok, but the relevance of this effort is not entirely defined at present. I believe that O&M for residential systems is an important topic, and I suspect that this effort might lead to improvements in that area.

- I suspect this one is really hard for folks to understand. We are looking at residential control applications in the IOT space. Primarily this is sensing and control for equipment installed behind the utility meter. The project is trying to identify opportunities and value propositions primary in the residential HVAC space. The information (mostly thru installed sensors and production of data) provides different value propositions to different players. At times those value propositions may be met thru the same data set and other times it may require specific data for a specific need.
- What this project is doing is trying to define what applications can be measured thru sensors. For example, the author sites basic functionality, refrigerant charge etc. This project is a first step to define the application. We see market trends in the residential IOT space indicating that a data market will emerge for these different applications. How the value propositions play out and what the market is willing to pay for these applications is still a ways off. It's at very immature state and there are a number of hurdles to overcome. Nevertheless it's important for the energy sector to begin defining propositions so we can voice our needs as this market develops. Other industries, such as homeowner insurance are doing the same. We have to remember that we (energy) are only monetization opportunity in this developing market place. Also, we are not driving the development of this space. The true developers and players are the big interconnected data and the big tech companies. We are trying to figure out how to help our sector join the game.

B. Approach

This project was rated:

1) **2.40** for the degree to which it focuses on critical market barriers, and
2) **2.40** for the degree to which the approach addresses the market barriers identified.

- The project is at this point essentially on a fact-finding mission to see if the gaps that DOE program managers perceive can be identified and addressed. I think the program is well on its way to identifying those gaps as they currently exist, but technology changes so fast that current gaps may be obsolete in a year or two, so the project will need to be flexible to adapt, adopt, and integrate new technologies into the study stream in order to stay relevant to the industry.

- I think your presentation and following discussion was much better than the attached presentation conveyed.
- Also nervous that without clear and consistent partners, you'll be disconnected from invaluable field feedback from installers and manufacturers, as mentioned in the follow up discussion.

- I don't believe the project really understands the market barriers.

- It wasn't entirely clear how this project will evolve to break down market barriers to intelligent residential comfort control applications. I think that the barriers are really cost; manufacturers don't want to add a penny to their equipment unless they find a clear benefit.

- I like the approach. See my statement in the relevance section.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.20** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **2.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Accomplishments are too early to tell at this relatively nascent stage of the project. Potential certainly exists. Market engagement over the next year will help determine the whether the potential is likely to be realized.

- Early in research project. Looking forward to seeing Task 1 report.

- I don't see this project having an impact in the HVAC community.

- This project is still in the early stages; a draft literature review has been prepared. Without it being released outside of the organization, it is difficult to rate it as being a significant accomplishment. There have been a number of literature reviews on this topic, so I will reserve judgment until I see the report.
- I question some of the energy savings claims made in the presentation; they seem to be rather dramatic.

- They did a good job. It's hard to build structure around this IOT topic. It's a good first step. There are going to be many steps. A complimentary step is the current DOE project titled, "Physics-based Interval Data Models to Automate and Scale Home Energy Performance Evaluations."

D. Project Integration and Collaborations

This project was rated:

1) **2.00** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **1.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Stakeholders have yet to be engaged primarily due to the early scoping stage of the project. Next phases are planned to begin outreach.

- I think better next steps were fleshed out during follow up conversation.
- If this research is only focused on pushing new technology out into the marketplace and not also on pulling the new tech (from consumers), then impact is only going to go so far.

- The project has no partners. DOE is doing it in a vacuum, and it shows. The idea that DOE can weigh in on this issue without engagement from actual market actors is absurd to me.

- This project is still in its infancy. The team is just trying to find its course. I am not sure that they have identified the key stakeholders that will improve energy efficiency through intelligent controls.

- This is not applicable at this time. It's too early in the process to build a meaningful engagement team.

E. Proposed Future Work

This project was rated **2.60** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Proposed future work at this point is to engage stakeholders outside of the DOE/BTO/RBI sphere. There seems to be some anecdotal indication that key stakeholders will be interested in this research, but it remains to be seen.

- I think the proposed work discussed (to include installer and manufacturer feedback) in the follow up discussion was very relevant, impactful and scalable.

- Hopefully the market will be engaged, as the presentation suggests. Based on how little attention is paid to this to date I am skeptical.

- I don't see the proposed future work as being very clear at the current time.

- The path forward is not clear, like it is for a discrete widget based technology development projects. This is a fast moving, complex system, which depends on a lot of system developments that are not in our direct control. My recommendation for a future approach is to focus on "win opportunities". One demonstrated win at a time. Slowly build the value proposition and demonstrate that we can move from concept to actual practice. It might be a project with one manufacturer and a single product to demonstrate device data collection and useful data analysis. The goal is to begin demonstrating valid market proposition and value.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 1** reviewer

- As stated earlier. This is an early scoping project. Defining the application in the HVAC IOT market is logical first step.

***Average*: 3** reviewers

- Deliverables thus far consist of literature review, diagrams of sensor and controls systems, and thoughts on advanced systems. These deliverable are not extraordinary, but are nonetheless important and necessary for moving forward.

- Could be high value for presentation and group conversation.
- But just average if for presentation alone.

- It's not clear that builders and architects will find great value in the initially planned deliverables.

***Low*: 1** reviewer

- Already clear.

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- I believe sufficient emphasis is being focused on the project's and BTO program objectives. It is a difficult issue to scope, but the seeds of crystallization are forming. I look forward to future updates and progress.

- This effort appears to be a lower priority for the BA program at present, but it could develop into a key focus area in the near future.

- None.

***No*: 2** reviewers

- Main point here is need for rapid feedback from field to ensure explorations are going in the right direction with product push (supply) and pull (demand).

- No further comment.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The primary strength of the project lies in the potential energy savings that could be realized from something as simple as better comfort system controls. The market is certainly disjointed and R&D efforts in this area lag, so it seems ripe for this sort of governmental programmatic intervention.

- Very creative and other previous comments.

- Honestly, I cannot say anything positive.

- Could be addressing an area of great opportunity in residential buildings by identifying faults as well as encouraging controls that could reduce HVAC energy consumption while maintaining comfort and ensuring no damage occurs to equipment.
- Project is looking out at future technologies so that BA program is ready to focus on this topic when it feels current focus areas have been sufficiently addressed.

- This is an early stage market scoping project. Some of the evaluation criteria do not apply and a low score does not necessarily represent a poor project. This reviewer thinks this project has a lot of value. We need to begin defining our role in the "Grid of things" space.

2) **Project Weaknesses**

- The main weakness of the project may lie in its ability to handle changing technology. It will be hard to predict where sensor and control technology will be as this project rolls along. Key stakeholder engagement will also be critical, but as of yet has not been demonstrated due to the early stage of the project.
- Other previous comments and no cost share.
- Already touched on this.
- The project is a bit new to be overly critical, but it is tough to judge current accomplishments to date considering the draft literature review is still within internal channels. A clear objective and a path to overcome a particular problem have not been clearly articulated.
- It's not clear that the key stakeholders have been identified.
- None.

3) **Recommendations**

- None.
- Have more dependable partners, which will ideally include folks with feedback from the field.
- Stop work on it. This is not an appropriate project for DOE.
- None.
- See earlier comments.

Project # 15116: Residential Building Analysis Tools & Support

Presenter: Scott Horowitz, National Renewable Energy Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers overwhelmingly agreed on the relevance of this project to BTO's goals, commenting that the simulation tools being developed as part of this project were key to assessing different combinations of technologies and their impact on the efficiency of the residential building stock. One reviewer believed that this project would have a huge impact on BTO's goals and that BTO's guidance was driving the project the right direction. Another remarked that energy modeling tools were the backbone of the future of energy savings, and that this project helped to ensure the backbone remained strong.

Reviewers generally approved of the project approach, remarking that it demonstrated a strong understanding of modeling issues and would likely lead to expected outcomes. One reviewer warned that keeping up with emerging technologies could disrupt the project flow, but another felt that the project's approach to incorporating new technologies appeared sound.

Reviewers commented that development of energy modeling tools stemmed from "the belly of a complex, organic beast," and that collaboration—like that demonstrated by the project team, with strong local, regional and national partners—was essential to "taming the beast." One reviewer was slightly concerned that the project was focused too much on modeling best-case energy savings based on lab testing, with insufficient focus on validating energy savings with field-based data. Another reviewer noted the need to evaluate real world impacts of modeled technologies, remarking that to do so required engaging with parties that were in a position to perform this validation.

Reviewers agreed that the project's accomplishments to date demonstrated the project team's commitment to producing actionable, useful information—commenting that the market had expressed a preference for this information because of the rigor with which it was developed. One reviewer remarked that potential impacts could be outstanding, but was not clear about how project outputs would be disseminated to have such impacts at the national level.

Looking forward, several reviewers described that the project's next steps clearly built on previous steps and would serve to add important, ongoing enhancements and information to project deliverables. One reviewer reiterated that they would like to see more field-based validation. Another reviewer reiterated that the inclusion of new technologies into the modeling tools was important, but also that the project team would have to identify the point at which there were diminishing returns. High on one reviewer's wish list were output reports based on non-energy benefits (i.e., thermal comfort, IAQ, and other IEQ issues).

Weighted Average: 3.51 # of Reviewers: 4
Relevance: 4.00[1] Approach: 3.38 Accomplishments: 3.50 Project Collaboration: 3.75 Future Work: 3.50

[1] Score not included in weighted average.

A. Relevance

This project was rated **4.00** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Energy modeling tools are the backbone of the future of energy savings. This project helps to ensure that backbone stays strong.

- Great initiative to align efforts with existing technology, new technology, modeling, validations and substantial partner involvement.

- I think this area has a huge impact on BTO goals and is in real need for DOE guidance to drive it in the right direction.

- The simulation tools being developed as part of this project are key to assessing the different combinations of technologies that will be most beneficial to improving the efficiency of the residential building stock. Especially with the drive to zero-ready homes, the interactions between systems has become critical, and this modeling is the best way to assess those interactions.

B. Approach

This project was rated:
1) **3.75** for the degree to which it focuses on critical market barriers, and
2) **3.00** for the degree to which the approach addresses the market barriers identified.

- Approach is well understood by project team the likely will lead to expected outcomes; however, keeping up with emerging technologies may disrupt flow of the project. Validated/high confidence models may help alleviate such disruptions.

- Great focuses and juggling valuable tasks.
- Slightly concerned that project may be focused more on modeling best case energy savings from lab testing (resulting in over-predicting) and not validating enough with field based data.

- Project demonstrates a strong understanding of how to address the modeling issue.

- As noted in previous response, the interaction among components is not totally clear to building professionals, so some effort is needed to assess it through modeling. Additionally, the vast differences in climates and building approaches across the country necessitate tools that can boil down those parameters for global or local decisions. The methods to incorporate new technologies seems sound.

C. Accomplishments/Progress/Impact

This project was rated:
1) **3.50** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The accomplishments to date demonstrate that the project team is committed and producing actionable, useful information that is being adopted in the market. The market also has a preference to the information from the project team because of the rigor with which it is developed.

- Information shared and potential impacts could be outstanding. But how has this information been disseminated with outreach to have substantial national impacts?

- Results appear strong, need to continue to drive into the market.

- Project has accomplished a significant number of progress, between BeOpt, Open Studio, and interaction with HERS rating approaches.

D. Project Integration and Collaborations

This project was rated:

1) **3.75** for the degree to which the presenter has demonstrated an understanding of the key stakeholders necessary to accelerate movement of technologies or practices into the market, and
2) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The development of energy modeling tools stems from the belly of a complex, organic beast. Collaboration is essential to taming the beast and is deftly demonstrated by the project team.

- Great strong local, regional and national scale partners.

- Project team is good, need to work more with builders and energy modelers to understand real world impact.

- Project team appears to be well-integrated with other BA teams as well as key industry groups, including RESNET and utilities.

E. Proposed Future Work

This project was rated **3.50** for degree to which the project has effectively planned its future in a logical manner by incorporating appropriate decision points, considering its contribution to the program interim market goals and, when sensible, mitigating risk by providing alternate pathways.

- Next steps clearly build on previous steps and serve to add important ongoing enhancements and information to the project deliverables.

- Great. As mentioned before, would like to see more field and installed based validation, especially given the DOE Code compliance studies going on.
- Wish list item: output reports based on non-energy benefits.

- Basic plan but it appears to address what is needed.

- Project team has crafted a strong timeline of past activities and ones that are planned. Inclusion of new technologies into modeling tools is important as is the translation of results in easier manner, through HERS index or other visualization and presentation methods. BA program will have to identify the point at which there are diminishing returns, as the tools seem rather strong at the current time.

F. Value of the Project's Deliverables to the Target Audience/Market

***High*: 4** reviewers

- Critical to future of adoption of energy measures.

- Looking forward to see more up-close and using.

- No comment.

- See notes on the strengths.

***Average*: 0** reviewers

- N/A

***Low*: 0** reviewers

- N/A

G. Are Key Research Areas/Deployment Activities Relevant to the Project's and Program's Objectives Receiving Sufficient Emphasis?

***Yes*: 4** reviewers

- A well-coordinated plan is in place and being followed.
- Thanks for your team's great work.
- Looking forward to test driving the tools and future progress reports.
- No comment.
- Team has struck a good balance of technical development and deployment of research results.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- One of the project's main strengths lies in the fact that the industry looks to the project team, in fact relies on them to produce useful tools. Another strength is that the team continues to deliver and to demonstrate that the reliance placed on the project team is well placed and rewarded.
- See previous comments. And very strong cost share.
- Addressing a critical market need that is best filled by DOE.
- Providing key tools to a wide range of stakeholders.
- A key central effort that brings together myriad of efforts in the field of residential building performance.
- Actionable products.

2) **Project Weaknesses**

- Garbage in/garbage out is always a weakness of any programming activity. Failing to deliver is also considered a weakness, but is unlikely.
- Minimal, per previous comments.
- Need to evaluate real world impact by engaging with parties who can provide such feedback.
- None of note.

3) **Recommendations**

- None.
- No more than what's already been shared.
- None.

- Much of the tools focus is on energy. With the stated importance of thermal comfort, IAQ, and other IEQ issues, could the team focus some effort on tools to address these issues? For example, could a tool be developed to "sell" a consumer on the resulting thermal comfort that would result from particular choices in either a new home or a retrofit?

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

For more information, visit: energy.gov/eere/buildings

DOE/EE-1671-A • November 2017