U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES OFFICE

2016 Building Technologies Office Peer Review Report

Appendix

December 2016

2016 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

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

2016
Building Technologies Office
Peer Review Report

APPENDIX

April 4–7, 2016
Falls Church, Virginia

NOTICE

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FINAL LIST OF REVIEWERS

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Zuba, Nicholas
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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 2016 Building Technologies Office Peer Review.

Evaluation Criteria: Building Technologies Office (BTO) Program Peer Review 2016

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. (**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

EMERGING TECHNOLOGIES
SOLID-STATE LIGHTING

Project # 31111: Advanced Light Extraction Structure for OLED Lighting

Presenter: Zhiyun Chen, Pixelligent
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers remarked that the gradient index substrate used in this project is a potential improvement to organic light-emitting diode (OLED) lighting, which in turn would help the solid-state lighting (SSL) market. They also commented that the higher light extraction efficiency (70%) is well-aligned with BTO's objectives and the DOE solid-state lighting program's roadmap. Reviewers liked the project's approach, including its use of stable scatter/nanocomposite formulation that promises low-cost manufacturing and for overcoming a well-defined technical barrier involving light extraction efficiency.

One reviewer observed that there have been some deviations from the original project plan involving computations and simulations early in the project timeline. This reviewer stated that while this hasn't stymied progress, it raises the issue of whether the lack of computation has affected the current formulation for creating an optimal gradient index layer. The reviewer wondered which of the partners was tasked with providing computational results and said that the critical importance of modeling and computations prior to implementation is such that it would be useful to know which computations were not done and why – and how to correct this.

Reviewers thought the project was progressing well, although one reviewer said it was difficult to judge overall progress because so little data was presented, including how far along the team was in reaching the 70% light extraction efficiency goal. One reviewer pointed out that the team was close to accomplishing a key goal – development of a 4-inch device with 2.9X light extraction – and wondered how that number was selected and if it would be revised upward.

However, these reviewers acknowledged that there are likely intellectual property (IP) issues at play that made it difficult for the principal investigator (PI) to provide more details. They suggested a closed-door review might be helpful in getting the PI to discuss information more freely without worrying about the presence of competitors. Reviewers praised the project as having good commercial prospects thanks to the processes it is developing and the work with key partners. During the question and answer (Q&A) session, the PI explained the project team is using a natural diffusion process to generate a gradient-index (GRIN), which prompted one of the reviewers to subsequently comment that this approach seems manufacturable.

Reviewers recommended that the project team look into roll-to-roll (R2R) manufacturing and have more experimental computations for benchmarking purposes.

Weighted Average: 3.48 # of Reviewers: 3
Relevance: 4.00[1] Approach: 3.50 Accomplishments: 3.50 Project Collaboration: 3.67 Future Work: 3.00

Program Response:

Pixelligent will continue this project on the stable nanocomposite formulation to enhance light scattering in OLEDs (a key barrier for OLED technology), and the related low-cost manufacturing process. The project is close to accomplishing the key goal – a 4-inch devise with 2.9 light extraction enhancement – and will conclude at the end of 2016. DOE's Acquisition and Project Management (APM) guidance will be used to wrap up.

[1] Score not included in weighted average.

Project # 31112: ITO-free white OLEDs on Flexible Substrates with Enhanced Light Outcoupling

Presenter: Barry Rand, Princeton University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, stating that the solid-state lighting program, and this project in particular, are in line with the BTO roadmap, efficiency targets and market needs. Additionally, a reviewer commented on a critical point: this project correctly identified a market need, increasing white organic light-emitting diodes (OLEDs).

Reviewers cited the project's technical goals as a strength, namely, the idea of using a porous substrate to make a low-cost enhanced light out-coupling substrate characterized by controllable voids in a polymer system. However, one reviewer remarked that market barriers such as manufacturability and cost impact were not mentioned, though the reviewer recognized they may be out of the scope of this project.

Reviewers felt the project successfully demonstrated a 1.6X enhancement using porous substrate and 1.9X enhancement with silver nanowire-embedded polyimide and porous polyimide combination. However, one reviewer pointed out that there is still a large gap between the 1.9X light extraction achieved and the 3X goal that must be achieved in the next few months. The reviewer also noted that the measured results of 32 lumens per watt (lm/W) is far from the 130 lm/W goal and questioned whether the 3X light extraction is consistent with that goal and if there is an issue with the material being used.

Reviewers each remarked on the lack of and need for industry collaborators, as well as clarification of roles of each participant to determine subsequent collaboration and integration into the project. These industry partners would be especially beneficial when transitioning from lab to prototype and production, as they might help identify processes that are scalable and those that are not.

One reviewer expressed concern on the path forward to large-scale manufacturing once the project is complete and recommended that there be large-scale demonstration of high-throughput production of the porous PI. This reviewer also suggested a possible technical recommendation for the project team on substrate-trapped light through use of certain scatterers.

Weighted Average: 3.38 # of Reviewers: 3
Relevance: 4.00[1] Approach: 3.84 Accomplishments: 3.50 Project Collaboration: 2.84 Future Work: 2.67

Program Response:

Princeton University will continue this project on applying a porous substrate with controllable voids in a polymer system to enhance light extraction in OLEDs – a key barrier for OLED technology. Tests with silver nanowires embedded in the substrate have reached a 1.9X light extraction enhancement. Further work will be performed to raise the light extraction toward the 3X level, as the project will conclude at the end of 2016. DOE's Acquisition and Project Management (APM) guidance will be used to wrap up.

[1] Score not included in weighted average.

Project # 31113: The Approach to Low-Cost High-Efficiency OLED Lighting

Presenter: Qibing Pei, University of California – Los Angeles
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers felt that the project was relevant to BTO's goals, noting that the project outcome of developing an integrated substrate to replace traditional materials for the fabrication of low-cost, high-efficiency OLEDs was consistent with BTO's target of achieving a light efficiency of 200 lumens per watt (lm/W) by 2020. They also felt that the project mostly addresses cost, a primary barrier to high-adoption rates for light-emitting diodes (LEDs). Reviewers gave the project high marks on the impressive progress to date, project approach, appropriate stakeholders, and great initial results.

One reviewer felt that the project approach was promising, in particular the effort to develop a scalable, low-cost process to fabricate an organic LED (OLED) substrate that integrates high surface conductivity, low surface roughness, and high light extraction efficiency in a plastic sheet using silver nanowires (Ag NWs). However, this same reviewer felt that the atomic layer deposition (ALD) process might be too expensive for a large-area, low-cost application. Another reviewer felt that the project approach and objectives will overcome significant market barriers, providing improvements in performance, cost, and efficiency.

The reviewers offered praise for both the accomplishments and project integration/collaboration. For the former, they noted the project has demonstrated very good results so far, including achieving 80 lm/W efficacy at 1000 candela per square meter (cd/m^2) using the integrated plastic substrate. The reviewers also noted that the project team has worked closely with the manufacturer OLEDWorks and has the necessary expertise and partners in academia and industry to achieve success – and to modify processes when needed.

Reviewers did comment that the use of ALD as a process is potentially too costly for low-cost, large-area manufacturing of integrated substrates. Another reviewer questioned how the project would go forward in reaching the target light efficiency value of 150 lm/W and whether the Ag NWs would tarnish over time.

Weighted Average: 3.82 # of Reviewers: 3
Relevance: 4.00[1] Approach: 3.84 Accomplishments: 3.84 Project Collaboration: 4.00 Future Work: 3.33

Program Response:

University of California at Los Angeles will continue this project on an integrated substrate based off plastic with silver nanowires. The goal is to provide light extraction enhancement, sealing, and current management. The project has achieved 80 lm/W at 1000 cd/m^2 with this integrated plastic substrate, and will conclude at the end of 2016. DOE's Acquisition and Project Management (APM) guidance will be used to wrap up.

[1] Score not included in weighted average.

Project # 31119: Novel Transparent Phosphor Conversion Matrix with High Thermal Conductivity for Next-Generation Phosphor-Converted LED-based Solid State Lighting

Presenter: Michael R. Bockstaller, Carnegie Mellon University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

This project received generally good marks across the various categories evaluated by the reviewers. With its goal of developing thermally conductive siloxane encapsulant materials that could replace standard silicone in light-emitting diode (LED) packages, reviewers generally saw this project as relevant to BTO's goals, with one reviewer noting that if the 20 to 30% of energy absorbed by phosphors lost to heat could be reduced, it would provide for cooler and longer life LED systems, which in turn would help with the marketing of mid-power phosphor-converted LEDs.

Reviewers were a bit uncertain of the accomplishments to date for this project, noting that they have been limited thus far and that the 1 watt per meter kelvin (W/m-K) thermal conductivity goal is an aggressive one in which the best results to date are only about 0.6 W/m-K and it is unclear if that gap can be closed – and whether that result is itself sufficient enough to provide the desired benefits. Echoing that sentiment, another reviewer noted that the first five tasks had been achieved, resulting in the synthesis of hybrid siloxanes with improved dispersion and reduced scattering but a thermal conductivity still below the 1 W/m-K goal.

Reviewers responded positively to the project's integration and collaboration, noting the project team had worked closely and effectively with Osram Sylvania Inc., and that partners were providing proper input and perspective. One reviewer suggested that it would be helpful to clarify the roles of the various parties including financial ones (i.e., who receives and who contributes funding?) and to know Osram's view on project progress and the likelihood of whether the approach is likely to be adapted for manufacturing and production.
Looking ahead, one reviewer said it was not clear what needed to be done to close the performance gap between the target and what has so far been achieved. Another reviewer said that the key parameters that need to be measured are LED package performance and reliability in order to provide an initial approximation of LED package reliability – and thus negate the need for significant testing by the LED manufacturer. Reviewers expressed some concern on technical issues involving the effect of scattering on transmissibility, the ability to produce particles of precise size, and the thermal stability of polymethyl methacrylate (PMMA) treated particles.

Reviewer recommendations included thermal modeling at the nano-and-microscale in addition to the molecular level, and addressing the effects of the ligands, surfactants, and particle loading on the curing rate and degree of cure of silicone (since these effects represent a potential reliability and manufacturability issue). Another reviewer cited an article by one of the collaborators, noting that it puts this project in a broader context, and the reviewer asked if this project has any bearing on other conversion layer architecture.

Weighted Average: 3.37 # of Reviewers: 3
Relevance: 3.33[1] Approach: 3.33 Accomplishments: 3.17 Project Collaboration: 3.84 Future Work: 3.33

Program Response:

Carnegie Mellon University will continue this project on thermally conductive siloxane materials with embedded phosphors (i.e. encapsulent) to enhance the heat transfer of LED packages. Test results have produced 0.6 W/m-K heat transfer towards a goal of 1.0 W/m-K. The project will conclude at the end of 2016. DOE's Acquisition and Project Management (APM) guidance will be used to wrap up.

[1] Score not included in weighted average.

EMERGING TECHNOLOGIES
HVAC, WATER HEATING, & APPLIANCES

Project # 30002: Advanced Hybrid Water Heater Using Electrochemical Compressors

Presenter: William Parmelee, Xergy, Inc.
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, noting that this project presents one of the key technologies of the BTO portfolio. Reviewers unanimously agreed on the high value of project deliverables, noting that technological challenges were resolved, favorable economics established, and pre-commercial testing started.

Reviewers praised the progress made with electrochemical conversion (ECC) technology on both the analytical and experimental fronts resulting from this project, as membranes and membrane electrode assemblies (MEAs) are now commercially available and have superior performance to competing off-the-shelf products. One reviewer referred to the "game changing" nature of the ECC technology and suggested such a water heating system could complement solar-powered systems since both use low voltages and the latter already has appropriate hardware to generate higher voltages required for household operations.

Reviewers concurred that this project successfully identified and addressed critical market barriers in areas such as component cost, long-term performance, and system integration. They were also impressed with the close collaboration with key market players as evidenced in the work with GE and other key stakeholders in the water heating market.

A number of reviewers were concerned about the long-term performance of the vacuum system's hermetic seals, finding that this needs to be evaluated under operating conditions, especially given the presence of non-condensable gas. One reviewer remarked that the resilience of the heretically-sealed vacuum system to contamination – especially when operating below ambient pressure – and air fouling need to be addressed. In particular, because cyanogen gas may be produced at the electrodes, one reviewer recommended that the project team should engage the certification agency in the pre-commercial design and testing process in order to help prevent subsequent follow-on design adjustments by manufacturers. Another reviewer noted that the technology has not been considered as a retrofit for current (conventional) systems.

Weighted Average: 3.61 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.63 Accomplishments: 3.50 Project Collaboration: 3.75 Future Work: 3.75

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 30003: Heat Pump Water Heating Using Solid-State Energy Converters

Presenter: Uttam Ghoshal, Sheetak Inc.
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of the project to BTO's goals, both the program's performance and market goals, by using thermoelectric module technology to transfer heat for heat pump water heaters (HPWHs). The reviewers praised the core technology as well-developed and both innovative and potentially transformative in creating an affordable, reliable, and high-performance product.

Reviewers concurred that this project appropriately identified critical market barriers, and one reviewer felt these were being addressed in an outstanding manner.

Some reviewers were concerned about stakeholder engagement, encouraging further manufacturing collaboration. Reviewers suggested the project team partner with companies involved in manufacturing HPWHs to learn more about the history of the technology and pitfalls to avoid as the project segues to a market deployment phase.

One reviewer cautioned that manufacturers are reluctant to change tank design. This could become an issue during market adoption because (as was noted during the question and answer(Q&A) session), tankless water heaters are popular but the current design of this HPWH is not.

While offering high praise for the technological concept underlying the project, including the coefficient of performance (COP) of this design, a few reviewers expressed concern about the path the project team would follow to achieve the stated goal of being a leader in high-volume manufacturing of this technology in the U.S. market.

Several reviewers acknowledged the project team's consultation with Whirlpool, although one reviewer suggested the principal investigator (PI) become acquainted with current and past HPWH promotions by electric utility companies. This reviewer expressed concern about what the actual retail customer price premium would be versus the $100 to $150 retail price that the PI suggested during the Q&A session. The reviewer recommended the project team undertake a review of retail cost and do a comparison with an add-on unit for efficiency and payback in order to show a payback comparison.

Weighted Average: 3.25 # of Reviewers: 6
Relevance: 3.67[1] Approach: 3.50 Accomplishments: 3.17 Project Collaboration: 3.00 Future Work: 3.33

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 30005: Manufacturing Competitiveness and Supply Chain Analysis

Presenter: Margaret Mann, CEMAC
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers were decidedly mixed in their evaluation of this project. However, they generally felt this project was relevant to BTO goals given the project's stated outcomes including (1) assessing current and future opportunities for thermal non-vapor compression (VC) heat pumping technologies versus conventional systems; (2) identifying the various drivers impacting their adoption; and (3) determining what portions of the heat pumping technology supply chain the U.S. has or could capture. One reviewer differed from this consensus, stating that it was difficult to see how any of the objectives were addressed given that nearly the entire presentation of the project discussed conventional heat pump manufacturing. Additionally, one reviewer noted that the project excludes ground source heat pumps, a technology that "can already meet" BTO goals.

While reviewers may have disagreed in their evaluations, there ended up being general consensus that the approach of this project, including the approach to critical market barriers, was average. One reviewer expressed concern that the approach focused too much on air source heat pump manufacturing as being independent of air conditioning manufacturing and another stated that the project, while helpfully informational, was unlikely to overcome barriers.

Reviewers viewed the project as a start in helping the industry transition to non-VC heat pump technologies and one that could indirectly meet BTO goals provided the approach uses the right set of assumptions. One reviewer observed that the non-VC technologies portion of the project is now complete and current work is focusing on magnetocaloric refrigeration – the development of which would indeed be a transformative contribution to program market goals.

While some reviewers felt there was an appropriate level of stakeholder engagement, others found collaboration in this project, especially with manufacturers, lacking.

Reviewers thought this project could serve as a good tool for examining manufacturing and market barriers for this technology and that it provides information on heat pump manufacturing not otherwise available.

Weighted Average: 2.69 # of Reviewers: 6
Relevance: 3.17[1] Approach: 2.75 Accomplishments: 2.59 Project Collaboration: 2.83 Future Work: 2.67

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31290: Natural Gas Fired Air Conditioner and Heat Pump

Presenter: Paul Schwartz, Thermolift, Inc.
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers differed in their assessments of the project's relevance to BTO goals. Although some reviewers felt that the project aligned well with BTO's goals, others expressed concern with the project's chances of success, with one reviewer citing specifically the competition the product would receive from developed or more mature heat pump technologies. In response to the principal investigator's (PI's) reply during the question and answer (Q&A) session that the heating-to-cooling output (ratio) can be "adjusted a little," one reviewer remarked that the flexibility between heating and cooling appears limited – meaning there will have to be potentially extensive periods of the sinking of heating and cooling to obtain the needed ratio.

Because the system is so significantly different from traditional heat pump technologies, reviewers expressed concern with how such a new technology would be marketed to and introduced into the residential market (including both installers and end users). "It is not likely to be an easy sell," remarked one reviewer. Another reviewer commented that this is a highly complex type of heat pump and it remains to be seen whether it can be manufactured at an acceptable cost, but felt the project team was moving in the right direction. An additional reviewer felt that the number of utilities or other organizations who expressed interest in this project was impressive.

Reviewers remarked favorably on the technical accomplishments and progress of the project including building and testing a second-generation prototype, making necessary redesigns of components, and developing baseline simulations for tuning and validation. However, reviewers expressed concern that it wasn't clear how this project would translate to meeting market goals, with one reviewer commenting that the anticipated first and second year unit sales goal was too ambitious. This reviewer warned that unexpected issues, troubleshooting, and replacing failed units over a wide geographic area could be very costly to the company.

While some reviewers praised the participation of so many stakeholders, they pointed out those who would manufacture, install, and maintain the units were so far missing. One reviewer questioned the nature of the contributions of the many advisors to the project, specifically requesting additional information on the guidance and advice they were providing. Another reviewer, however, saw all this participation as evidence of the significant interest by many stakeholders as an indication of the project's value.

While reviewers praised the strong technical capabilities and dedication to success of the project team, as well as its success to date, they warned that this is a complicated and expensive new technology. They cautioned that there is a long way to go in many areas of design, analysis, integration and modulating, reducing cost while improving durability, and carrying out demonstrations and pilot testing. One reviewer expressed concern over marketing such a novel technology in the residential heat pump, while another recommended a more cautious approach to market introduction, whereby the first 100 units in the field are carefully monitored, especially as controls and sensors have been problematic features for many HVAC and water heating products.

Weighted Average: 2.96 # of Reviewers: 6
Relevance: 3.17[1] Approach: 2.92 Accomplishments: 2.67 Project Collaboration: 3.33 Future Work: 3.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31291: Natural Refrigerant High-Performance Heat Pump for Commercial Applications

Presenter: Ricardo Carde, ReGen Power Systems
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers viewed this project as relevant and aligned with BTO goals. Reviewers were intrigued by the potential of the S-RAM compressor technology that uses air (ASHRAE number R-729) as a refrigerant and is capable of achieving 50% energy savings with a payback period under four years. They viewed this as a unique project with an excellent team involved in very innovative work, with an air refrigerant system that looks very promising for improving efficiency and reducing energy usage.

However, noting that the project is still in an early stage and running behind schedule (valve development has been underway for 8 years), reviewers expressed concern that the technology (including the regenerator) has not yet been successfully tested with efficiency predictions yet to be verified. Instead, they noted the focus still on overcoming the market barrier of developing a suitable compressor, the test stand for which is still being built at Purdue University.

Reviewers remarked that even with this market barrier being addressed, it is still very hard to see the path toward commercial application of this technology and wondered if it would be configured with carbon dioxide (CO_2) or air cycles in real-world applications. Another reviewer said that the approach had not been described in enough detail during the presentation to assess, but that overall the project team seems to have things under control.

Reviewers also expressed concern that the project was heavy on institutions helping develop the technology and short on industry partners that will be needed to move ahead with commercialization. One reviewer said that the technology is still not ready to be shared with manufacturers. Another wondered how “manufacturable” is the compressor/expander system since that would influence its cost-effectiveness.

Looking ahead, reviewers said compressor and cycle testing is the critical next step and will help determine the best applications for this system. Reviewers expressed hope that the focus would be on component testing and heat pump system testing to ensure reliability and manufacturability. One reviewer said that DOE should consider this a high-risk technology that does not presently have a widespread effective application and that the listed applications should undergo vetting to settle on initial ones. The reviewer suggested an application in heat recovery chillers.

Weighted Average: 2.90 # of Reviewers: 6
Relevance: 3.67[1] Approach: 2.84 Accomplishments: 2.92 Project Collaboration: 2.92 Future Work: 3.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31293: ORNL- High-Performance Refrigerator Using Novel Rotating Heat Exchanger

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

Brief Summary of Reviewers Comments

Reviewers differed in their ratings of the relevance of the project. One reviewer was very enthusiastic about it, rating as outstanding the relevance to BTO's goals of energy efficiency improvements, praising the 12% efficiency improvement with 3-year payback goals as a significant advancement in appliance performance, and with good progress and appropriate future work for a promising and "solid technology. However, another reviewer was deeply skeptical of this project's goals, on the basis that such a 12% improvement can only come with a significantly more complex system, and remarking that in a typical refrigerator, the evaporator and fan are typically the simplest components. This reviewer also took issue with the project plans to replace a relatively simple heat exchanger and fan with a much more complex sealed rotating heat exchanger with air bearings that is expected to be maintenance-free for 20 years. The reviewer concluded that the complexity and risk in such a system may not be amenable to refrigerator manufacturers.

Reviewers disagreed on accomplishments to date, with one reviewer commenting that the complications of this system for defrosting and system reliability likely will not be addressed with a single working prototype and that it was unlikely any manufacturer would want to move forward with commercialization. But another reviewer viewed the technical achievements favorably and concluded that the team identified several lessons learned even as it moves forward in a good direction.

Regarding collaboration, two reviewers found the partnership between two DOE national laboratories (Oak Ridge and Sandia) and the University of Maryland to be robust and appropriate to date, while a third claimed that the project needs a refrigerator manufacturer to emphasize simplicity and system reliability.

In assessing the project, one reviewer identified no major weaknesses but only minor technical issues that need to be addressed, such as ensuring baseplate design allows for good heat transfer and refrigeration distribution. Other reviewers expressed some concerns, with one commenting that the project seems to be a continuation of previous work with planned activities failing to show strength. This reviewer recommended the project team explain succinctly the new concept and why it is worth funding. A third reviewer claimed that the whole concept replaces a simple system with an overly complicated one for only modest efficiency gains, and in which no refrigerator manufacturer seems to have any interest. This reviewer urged the project team to try to find one before completing the prototype.

Weighted Average: 3.07 # of Reviewers: 3
Relevance: 3.33[1] Approach: 3.33 Accomplishments: 3.17 Project Collaboration: 2.67 Future Work: 2.67

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31294: A Combined Water Heater, Dehumidifier, and Cooler

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

Brief Summary of Reviewer Comments

Reviewers gave this project, on average, moderately good scores, judging it to embody a good idea with a solid plan from which a lot could potentially be learned. Reviewers commented that good progress has been made to date. One reviewer suggested that the absorption system should be evaluated as a viable option for residential applications. Reviewers also stated that the project was relevant to BTO's goals, in particular, doubling the water heater energy factor from the current 0.62 to 1.3.

One reviewer noted that there is a substantial existing water heater market for which this technology can be deployed given that there are currently no gas-fired water heat pumps on the market. A reviewer commented favorably on the use of a membrane-based absorption technology, but another expressed concern about the size of the system and cost, noting that the project team did not compare the design to those that are presently on the market or soon will be, nor did the team show a schedule.

The project scored well on accomplishments and progress, with one reviewer noting the team has developed capabilities to measure a range of criteria (e.g., thermal conductivity, capacity, heat of absorption, density, viscosity, etc.) and another one observing that a demonstration has been built with an energy factor of 1.2 having been achieved. This reviewer also listed as a project strength the development of ionic liquids and other absorption technology. However, a third reviewer said that while good progress has been made, it would be a surprise if the project team completed the work by November since this is a complicated flow system with complicated heat transfer processes.

Regarding collaboration and integration, one reviewer noted that there was no mention of industry collaboration but only "continual" communication. Another reviewer expressed concern over the lack of manufacturers involved in the project because absorption systems for residential applications are generally not well-received owing to size, cost, and complexity.

While proposed future work was generally viewed favorably – with one reviewer calling it "logical and on track" in the steps to be completed, another reviewer said the schedule is "overly ambitious" given the November end date.

Reviewers recommended more industry involvement, as well as an HVAC company, in order to provide useful inputs on practical constraints on cost and size targets before the design gets too far along.

Weighted Average: 3.20 # of Reviewers: 3
Relevance: 3.00[1] Approach: 3.34 Accomplishments: 3.50 Project Collaboration: 2.33 Future Work: 3.33

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

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

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

Brief Summary of Reviewer Comments

Reviewers agreed that air conditioning is a major energy user in the U.S. and this project represents an opportunity for significant energy savings relevant to BTO's goals. Reviewers were generally dubious to potential energy savings from this technology due to its early stage in the development cycle, while feasibility and potential still remain theoretical.

Reviewers noted that the rotary vapor compression cycle (RVCC) technology being developed is not a new concept, but has been around "for several decades," although one reviewer described this effort as one of the larger efforts so far. One reviewer described the project as fundamental research, with the project team attempting to establish feasibility. Reviewers noted good initial investigation results with identification of a research area, namely, the effect of centrifugal and Coriolis forces on refrigerants in a rotating heat exchanger. One reviewer said it "might be warranted" to explore using very low global warming potential (GWP) refrigerants.

Another reviewer offered the technical criticism that the project team has only looked at the "easy parts so far [air side heat transfer]" while not yet addressing the compressor side and expressed little confidence that a working prototype could be developed by the September 2016 time frame described in the presentation. One reviewer recommended the project team bring in a vapor-compressing cooling systems manufacturing partner for the prototype design phase of the work, especially given outstanding questions of economical manufacturing. Overall, the project received generally good marks for integration and collaboration with good research organizations involved and appropriate partners at this stage of development.

For future work, while one reviewer believed the team has a well-developed plan for the next six years of research, another feared the team has "seriously underestimate[d] the difficulties they will face in addressing the refrigerant side of the problem" and expressed skepticism that this will be done within the budget or current timeframe.

Weighted Average: 3.09 # of Reviewers: 4
Relevance: 3.25[1] Approach: 2.88 Accomplishments: 3.13 Project Collaboration: 3.25 Future Work: 3.25

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31296: Higher Efficiency HVAC Motors

Presenter: Steve Nichols, QM Power
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed that improving the efficiency of motors in the ¼ to 1-horsepower range are relevant to BTO's program goals, especially since motors are a significant user of energy. One reviewer specifically noted that the project's approach to improving the electronics of an electronically controlled motor (ECM) by reducing energy draw once the motor reaches synchronous speed aligned with BTO's energy efficiency goals. While one reviewer noted that the project team indicated primary energy savings from the motor in commercial and residential systems, another reviewer noted the project did not explicitly explain their efficiency goals so it could not be determined if the project meets BTO's targets. Reviewers recommended that in future presentations, the project team should show more details including project elements, specific objectives, previous milestones and deliverables, and metrics for measuring the value of efficiency improvements of the technology.

Reviewers generally questioned the project's approach and accomplishments due to a perceived lack of information on the project's ability to address market barriers, performance data to date, and specific goals and target information. Specifically, reviewers noted that without a prototype, there was no data from which to judge design or performance to date. Another reviewer noted that HVAC industry motors already have quite high efficiencies so this efficiency issue does not represent a bottleneck. One wondered why, in an era of variable frequency drives (VFDs), would money and time be spent on a project to develop an ECM with five speed/torque-controlled speed settings. Another commented that various standard design issues such as motor requirements for torque, reliability, and UL approval were not addressed.

Reviewers also expressed some uncertainty over what is the ultimate purpose of this effort with one reviewer remarking that it is "confusing to understand what is to be accomplished – is it a novel design concept or a control problem which entails variation of motor speed?" Reviewers recommended the project team should clearly identify which aspect this project is intended to resolve. One reviewer also made the observation that the project will address part-load issues through variation of speed and that efficiency drops during part-load are "serious challenges," but that "the project is not presented as such."

Reviewers favorably rated this project's collaboration approach, with one reviewer saying Carrier and UTRC are "solid and key industry partners to help develop and deploy this technology," though another felt UTRC's input was unclear from the presentation. One reviewer recommended that BTO should clarify if the technology developed under this project will be limited to Carrier products only.

Reviewers positively rated the project's future work plans to complete prototype fabrication, conduct testing, and demonstrate the technology in the field. Reviewers pointed to QM Power's past BTO demonstration projects, which they thought could be a positive indicator for this project. One reviewer recommended the team document any cost premiums from this motor.

Weighted Average: 3.05 # of Reviewers: 4
Relevance: 3.00[1] Approach: 2.75 Accomplishments: 3.13 Project Collaboration: 3.25 Future Work: 3.25

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31297: Novel Ultra-Low Energy Consumption Ultrasonic Clothes Dryer

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

Brief Summary of Reviewer Comments

Reviewers generally agreed that the concept of the ultrasonic clothes dryer was a great idea that "could be a disruptive technology" and "can radically advance clothes dryer technology and energy savings," which has so far been well-developed and executed. Reviewers noted that the project fit well within BTO's goals of reducing energy use and, if successful, could result in an appliance more efficient than any currently on the market. Reviewers noted that the barriers encountered by the research team, such as amplification and synchronizing the nested piezoelectric units, were to be expected of cutting edge technologies. One reviewer noted the new technology offered an opportunity to radically reconfigure dryer design given it does not need to rely on conventional drum design.

Reviewers agreed the team was working well with its academic and industry partners, though one reviewer questioned if the impact on the industry partners' conventional appliance sales had been considered.

Reviewers disagreed on project accomplishments and impacts to date. While some reviewers praised the research strategy and demonstration results to date, others were doubtful that the results indicated the technology could be successfully scaled up. In particular, one reviewer noted the discrepancy in results reporting, citing that the presentation reported- a drying time of a 14-square inch piece of fabric alternatively as 14 seconds or 7.5 minutes in the course of the presentation. Given the 7.5 minute drying time for such a small fabric sample, there was doubt the technology could be scaled up to handle large clothing loads. Another reviewer questioned the capability of the technology to handle complex, multi-layer fabrics – a requirement this reviewer said was key to convincing skeptics of the technology.

Similarly, reviewers noted that while the original project plan called for full-scale prototype testing to begin in December 2015, it appeared the project team was still working on fundamental concept development issues. It was unclear to reviewers when a full-scale working prototype would be developed. Reviewers generally thought the research team needed to demonstrate the technology's ability to work across larger clothes loads and fabric types to give the community a better idea of its full-scale applications.

Weighted Average: 3.27 # of Reviewers: 3
Relevance: 3.34[1] Approach: 3.33 Accomplishments: 3.33 Project Collaboration: 3.33 Future Work: 2.67

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31298: Novel Energy-Efficient Ventless Thermoelectric Clothes Dryer

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

Brief Summary of Reviewer Comments

Reviewers strongly agreed this project was highly relevant to BTO's goals of reducing energy consumption from clothes dryers as stated in BTO's 2016 - 2020 Multi-Year Program Plan (MYPP). Reviewers pointed to the performance targets of this new technology matching the goals set out in the MYPP with a target of an energy factor (EF) of at least 6 and energy savings of 40%, which represents significant savings over conventional electric resistance dryers. Multiple reviewers commented that the project appeared promising in offering improved efficiency at a reasonable cost point that could encourage pickup in the market.

Reviewers agreed the project approach was "solid," in the words of one reviewer, with the project team recognizing technical and market barriers and utilizing an approach to mitigate those factors. One reviewer specifically praised the project team's effort to encompass thermoelectric technology into the current dryer footprint in a way that is not a "radical departure" from current technology. Reviewers favorably rated the project on its prototype and associated experimental data, as well as the project team's modeling work.

Reviewers pointed to improvements, independent of this project, in thermoelectric technology gained from moving to a polymer substrate (away from a ceramic substrate) that would help this project achieve its desired goals. One reviewer did caution that the incremental first cost impact from the thermoelectric technology remains to be seen, which could have a major impact on meeting its cost goals.

Reviewers praised the partnership between Oak Ridge National Laboratory (ORNL) and Sheetak, though one reviewer worried that with Sheetak participating in multiple DOE projects and being a small business, their resources may be stretched such that attention to each project may be limited. Other reviewer comments focused on the need to involve appliance manufacturers in this work.

Reviewers remarked that controls, performance, and design improvement work plans were in place for future work, with one reviewer saying "the next phase of work is warranted." However, without a manufacturer on board, reviewers worried that future commercialization opportunities for this technology are limited.

Weighted Average: 3.30 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.33 Accomplishments: 3.50 Project Collaboration: 3.00 Future Work: 3.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

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

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

Brief Summary of Reviewer Comments

Reviewers agreed that improving efficiency in clothes dryers represents a major opportunity for energy savings in the United States. Reviewers noted the proposed energy factor (EF) targets for this efficient ventless closed-loop clothes dryer using advanced infrared (IR) heating and an electrostatic precipitator (ESP) are higher than current resistance dryers, but lower than some of the better performing heat pump dryers currently available on the market.

Reviewers disagreed on the strength of the project approach, specifically on if market barriers were clearly approached – with some arguing key barriers were addressed and others disagreeing. One reviewer specified that while market barriers are addressed by virtue of the proposed EF increase, the improvement is such that market cost increase must be small compared to the better-performing heat pump dryers and there were a number of commercialization barriers that might make it difficult to beat the cost point of those existing appliances – especially given the goal of a 5-year payback period. Another reviewer said the whole approach is simply too complex and that the system has "little chance in even approaching [the] milestone target."

Reviewers agreed that the project accomplishments to date did not look promising. Reviewers noted that while water extraction using the proposed technology has been demonstrated, the delivered efficiency of that method is below the milestone target of 40% extraction efficiency at only 7.3%. Reviewers also noted the ESP/exchanger efficiency had only reached efficiencies of 13%. Reviewers pointed to potential mechanical issues that could further reduce the efficiency once in place in residential systems given the dust and lint typically found in most clothes dryers, including the potential for clogging in the submicron spray head, the possibility of arcing in the precipitator, and build-up in the precipitator water collection area leading to reduced system performance (and maintenance).

This project does not have any partners outside GE, leading to low collaboration scores. While some pointed to the benefit of working entirely in-house, specifically the ease in this technology entering their product line, others worried that corporate decision makers could stop work on this effort at any point. Others believed collaboration with a national lab on this pre-commercialization work could have been beneficial.

Reviewers pointed to several technical challenges that need to be overcome in future work, including the optimization of nebulizer parameters, solving the arcing issues, and improving the efficiency of water extraction. However, many doubted the solutions presented by the project team would be able to resolve these issues completely. Additionally, other reviewers were unclear if this technology solution was the most promising avenue for clothes dryer energy efficiency improvement, pointing to other emerging technologies such as ultrasonic and thermoelectric that might be a better fit for the operating conditions of clothes dryers.

Weighted Average: 2.58 # of Reviewers: 4
Relevance: 3.00[1] Approach: 2.75 Accomplishments: 2.38 Project Collaboration: 2.63 Future Work: 2.75

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 312103: Miniaturized Air to Refrigerant Heat Exchangers

Presenter: Reinhard Radermacher, University of Maryland
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers characterized the development of miniaturized heat exchangers (HXs) as critical to BTO's program goals and fundamental in supporting performance improvements across a wide range of energy-consuming devices such as heat pumps, air conditioners, refrigerators, and water heaters. As a fundamental research project, reviewers noted it was difficult to rate them on market barriers as the focus was on optimizing design to enable new manufacturing and overcoming fundamental knowledge barriers.

Reviewers were impressed by the project's progress to date, including the fact the project team had analyzed over 15 HX geometries, developed multi-scale modeling and optimization methodologies, developed a system-test facility, and fabricated both 1-kilowatt (kW) and 10-kW prototypes. One reviewer was concerned that the configurations were mechanically sound or could sufficiently address air or hydronic contamination issues, though reviewers were otherwise generally optimistic about the tube's shapes and flow patterns findings might be applied to practical products. One reviewer was confused if additive manufacturing had been abandoned in place of assembling individual tubes. Some reviewers noted it was unclear if there has been sufficient dialogue across the project team to actually enable viable products and applications. Despite these misgivings, reviewers generally praised the project's teamwork and collaboration, especially with industry partners, whom reviewers felt had a solid understanding of the problem and how to best approach it within the budget. Reviewers also praised the project team's publications in open literature.

Reviewers recommended that the project consider the volume of physical materials used for this type of HX, citing the sensitivity of manufacturers to the price of copper. Another recommended DOE and stakeholders develop minimum mechanical and fluid constraints for the test modules. Other reviewers recommended that the project team should consider durability issues more, focusing on physical environmental and contamination potential of miniaturized HXs and ensuring miniaturized designs would be able to tolerate the abuse that conventional HXs undergo and would not be more susceptible to environmental contaminants.

Weighted Average: 3.33 # of Reviewers: 6
Relevance: 3.67[1] Approach: 3.25 Accomplishments: 3.25 Project Collaboration: 3.67 Future Work: 3.17

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 312104: High Performance Commercial Cold-Climate Heat Pump (CCCHP)

Presenter: Ahmad Mahmoud, United Technologies Research Center
DOE Manager: Tony Bouza

Summary of Reviewer Comments

Reviewers rated this project highly relevant towards BTO's goals, citing the need for high-performance cold-climate heat pumps and the project performer's close relationship to an original equipment manufacturer (OEM) capable of building market share in the area. Because of this close collaboration with Carrier, reviewers were positive about the potential for commercialization – though a few were unclear if this partnership was sufficient for DOE's teamwork and collaboration purposes. Reviewers were also generally approving of the project team's approach, specifically praising the iterative design steps, attention to overcoming market barriers, and utilizing a realistic approach to the issue of needing to raise the supply air temperature in cold weather. However, one reviewer was unclear what the project's baseline target was competing against (gas or electric heat) while another said that while the project appears to be addressing certain market barriers, the proprietary nature of so much of the project made it all a "black box" in terms of evaluating performance testing.

Reviewers praised the project in meeting or exceeding BTO's coefficient of performance (COP) and capacity targets. These accomplishments were marked among project strengths that give it "an excellent path to production and marketing." However, one reviewer said the lack of description of the technology made it difficult to determine the likelihood of success or degree of accomplishment. Reviewers recommended that field test results be presented at a future meeting and suggested an electric utility company comment on system performance under extremely cold conditions (-10°F) to determine whether this contributes to winter peak loading due to resistance heating coming on at that temperature, which in turn could affect customer demand charges.

Reviewers noted that proposed future work would be focused on production, marketing, and distribution. One reviewer noted that during the presentation, the principal investigator (PI) suggested that a very different design is now being pursued than was developed earlier in the project. Another took issue with the proposed cost-cutting to reduce the payback period to less than one year, arguing a two-to-three-year payback for commercial applications was sufficient. Cost-cutting to meet the return on investment (ROI) criterion was marked as a project weakness because it could degrade efficiency and durability. Still another said that more attention should be paid to defrosting at low ambient temperatures.

Weighted Average: 3.19 # of Reviewers: 5
Relevance: 3.60[1] Approach: 3.30 Accomplishments: 3.20 Project Collaboration: 3.20 Future Work: 2.80

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 312105: Low-Cost Gas Heat Pump for Building Space Heating

Presenter: Michael Garrabrant, Stone Mountain Technologies, Inc.
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Most reviewers agreed this was relevant for BTO's goals, with several commenting on its potential to reduce energy consumption and achieve market penetration for residential-scale gas-fired absorption heat pumps given the presented two-to-five year payback period and technical specifications, design simplicity, and volume manufacturing requirements. However, one reviewer noted that comparisons to standard heat pump technology overstate the savings by not considering the improved efficiencies of the latter; while lower sales prices on gas-fired heat pumps have dropped, the requirement for more indoor components renders cost-effectiveness uncertain.

Reviewers were generally positive on the project's adherence to four basic elements, the design approach focused on cost-and reliability optimization, and the participation of major gas industry players such as A.O. Smith and Gas Technology Institute. However, one reviewer was concerned that the project's lack of cooling results in additional cost to the consumer, resulting in an expensive full home conditioning system potentially significantly above the $4,500 target price. Reviewers commented that while prototypes have been developed and tested, there were doubts that the efficiency targets and cost objectives could be met in the market. One reviewer commented that with unit performance looking promising, the unit sales would need to become very substantial before the cost objective could be met.

Reviewers generally viewed the project as having high value deliverables to the target audience, success in reaching performance goals, success in creating a marketable product, and good alignment with BTO program goals. However, one reviewer recommended that there be no further funding of this or similar projects due to cost and a lack of savings over electric alternatives; with the increased penetration of renewables, they argued, the technology's greenhouse gas source reductions vanish.

Most reviewers were pleased with the project's beta testing plans and were hopeful the company could help the product find its way into the market without future DOE funding. One reviewer recommended that while the project has collaborated with existing players in the gas heat market, future collaboration with new players such as builders in cold climates and air handler/water heater manufacturers might help develop a more realistic approach to market entry. Reviewers also recommended the project team consider emphasizing issues of serviceability to improve market entry and fully addressing defrosting control. Specifically, they recommended giving special attention to defrosting at low outdoor temperatures and observing worst-case defrost cycles.

Weighted Average: 3.38 # of Reviewers: 6
Relevance: 3.50[1] Approach: 3.25 Accomplishments: 3.42 Project Collaboration: 3.50 Future Work: 3.33

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 312106: High Efficiency Low Global-Warming (GWP) Compressor

Presenter: Frederick Cogswell, United Technologies Research Center
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this HVAC project focused on refrigerants was relevant to BTO's goals due to its primary energy improvement goal of 30%, but one reviewer noted that given the sparse information shared on the technology it was hard to be sure. Reviewers noted the project team's approach to maximizing compressor efficiency and reliable operation under a wide range of conditions was reasonable, though again they noted the lack of specific technical information presented that might help better information project evaluation. One reviewer noted, however, that while specific global warming potential (GWP) was not disclosed, the presenter indicated the new refrigerant had a GWP reduction of 75% compared to R-410A.

This project is in its first phase and approaching an August 2016 Go/No-go review, as such many reviewers noted that there was not much to evaluate at this stage. However, it appeared to many reviewers that the project seemed to be on track and that a proof-of-concept test was scheduled for July 2016. UTRC is partnering with in-house manufacturer Carrier on this work, which reviewers thought was well planned and enabled the project team to commercialize the resulting product and that the Go/No-Go meeting would help reduce risk and improve the value proposition for Carrier.

Reviewers noted that Carrier has a long history of developing successful HVAC projects, that the team is very knowledgeable, and that the GWP target reduction of 75% is good. While one reviewer noted the lack of firm information to rate the project's accomplishments to date, another thought the presenter illustrated that the new refrigerant system design indicated energy efficiency gains and that additional savings could be gained from incorporating variable speed functionality.

The project team aims to move the technology from a technology readiness level (TRL) of 2 to TRL 5 and achieve 30% primary energy savings over the project term. Reviewers recommended that DOE staff should be provided complete access to research work – even if that means signing a confidentiality agreement – in order to project the agency's investments in such proprietary projects. Another reviewer suggested that BTO verify the 75% GWP reduction in the refrigerant being used.

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

Program Response:

DOE staff have complete access to the research work.

[1] Score not included in weighted average.

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

Presenter: Edward Bennett, Mechanical Solutions, Inc.
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that an efficient compressor capable of handling low-global warming potential (GWP) refrigerants is a key concern of BTO's, though one reviewer cautioned that previous work using centrifugal compressors for ultra-small scale has faced serious challenges that the presentation did not address. One reviewer noted that the experience of the project team and their resources should enable them to "give it a good shot."

The project team noted the key issues were efficiency, system integration, and cost with compressor efficiency greater than 78% needed. Reviewers were unable to evaluate the exact refrigerant GWP value or name, although the presenter noted in the question and answer (Q&A) session that they would be able to do so once the producer gave them the permission. The presenter specified the refrigerant was non-flammable with approximately 50% improved GWP, as that characteristic was a requirement of project partner Lennox. Overall, reviewers agreed that the project had a competent team with thorough knowledge required to develop this new technology – though one reviewer questioned how much work was shared between groups. Most, however, felt the team was equipped to handle the design challenges posed by the technology. Several reviewers questioned the 50% improved GWP figure, with some recommending DOE verify the findings and others wondering why the goal was set so low (instead of a higher figure such as 80% improved).

Reviewers were divided when evaluating project accomplishments to date, with some noting the project is on track with stated goals, others arguing some tasks are behind schedule, one saying it was too early in the process for meaningful results, and another fearing the task was not well defined and the lack of data reduced confidence that this project was a good investment.

Reviewers agreed that future work looked promising and could lead to a mature product, but several reviewers expressed concern over the lack of presented milestones and Go/No-Go decision points and worried the scope might exceed the schedule presented. One reviewer recommended the project team better explain why and how this technology will be superior to existing compressors with another noting that Lennox was involved in a similar project in the 1980s, pointing out the problems that team encountered with motor drive and gear box designs as a warning to the project team.

Weighted Average: 3.08 # of Reviewers: 4
Relevance: 3.00[1] Approach: 3.00 Accomplishments: 3.00 Project Collaboration: 3.25 Future Work: 3.25

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 312108: Membrane Based Air Conditioning

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

Brief Summary of Reviewer Comments

Reviewers agreed this project is highly relevant and well aligned with BTO's energy efficiency improvement goals, with one adding the technology looked to be the most promising competitor to conventional vapor compression systems in the near term. Reviewers noted the solid approach to packaging roof-top air conditioning technologies and increasing the technology readiness level, but some were confused if the project was truly a non-vapor compression project given the inclusion of electrochemical compression and mechanical vapor compression components.

Reviewers generally agreed that a major strength of the work is the game-changing use of membrane technology in AC applications in various climates, though some expressed concern over technical and performance issues with membrane-based systems, including fouling, reliability, performance, and cost-effectiveness. One reviewer said the system had too many energy-consuming components and another was concerned that any air leaks introduced into the system could seriously degrade performance.

The project presented at the Peer Review less than six months into the performance period, which led many reviewers to remark there had been few accomplishments to date aside from partner identification, high-level system design, and membrane dehumidification modeling. One reviewer warned that the high uncertainty in vapor compressor component may be the critical item preventing the project from achieving its stated objectives. Several reviewers were concerned cost might be a serious barrier to entry, with one reviewer noting that relatively little cost analysis data had been presented. Reviewers agreed the project team had a good mix of industrial and academic partners, subcontractors, and collaborators, though one recommended the inclusion of a large manufacturing partner of air-conditioning systems.

Reviewers emphasized that this project is very early stage technology research and development (R&D) and generally agreed that developing prototypes, undergoing laboratory demonstrations and testing, and evaluating markets were logical future plans. One reviewer proposed market evaluation and target selection be conducted prior to engineering, design, and fabrication and another one urged the project team to identify scaled-up prototype performance targets soon, and then focus on testing and providing experimental results to provide confidence in the performance and reliability levels. Another recommended the team demonstrate how particle contamination effects the long-term performance of the membrane.

Weighted Average: 2.79 # of Reviewers: 4
Relevance: 3.50[1] Approach: 2.63 Accomplishments: 2.75 Project Collaboration: 3.25 Future Work: 2.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 312109: Compact Thermoelastic Cooling System

Presenter: Ichiro Takeuchi, Maryland Energy & Sensor Technologies
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers found the project aligned with BTO's goals, although several wondered if the project's impact statement was too ambitious for such an early stage project and questioned the realism of the 50% penetration and resulting energy savings by 2025. Reviewers pointed to a large number of potential barriers facing the project, including material selection, cost reduction, and design adjustment of the "roller-belt" (including tension, compression, rollers, rods, etc.).

Reviewers noted the extensive work on this technology conducted under DOE's Advanced Research Projects Agency- Energy (ARPA-E) from 2010 to 2015 resulting in the filing of a provisional patent. The project is currently working on a Generation V prototype with simulation and testing already performed. Reviewers noted the project team appeared to have a solid understanding of the physical mechanisms and principles associated with membrane-based thermal and mass transport. Reviewers noted the project team was small at this point, but the collaboration appeared to be strong and well-defined. Reviewers recommended partnership with commercial partners, one suggested a materials supplier and another original equipment manufacturers (OEMs) or HVAC manufacturers, to provide cost-favorable design insights.

Reviewers warned of the challenges associated with measurement accuracy (particularly concerning brush thermocouples), measurement protocols, thermal capture (including parametrical optimization), the cost of materials at scale, and risk mitigation, with a few reviewers remarked the team appeared to be well aware of them and has a realistic assessment in the complexities involved in bring the technology to maturity. One reviewer recommended quantitative demonstration of the coefficient of performance (COP) would be helpful to convince others this technology is a viable path forward, with another noting the performance of preliminary laboratory systems appeared to be lower than the level expected for the target performance. Another felt that more discussion of the challenges involved in scaling up this technology would be useful; 1 kilowatt (kW) cooling power is still too small to be relevant, but scaling it up by a factor of ten in a cost effective way is a big step whose feasibility the project team should address.

Weighted Average: 2.74 # of Reviewers: 4
Relevance: 3.00[1] Approach: 2.63 Accomplishments: 3.00 Project Collaboration: 2.38 Future Work: 2.75

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

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

Presenter: William Parmelee, Xergy
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers agreed the project was well aligned with BTO's goals and that the development of an electrochemical compressor (ECC)-based system for air-conditioning applications is highly relevant for BTO's mission both by the advancement of innovative technologies and potential energy savings. Reviewers described the project team having strong teamwork and collaboration, with one noting the team is working an array of global market leaders. Reviewers positively commented on the partnership ranging from fundamental research (University of Delaware), testing and validation (Oak Ridge National Laboratory), and commercial (Haier), though one said the role of Haier was not clearly presented.

Reviewers agreed that the project team has a good grasp of the challenges facing ECC and that close cooperation with market leaders enabled the project team to identify critical barriers. Another reviewer remarked that the barriers and risks in the form of sensitivity to non-condensable gases and sensitivity to condenser and evaporator pressure were not explicitly addressed. The project's prototype design, construction, and testing generally were rated as satisfactory by reviewers, with one noting that achieving a coefficient of performance (COP) greater than 4 is a noteworthy challenge and it would be a "significant advance" if the team can do this.

One reviewer suggested it would be beneficial to provide interim evaluation steps of the experimental results during testing and provide an approached statement of work (SOW). Reviewers recommended increased testing and modeling to generate confidence with the project's performance and reliability targets across operating conditions, addressing technical risks (such as durability and operating envelope range for a fixed systems), and the long-term performance impacts from the presence of non-condensable gas (and how to mitigate it with proper sealing with consumer grade equipment). Another reviewer recommended exploring the issues of the narrow voltage range for peak COP, which could result in a substantial drop in membrane performance from variations in the power supply.

Weighted Average: 3.20 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 3.25 Project Collaboration: 3.50 Future Work: 3.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

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

Presenter: Ravi Annapragada, United Technologies Research Center
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers described the project as timely, relevant, and clearly aligned with BTO's goals, with an innovative approach that has potential for future advances. Reviewers generally believed this technology had the potential to replace current state-of-the-art using a novel approach with a comprehensive methodology. Reviewers noted the project team had identified critical barriers, both in terms of fundamental research barriers standing in the way of technology development (by focusing on module/system development) and also market barriers (such as cost and operating efficiency). Reviewers praised the in-house partnership with Carrier Corporation in providing metrics and market requirements to help mitigate risks and market barriers as it progresses.

Reviewers noted this early-stage research had successfully met its first milestones by developing and demonstrating micro-electro-calorimeter necessary to measure temperature change for electro-caloric materials. However, one reviewer noted it was unclear what other progress has been made to date, and suggested the team provide additional content or background when presenting results, especially to those not familiar with the project. Reviewers also called for additional information on the modeling approaches used to calculate the operating conditions the technology will demonstrate a coefficient of performance (COP) of 6.0.

Moving forward, most reviewers believed the work plan to be reasonable in addressing challenges such as scalability, demonstrating a COP of 6.0, and a complete heat pump module. Reviewers warned the project will face significant technological challenges to minimize system losses (e.g., energy, pressure, and electrical) and to resolve scale-up and long-term performance issues. One specifically pointed out the later-term issue to explore – namely the issue of long-term performance of the electro-caloric material, with fatigue and long-term degradation potentially resulting in compromised system performance. Another reviewer recommended system model validations to support the COP performance targets in the environmental application. One reviewer commented that the issue of proprietary information makes it difficult to accurately assess the project since so much cannot be divulged. Another recommended that the project team should provide more consideration on the influence of the external electric fields on the stable and safe performance of the system.

Weighted Average: 3.08 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.25 Accomplishments: 2.88 Project Collaboration: 3.38 Future Work: 2.75

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 312112: Magnetocaloric Air Conditioner

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

Brief Summary of Reviewer Comments

Reviewers gave the project uniformly high marks for relevance to BTO's goals, describing the project as timely and relevant. They were also generally positive in their remarks on project approach, noting that it is still in its early stages with much yet to be developed. With such an early stage project, reviewers approved of the project team's progress in reaching out to commercial partners, with one reviewer recommending engaging with a material supplier sooner to help overcome risk from magnet cost, form factor, and availability.

Reviewers noted the project had only been working for six months and that initial steps such as establishing partnerships with materials manufacturers, developing a one-dimensional (1-D) discrete model, and formulating the concept design were in support of project objectives. One reviewer said that the project team had identified as many critical barriers with these issues having been presented – such as magnet design and accuracy of machining along with the need to mitigate the effect of increased frequency on system balance. Another reviewer said that the team had designed a project to overcome the barrier of system cost, complicity, and achieving theoretical efficiency by exploring a new magnetocaloric material (MCM) architecture using solids to transfer heat.

Reviewers noted a few technical weaknesses, the cost-effectiveness and availability of the MCM and its design; refinement and validation of the thermodynamic model; and addressing technical risk from increasing frequency of system, managing friction between the rods; and the strength of the magnetic field and the losses associated with producing such a field that could offset potential increased coefficient of performance (COP) benefits of the device itself. Reviewers recommended the team provide additional experimental data to validate the modeling or provided suggested improvements to its fidelity.

For future work, one reviewer said that there are many technical risks that could prevent this project from achieving its goals and another urged the team to move forward to advance this "potentially very useful technology." Another reviewer noted that the lack of a negative effect on magnetic fields on human health should be "emphasized and strongly justified." A second reviewer suggested taking into account heat exchanger effectiveness to system performance.

Weighted Average: 2.96 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.13 Accomplishments: 2.88 Project Collaboration: 3.00 Future Work: 2.75

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 32210a: High-Efficiency, Low-Emission Refrigeration

Presenter: Brian Fricke, Oak Ridge National Laboratory
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project to BTO's goals, but one reviewer expressed serious reservations about the likelihood that this technology would have significant impact in the United States, and felt that the presentation did not make a compelling case for carbon dioxide (CO_2)-based refrigeration systems. Reviewers also generally agreed that the project's approach was appropriate, noting that taking a system-wide approach to improving efficiency and technology was reasonable, that most critical barriers had been identified and were being overcome, and that the project's program for testing the technology was well laid out.

Here too, however, one reviewer had serious misgivings, commenting that cost barriers had not been realistically addressed, and that because the system performed poorly at higher ambient temperatures it was an unsuitable technology for large areas of the U.S. One reviewer recommended that the project's modeling should take into account the full range of outdoor operating temperatures, especially on rooftops and in hot climates, as the technology's reported coefficient of performance (COP) is worse than existing systems above 90°F.

Reviewers noted that the supermarket refrigeration system being developed by this project – described as a proven technology in Europe – has exceeded the project's energy and emissions savings targets, that the project was very likely to contribute to the BTO Emerging Technologies (ET) Program's interim market goal, and that the project had accomplished much in terms of increasing component and system performance efficiencies. Other reviewers described the project's work as transformative within the limits of the market's use of the particular refrigeration system configurations, and another reviewer highlighted that the primary question at this point was how large the market penetration would actually be. One reviewer dissented with the majority, however, describing that while the project's approach to the problem was good, the results were not positive.

Most reviewers agreed that the project's future plans were appropriate, though one reviewer noted that it was unclear from the presentation whether certain milestones scheduled for the end of 2014 had been met. One reviewer commented that it was imperative for the project team to explore system limitations and efficiencies across the full range of operating ambient temperatures, but noted that this would be supported through field testing.

Reviewers unanimously agreed on the strength of the project's collaborations and partnerships, commenting that the project had demonstrated an excellent level of understanding of key stakeholders, and also had assembled an impressive number of interested industrial partners.

Weighted Average: 3.38 # of Reviewers: 6
Relevance: 3.67[1] Approach: 3.17 Accomplishments: 3.34 Project Collaboration: 3.75 Future Work: 3.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 32210b: Magnetocaloric Refrigerator

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

Brief Summary of Reviewer Comments

Reviewers disagreed on the relevance of the project to BTO's goals. One reviewer expressed that the development of magnetocaloric refrigeration technology was very relevant to BTO's program goals. However, a different reviewer felt that the project was not yet sufficiently developed to determine if the technology could be successful overall, while another commented that current ENERGY STAR refrigerator energy use was so low that this project's technology would have to have minimal incremental cost relative to traditional compressor systems to achieve market penetration. Another reviewer noted that the project report had focused on the manufacture of magnetocaloric heat exchangers, whereas it presented little evidence that an energy efficiency improvement can be reached.

Though one reviewer identified this technology as one of the most promising and innovative being investigated, others felt that a path to commercialization was not being sufficiently pursued. One reviewer commented that they had been presented with information only on manufacturing work, rather than performance data, so any market barriers related to efficiency were not addressed. Another described that because the project had focused primarily on getting the cooling output targeted, there were a whole lineup of potentially new barriers that might need to be addressed. Finally, one reviewer noted that while a compressor had been eliminated, there would still be a power supply, valves, and pumps that might have reliability issues.

Regarding the project's accomplishments, one reviewer described the magnetocaloric science as being well demonstrated and advanced, but warned that it was too early to know whether the science and technology could be implemented in a marketable and reliable product. Other reviewers echoed this warning, noting that there was still work to do to show that interim market goals could be achieved with such a different approach, and that there were a number of other issues and obstacles that had to be resolved, some of which likely had not yet been identified.

Numerous reviewers agreed on the importance of the project team's collaboration with GE, describing this partnership as wise, significant, and highly appropriate. However, one reviewer expressed misgiving regarding the broader collaboration environment, describing that it was not clear where there was an effective dialog with the industry that would have to adopt this technology. This reviewer recommended taking a more holistic approach to integration and collaboration could prevent the project from going down a dead end.

In terms of the project's ongoing work plan, one reviewer commented that the project's future work on manufacturing was appropriate, whereas another reviewer was worried that implementation of the technology into a product was not part of the current project. One reviewer commented that major steps and milestones were still to be undertaken, while another recommended broadening the project scope so that a more complete evaluation of the technology's viability could be made. Similarly, another reviewer asked to see a more in depth analysis of the practicality of the overall technology package, so that a preliminary analysis could be made on the likelihood of meeting performance and cost-effectiveness program goals.

Weighted Average: 2.75 # of Reviewers: 5
Relevance: 3.00[1] Approach: 2.70 Accomplishments: 2.50 Project Collaboration: 3.30 Future Work: 2.80

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 32212: High-Performance Cold-Climate Multi-Stage Heat Pump

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

Brief Summary of Reviewer Comments

Reviewers agreed that this project was relevant to BTO's mission and goals, both in terms of its advancement of innovative enabling technologies as well as its potential for energy savings. One reviewer noted, however, that despite its potential success in these arenas, the project did not address the more recent goal of moving to low-global warming potential (GWP) working fluids.

In terms of approach, reviewers described the market barriers being addressed as first cost and operating cost, as well as cold-climate heat pump operations. One reviewer remarked that the project team had identified these critical market barriers, assessed them quantitatively, and had oriented the product research and development appropriately. However, a different reviewer noted that barriers related to delivered-air temperature and thermal comfort were not addressed, while another felt that it would have been helpful if actual dollar amounts had been included for cost, both for the project's developed technologies as well as for its competition (e.g., variable speed systems). In addition, one reviewer commented that the project laboratory and field testing methodologies should have been elaborated in more detail in order to justify the project's claimed benefits.

For accomplishments, reviewers noted that prototype testing had confirmed a 40% reduction in daily energy use at the coldest conditions, and that a coefficient of performance (COP) of greater than 2 had been achieved. Reviewers described that all test prototypes demonstrated compliance with established project goals, and felt that additional data from an upcoming Alaska field test would help further verify progress. Although technology advances were largely incremental, reviewers felt that the results were still significant, and might provide the bump in efficiency to make heat pump systems more attractive to the U.S. market. One reviewer noted that there were still some cost-effectiveness challenges, while another commented that the team should try to further isolate the contribution of the heat pump to observed declines in utility bills.

Reviewers described the broader project team – led by Oak Ridge National Laboratory (ORNL) – as being quite impressive and including all necessary expertise and experiences, with one reviewer commenting that the project had identified and was working with key stakeholders. One reviewer thought that the role of these stakeholders should have been more clearly defined so as to better understand project coordination, while another felt that it would have been interesting had the project team engaged with other stakeholders, including system integrators, other heat pump manufacturers, and electric utilities.

Looking forward, reviewers thought that the project was nearly complete, and that final field testing data should provide a satisfactory conclusion and assessment of the project's ability to achieve its stated goals. Reviewers also agreed with the project's follow-on commercialization activities. One reviewer wanted the project team to further clarify the criteria used during the comparison of the proposed system against existing cold-climate heat pump units, while another reviewer recommended engaging certification bodies in the testing process to avoid possible re-designs. Finally, one reviewer noted that it might be valuable to investigate if lessons learned here could be applied to low-GWP refrigerant systems.

Weighted Average: 3.34 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.38 Accomplishments: 3.25 Project Collaboration: 3.38 Future Work: 3.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 32218a: CO_2 Heat Pump Water Heater

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

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's program goals, both in terms of advancing an innovative enabling technology as well as the technology's potential to lower energy consumption while reducing use of high-global warming potential (GWP) fluids in HVAC/water heating systems. Reviewers also generally agreed on the appropriateness of the project team's approach, with one highlighting that the project team had identified critical market barriers, assessed them quantitatively, and oriented the product research and development accordingly. One reviewer did feel that the project focused on cost – specifically developing carbon dioxide (CO_2) heat pumps at a price point that was viable for the U.S. residential market – at the expense of other relevant barriers to the technology. In addition, this reviewer felt that no information was provided regarding experimental or analytical work on balance-of-plant, whereas the reviewer felt that significant cost reductions and energy improvements could be realized in other components (e.g., suction line, heat exchanger, compressor, valves, controls, etc.).

Reviewers identified four main accomplishments to date, including the simulation, selection, fabrication, and evaluation of a design. However, many reviewers noted that while the project appears to have met many targets in terms of cost and performance, the presentation was nearly identical to a presentation given in 2014; reviewers felt that it was not clear what accomplishments or progress has been made over the past two years. Reviewers recommended that, in the future, the project team should make clear the distinction between past and current project activities.

Reviewers lauded the project team's extensive integration activities, including their publications, presentations, and technical/business communications, and highlighted that the project's partnership with GE Appliances was particularly attractive for commercialization of the technology. One reviewer felt that GE's role was unclear, however, while another commented that partnerships with HVAC original equipment manufacturers (OEMs) would have been valuable.

Reviewers highlighted that a majority of project work was complete, and that a clear path for future work had been set, to include the final uniform energy factor (UEF) evaluation and final reporting. Reviewers offered several recommendations as the project moved towards closing, including to (1) consider preparing journal papers based on the results, so that others in the community could learn from the research efforts; (2) **e**ngage certification parties into the final UEF testing to avoid possible re-designs during certification; and (3) use the final report to clarify some of the selection criteria for the final system design, as well as to identify the main drivers for the final system realization (efficiency, cost, low GWP, reliability, safety, etc.).

Weighted Average: 3.09 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.13 Accomplishments: 3.00 Project Collaboration: 3.13 Future Work: 3.25

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 32218b: Commercial Absorption Heat Pump Water Heater

Presenter: Patrick Geoghegan, Oak Ridge National Laboratory
DOE Manager: Tony Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance and alignment of this project to BTO's program goals, highlighting that water heaters make up a significant portion of the energy consumption for some commercial building types. Reviewers were mixed on the project's approach, however. Some reviewers described the project's approach as very worthwhile and a well-chosen first effort, while others felt that relevant and important market barriers were not discussed, including first cost, constraints related to building layouts, and maintenance/service issues. Another reviewer felt that it was not reasonable to assume that the project's efforts would encourage entries into the market, a consequence of the technology's high cost relative to its modest reductions in energy use. In addition, one reviewer expressed a desire to see the efficiency measurement and rating process reexamined, specifically looking at whether the proposed system's booster tank would be an integral system component, and therefore would need to have its performance considered as part of the system's efficiency.

In terms of progress, reviewers agreed that the project had provided a good demonstration of technology, with one reviewer commenting that the project's alpha test showed good performance approaching target levels, while another commended the project team for testing to outdoor temperatures as low as 8°F. One reviewer cautioned, however, that a big barrier that would need to be overcome to achieve market goals was the fragmentation of the market in terms of equipment sizes required for different applications. Another reviewer pointedly commented that the envisioned product would likely not save substantial energy, and was therefore unlikely to achieve any meaningful market penetration.

Reviewers generally agreed that the project offered a good demonstration of collaboration with partners, including A.O. Smith and SMTI, which together have provided component and system design, fabrication, testing, testing support, market research, and cost share. Despite the collaboration that was present, however, one reviewer felt it was hard to see how the project would result in a successful product given the absence of engagement with the maintenance and repair community.

Reviewers agreed that an appropriate work plan was presented for the project moving forward. However, reviewers did offer numerous recommendations for additions or adjustments that the project team should consider for future work including (1) that future work should field test several monitored units in different applications, to help discover operating conditions that were not anticipated; and (2) that attention should be paid to how the unit defrosts its outdoor coil during cold weather operation, as defrost controls can get complicated. One reviewer also recommended the project should be completed as soon as possible, so that the results can be made public to the gas appliance community for any further action on this community's part.

Weighted Average: 3.11 # of Reviewers: 6
Relevance: 3.33[1] Approach: 2.92 Accomplishments: 3.25 Project Collaboration: 3.17 Future Work: 3.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

EMERGING TECHNOLOGIES
WINDOWS & BUILDING ENVELOPE

Project # 30001: Certification and Rating of Attachments for Fenestration Technologies (CRAFT)

Presenter: Ralph Vasami, Window Covering Manufacturers Association
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers found this project to be highly relevant to BTO's building energy efficiency goals and they favorably judged its approach in identifying critical market barriers. However, a number of reviewers expressed concern that the project had too much focus on a marketing and business model to promote the certification and rating system for window attachments and a lack of a well-grounded technical approach required to develop such a system. At issue is the need to have a standard method to evaluate, rate, and compare window attachment product performance. One reviewer attributed the slippage of project goals to the difficulty of achieving consensus in a fragmented industry.

Several reviewers expressed concern that the project has yet to realize the necessary technical achievements to create a methodology that makes the certification program a reality. Instead, they noted, the achievements have focused on forming an organization and outreach to stakeholders to increase awareness of window attachments as an energy savings measure. One reviewer expressed concern that the ultimate goal of the project – launching a certification program – could take some time.

Reviewers gave the project high marks for integration and collaboration, remarking favorably on the strong and diverse public-private collaborative efforts bringing together manufacturers, public interest groups, and others. In terms of weaknesses, reviewers pointed to the challenges of developing a nationally effective organization and lack of a technical approach and methodology to date for a certification that would allow for better targeted marketing and solutions.

Looking ahead to project future work, reviewers said the planned publicly-available website and database would be of great value. However, owing to the lack of specific steps for technical effort, one reviewer said there is a need for testbeds or small pilot projects to help verify and improve the certification system. Other reviewer recommendations were to conduct simulation modeling and experimental testing to ascertain and compare product performance and to bring the technology team more actively into the project.

Weighted Average: 3.06 # of Reviewers: 7
Relevance: 3.86[1] Approach: 3.00 Accomplishments: 2.93 Project Collaboration: 3.50 Future Work: 2.86

Program Response:

The primary weakness identified by the reviewers centers on the lack of a technical approach for the rating system. While it is well-taken that the presentation by the Window Covering Manufacturers Association (WCMA) would have benefited from a discussion regarding the method by which the technical approach is being developed, Lawrence Berkeley National Laboratory (LBNL) is principally responsible for that aspect of the project and presented separately at the Peer Review on its work plan and achievements thus far. LBNL's scope of work includes many of the activities (e.g., modeling and empirical evaluation/validation) that reviewers identified as important to the development of a robust certification and labeling methodology.

[1] Score not included in weighted average.

Project # 30004: Building Integrated Heat and Moisture Exchange

Presenter: John Breshears, Architectural Applications
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

While reviewers were intrigued by this energy recovery ventilator (ERV) technology integrated directly into a building's envelope (as wall components) rather than within a central HVAC system, they repeatedly expressed real reservations about the likelihood of widespread market penetration. Reviewers cited the enormous architectural and mechanical issues that would have to be addressed before such a technology would be widely accepted. They also expressed concern about the likely higher cost of manufacturing an array of ERV panels as wall components and questioned why such a technology would be better than centralized ERV integration within a building's HVAC system.

Among the technical issues that reviewers raised about this ERV technology was the relatively high pressure drop through the units and the effect on market acceptance as a result of fan noise caused by the high air flow of 200 cubic feet per minute (cfm) through the units. (During the question and answer (Q&A) session, the presenter said the goal was to reach 300 cfm). Another reviewer commented that it was not clear whether performance deterioration would occur as a result of particulate deposition from the air streams and, if so, how this would be cleaned.

It was also noted that this wall component-based ERV technology would be more effective in warm and humid climates rather than colder climates. (During the Q&A session, the presenter stated the focus has been on climates where there is a need for dehumidification). A reviewer commented that it was difficult to see how this technology could achieve sufficiently high performance and market penetration to meet BTO goals. These concerns were compounded by the fact that the project is due to conclude soon without having addressed these issues.

Reviewers were pleased with the amount of collaboration and coordination with stakeholders in academia and industry since the radical nature of this new ERV approach represents a challenge to its acceptance.

The project received its highest marks on proposed future work given that this involves demonstration of manufacturing the units at target cost, completing needed product certifications, and building a sales pipeline. One reviewer suggested the principal investigator (PI) work directly with a hands-on designer and construction crew to explore actual implementation details. Another reviewer concurred, saying that such real-life testing will be critical to determine if this ERV technology will be successful, especially at the office building scale.

Weighted Average: 2.80 # of Reviewers: 6
Relevance: 2.83[1] Approach: 2.83 Accomplishments: 2.58 Project Collaboration: 3.00 Future Work: 3.17

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31397: Bio-based, Noncorrosive, Nonflammable Phenolic Foam Insulation

Presenter: Jan Kosny, Fraunhofer USA
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers strongly agreed on the relevance of this project to BTO's goals, describing the project's objective of developing new bio-based phenolic foam thermal insulation materials as being well aligned with both BTO's goal to improve buildings' energy efficiency and the Windows and Building Envelope Research and Development (R&D) Roadmap.

Reviewers agreed on the appropriateness of the project's approach, with one reviewer describing the approach as reasonable, and another noting that clear project goals had been developed as a result of the project team's experience and solid understanding of the technical issues involved. Reviewers described that critical barriers had been identified, and that the project team was employing a comprehensive approach to address these challenges. One reviewer did highlight a few limitations of the approach, however, specifically noting that the level of thermal conductivity of the proposed foam – a key parameter to be addressed – had not been defined, and that a cost per square foot metric for the proposed foam materials had not been proposed. Some additional activities that this reviewer would have liked to see were validation of the findings, the introduction of error analysis, and a clear identification of whether the foam used in the project had isotropic or anisotropic properties.

Despite these limitations, reviewers applauded the progress being made by the project team, with reviewers commenting that the project had met all key milestones and had made meaningful contributions to the field with clear achievements. One reviewer said that the potential market impact of this project was evident, while another highlighted that the project's six patent applications demonstrated its level of accomplishment.

Reviewers described the project team as well balanced, and commented that it had built strong communications with key stakeholders to accelerate movement of its proposed technology. Reviewers further described that the project had demonstrated good collaboration with industry actors, including manufacturers, research organizations, and consumer groups, and highlighted that this strong connection with industry would enable the transfer of technology from the lab to the market.

Reviewers described the proposed future work as well planned, meaningful, and built on past progress with a focus on making the product marketable as quickly as possible. Despite this overall assessment, however, reviewers identified several possible improvements that the project team could implement, including introducing and verifying a plan for measuring the thermal properties of the produced foam materials, and considering the foam's level of fire resistance and durability. One reviewer also expressed a desire for more information on patent applications and intellectual property issues, while another would have liked to see techno-economic analysis that addressed the cost target.

Weighted Average: 3.49 # of Reviewers: 6
Relevance: 3.67[1] Approach: 3.42 Accomplishments: 3.50 Project Collaboration: 3.75 Future Work: 3.17

Program Response:

Consistent with the comments from the reviewers, this project is progressing well. The PI will be continuing to characterize the foam in the final months of the project. Concerns from the reviewers regarding foam anisotropy and bulk thermal conductivity can be addressed as part of that work.

[1] Score not included in weighted average.

Project # 31395: R25 Polyisocyanurate Composite Insulation Material

Presenter: Kaushik Biswas, Oak Ridge National Laboratory
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers strongly agreed on the relevance of this project to BTO's goals. One reviewer commented that the development of a low-cost, R25 composite foam insulation board for high performance building envelopes was well aligned with BTO's goals to improve buildings' energy efficiency. Another reviewer echoed this sentiment, noting that the advanced insulation product that would result from this project was directly supportive of the goals of the Windows and Building Envelope Research and Development (R&D) Roadmap.

Reviewers similarly agreed on the appropriateness of the project's approach. One reviewer described the approach – which at this stage was about prototype fabrication and testing – as clear and convincing, while another noted that critical barriers had been identified and were being addressed comprehensively. From a technical perspective, one reviewer noted that the project's approach was reasonable, but another warned that the void-to-solid ratio – a key parameter of encapsulated foam – had not been considered. Finally, one reviewer flagged that while both R-value and cost were performance targets, efforts appeared focused on R-value whereas there was much less discussion of the targeted cost goal.

Reviewers commented that the project was progressing well, having already carried out lab-scale and thermal testing and modeling of a first-phase assembly-line product, and were pleased that lessons learned from the initial test were being integrated into the second phase. One reviewer noted that the research's achievements can be found in the favorable performance of test products, though they cautioned that quality control might still be an issue. One reviewer suggested that more samples should be tested to produce more conclusive results, while another identified several specific flaws in the project's approach, including that simulation models considered heat flow in only one dimension and that the project team did not validate the simulation models.

Reviewers agreed that the project demonstrated good collaboration between Oak Ridge National Laboratory (ORNL), Firestone Building Products Company, and NanoPore, Inc., and that the project team showed a strong understanding of the key stakeholders needed to accelerate movement of the new composite insulation into the market. Reviewers concurred that proposed future work appeared appropriate to address identified issues, and that proposed next steps were necessary and suitable for reaching project goals.

Reviewers noted that there appeared to be a lot of work to do to make the composite insulation a cost-effective, commercially-available product with satisfactory long-term durability, but highlighted that the project was already looking at code compliance, which reviewers identified as a positive step. Reviewers' main concerns around future work were that the project team provided no timeline for additional tasks, and that the presentation did not clearly highlight potential risks or mitigation strategies.

Weighted Average: 3.31 # of Reviewers: 6
Relevance: 3.67[1] Approach: 3.25 Accomplishments: 3.25 Project Collaboration: 3.42 Future Work: 3.50

Program Response:

This research program has involved extensive collaboration between all of the major parties participating on the project, which is reflected in the quality of the work and the generally favorable responses from the reviewers. The concerns that were raised by the reviewers will, in general, be addressed during the balance of the project performance period, or were omitted from the presentation in the interest of time. In particular, work will continue to examine uniformity of foam filling with the composite boards and the effect of various modified atmosphere insulation (MAI) panel configurations on foam filling and void formation, and a techno-economic analysis to examine market conditions and production costs is ongoing and will help define the required price point for the

[1] Score not included in weighted average.

composite boards to be cost-effective and priced appropriately for the target market(s). Reviewers raised some specific concerns regarding a lack of characterization of the polyisocyanurate (PIC) foam, but it should be noted that this project does not focus on changing the PIC chemistry or deposition method, but rather on the engineering challenges associated with fabricating PIC boards with encapsulated MAI panels.

Project # 31396: Low-Cost Haziness-Free Transparent Insulation Based on Hierarchical Porous Silica Particles

Presenter: Jaswinder Sharma, Oak Ridge National Laboratory
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers generally agreed that the project's intention to develop transparent insulation for fenestration was a critical area for building energy and BTO, and therefore the project was well aligned with BTO's mission and its Windows and Building Envelope Research and Development (R&D) Roadmap. One reviewer commented, however, that while the project had a nice goal, its scientific approach was not solidly established in physics.

Reviewers agreed that the project team was approaching the project's core objective appropriately, but they also highlighted several technical challenges that remained to be addressed. Reviewers noted that the project had identified challenges relating to cost, durability, and visible transmittance, and was correctly focused on investigating different processing methods to overcome these technical challenges and achieve the required visible transmittance at lower cost. However, one reviewer felt that the key challenge of combining transparent features with high insulating abilities was not yet being addressed, and was also concerned that a key criterion (transmissivity) was not being paid sufficient attention.

In terms of progress, one reviewer noted that sufficient visible transmittance had been achieved at a low cost, but also flagged other issues that need to be solved to achieve near-term goals. This reviewer further asserted that there was a long way to go toward the project's medium- and long-term goals. Another reviewer commented that it was too early to demonstrate the market impact of this project, given that product development was still at an initial stage and that there were still challenges to overcome. Similarly, a third noted that while the project team had presented some scientific evidence of one possibility for developing the targeted glazing, this possibility represented a high risk due to unclear technical solutions.

Reviewers disagreed on the project team's level of collaboration with external partners. One reviewer described the project as having strong collaborations, with one formal partner already on board and discussions underway with others that could help bring the technology to market. In contrast, a second reviewer described the project's communications with the key stakeholders as "limited," while a third commented that the project team did not demonstrate any strong connections with stakeholders. Another reviewer felt that no substantial collaboration was mentioned, but conjectured that perhaps this was due to the early stage of the research.

Reviewers disagreed about the project's future plans. Some reviewers described the project's proposed future work as reasonable, noting that the team had identified challenges and had proposed research plans to overcome these barriers. Further, these reviewers concurred with the project's pursuit of industrial manufacturing, and felt that its industry partner's interest in funding this work was promising. Another reviewer, however, described the planned next steps as highly exploratory, and was concerned that it might end up having little success, given that the project was ending soon. This same reviewer also felt that a thorough feasibility study would have been nice for all proposed solutions.

Weighted Average: 2.58 # of Reviewers: 6
Relevance: 3.17[1] Approach: 2.83 Accomplishments: 2.34 Project Collaboration: 2.59 Future Work: 2.83

Program Response:

The work conducted in this project has been principally focused on an exploration of the potential for the proposed chemistry. The scope and budget were sufficiently limited that the principal investigator (PI) necessarily had to limit his pursuit of technical challenges or opportunities to only those that he felt would be most fruitful. As a result, medium- and long-term goals were sometimes beyond the reach of the project. Guidance from BTO focused on

[1] Score not included in weighted average.

ensuring that the nanoparticles had the potential to provide appropriate properties for the desired application. While windows and skylights were the target application area, BTO also suggested that if visible transmittance (VT) and haze goals were not attainable, high R-value particles could be valuable in opaque insulation applications.

Given the limited scope of the project, there was an appropriate level of engagement with the industrial partner. In particular, in the latter part of the project the partner was able to provide good feedback to the PI regarding the needs of the industry with respect to R-value, cost, and haze and VT. The test window constructed with the industry partner provided valuable insights to the PI and original equipment manufacturer (OEM) with respect to how the nanoparticles need to be prepared if they are to be suitable for the insulating glass unit (IGU) fabrication process. It appears that the presentation did not make sufficiently clear the benefits to both the project and the partner through their engagement in the research.

The PI for this project recently received a DOE Advanced Research Projects Agency – Energy (ARPA-E) Single-Pane Highly Insulating Efficient Lucid Design (SHIELD) award for similar highly-insulating low-haze porous silica nanoparticles. While a research project moving from BTO to ARPA-E is perhaps the "wrong direction" from a technology development or technology readiness level (TRL) perspective, the work conducted under the BTO award helped demonstrate the potential viability of the technology and approach with sufficient depth to secure follow-on funding that will address many of the concerns raised by reviewers.

Project # 33390: Novel Thermal Break with Simplified Manufacturing for R7 Commercial Windows

Presenter: Sneh Kumar, Alcoa
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers agreed that this project was highly relevant to BTO's program goals, based on its aspirations to both improve window performance and reduce manufacturing costs. If successful, one reviewer believed this project could have a large impact on the market for high performance windows.

Reviewers also generally agreed on the project's approach, with one reviewer commenting that the approach comprehensively addressed technical and market challenges, including developing test specifications and protocols and carrying out a series of performance tests at levels. Reviewers did identify certain issues, however including the following:

1) the project focused exclusively on the thermal bridge issue while underestimating other barriers to R7 windows (e.g. glazing, spacer);
2) certain assumptions in its simulation models could lead to inaccurate predictions for the heat flow and temperature patterns in the system;
3) the proposed approach to foam materials introduced the foam properties without defining the direction; and;
4) no initial cost prediction was provided.

One reviewer also recommended that the project team add an overall description, analysis, and justification of its envisioned R7 commercial window, specifically identifying how its novel thermal bridge technology played a critical role in the final product. Reviewers felt that the project was making good progress, that it was on track to achieving its original research objectives, and that its potential market impact was evident. Despite this overall assessment, however, reviewers did note that several critical properties had not yet been tested, and that the simulation model had not yet been validated, so there was work left to do.

Reviewers observed good collaboration between the project team and its partners, notably Kawneer and certain key material partners, and also that the project team had built strong communications with key stakeholders to accelerate movement of its proposed technology. One reviewer also noted that further partnerships with a manufacturing line integrator were being initiated, which the reviewer felt was a reasonable step.

Reviewers described the project's future plans as comprehensive, meaningful, and built on past progress with a focus on market development and assessment, which would help advance commercialization and deployment of the product. Moving forward, one reviewer encouraged the project team to consider the thermal cycling effect and the interface between the foam and window frame, while another observed that additional and thorough testing may be needed around structural and thermal condition at different window sizes.

Weighted Average: 3.23 # of Reviewers: 6
Relevance: 3.50[1] Approach: 3.34 Accomplishments: 3.25 Project Collaboration: 3.17 Future Work: 3.00

Program Response:

The assessment of the reviewers is consistent with the perspective of the program that, on the whole, the project is progressing well and has addressed many of the major technical risks with respect to the frame design under investigation. It is anticipated that many of the concerns raised by reviewers with respect to foam properties, cost, and overall performance, are being addressed by the performer and other project partners. Validation of the

[1] Score not included in weighted average.

simulation models is an issue that can be investigated further by the principal investigator (PI), as is thermal cycling, though the latter is likely outside the schedule and budget of the current award.

Project # 33391: Fabricate-On-Demand Vacuum Insulating Glazings

Presenter: Jim McCamy, PPG
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance and alignment of this project with BTO's goals, and with BTO's Windows and Building Envelope Research and Development (R&D) Roadmap. If successful, reviewers felt that this project could overcome the cost and supply chain issues associated with traditional vacuum insulated glazing (VIG) manufacturing, which could engender significant energy savings if it spurred on the widespread adoption of VIGs.

Despite this promise, reviewers agreed that the project's approach had failed to make sufficient progress or to achieve its objectives. Reviewers noted that the project team had clearly and meaningfully articulated their approach to reducing manufacturing costs while improving product quality, and reviewers also highlighted that the project was correctly focused on addressing the cost issue related to developing VIGs, which was preventing smaller manufacturers from entering the market.

However, reviewers were quick to note that while the project's simulation models and experimental tests worked well, and that certain elements of the project's deliverables had been tested and small prototypes fabricated, the main goal of the project was not achieved: the manufacturing process developed by the project team resulted in very high capital and fabrication costs, which did not meet the cost goals of the R&D roadmap and exceeded both the window manufacturer's expectations and the market acceptance threshold. In short, reviewers found that the project had shown that the fabricate-on-demand VIG would not result in a cost-effective product.

Reviewers agreed that the project demonstrated good collaboration among national laboratories, technology partners, and manufacturing equipment providers, but they also noted that this collaboration did not successfully achieve the main goal of the project.

Looking forward, reviewers agreed that the project team's proposed future work was vague. Reviewers noted that the project team recommended a redirection to pursue an alternate high-performance window insulated glazed unit design that could meet both the performance and cost goals. However, while one reviewer noted that such a redirection seemed worthwhile, another was discomfited by the fact that no clear objectives or tasks were described around this effort.

Weighted Average: 2.63 # of Reviewers: 6
Relevance: 3.17[1] Approach: 2.67 Accomplishments: 2.59 Project Collaboration: 3.00 Future Work: 2.00

Program Response:

As noted in the presentation by PPG and the comments from reviewers, the research effort achieved several of the interim technical targets outlined in the scope of work for the project, but failed to meet the cost targets. Further, the performer did not believe that there were opportunities to modify the product or fabrication process enough to bring costs to a level that would be acceptable for window fabricators. The reviewers noted that the plans presented by PPG for moving forward with the project were vague. This lack of specificity is likely a result of the ongoing effort by BTO and PPG to clarify an acceptable future direction for the project that can achieve the long-term technical and cost targets required if the product is to be commercialized.

[1] Score not included in weighted average.

Project # 35312: Fenestration Software Tools

Presenter: Charlie Curcija, Lawrence Berkeley National Laboratory
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

In seeking to develop and validate simulation models, develop test methods and procedures, and develop web-based tools for rating the energy performance of window attachments, reviewers strongly agreed this project supported BTO's goals. Reviewers said by helping manufacturers and consumers develop and select the best energy saving fenestration attachments in quantifiable terms, this project would provide a "technical backbone" for the Attachments Energy Rating Council (AERC), help new fenestration attachments into the market, and ultimately help achieve high performance buildings.

Reviewers agreed the project approach seemed well-thought out and executed, with key issues identified and a clear plan for testing, measuring, and incorporation into simulation methods identified. Many reviewers agreed the approach seemed likely to enable cost-effective rating tools.

Reviewers generally agreed that the research team appeared to have a strong and excellent collaboration among multiple partners and subcontractors with good connections with industry/manufacturers. One reviewer, however, found the relationship between the project and AERC to be insufficient.

Reviewers strongly agreed the project deliverables will be useful in getting energy efficient fenestration attached to the market, which could be quite large, and will help various stakeholders "make informed decisions on product specification, policy making, [and] new product development." One reviewer praised the validated simulation models and their incorporation into associated software tools as an alternative to physical testing, but another reviewer questioned the linkages of the project to targeted labeling programs.

Proposed future work received high marks with a "clear plan and meaningful activities" on both the technical and organizational side and included a variety of stakeholders such as certification agencies, consumer groups, and manufacturers. Reviewers questioned if a simpler and more user-friendly program could be developed to promote wider adoption into the market, with one reviewer suggesting a web-based program could be developed to allow the public to easily use this program to evaluate window attachments.

Weighted Average: 3.43 # of Reviewers: 6
Relevance: 3.83[1] Approach: 3.33 Accomplishments: 3.42 Project Collaboration: 3.59 Future Work: 3.50

Program Response:

The reviewer comments of AERC and their presentation were somewhat more critical than for Lawrence Berkeley National Laboratory's (LBNL's) presentation of the technical work underpinning the ratings program coordinated by AERC. The focus on technical work in LBNL's presentation as compared to the Window Covering Manufacturers Association (WCMA) could be the source of the difference in reviewer appraisals of the two presentations, even though they were simply presenting the project from two perspectives. With respect to the comments on this presentation, it is expected that AERC will develop the web-based program that one of the reviewers described, to make it easy for consumers/building owners to get information about the energy performance of the window attachments they plan to purchase or specify.

[1] Score not included in weighted average.

Project # 94151be: CBERD: R&D Building Envelopes

Presenter: Christian Kohler, Lawrence Berkeley National Laboratory
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments

Reviewers were split on the relevance of this project to BTO's goals, with half rating it an "outstanding" project and the other half rating it "fair." Supporting reviewers cited the relevance of advanced building technologies and techniques to BTO's mission, while dissenting reviewers questioned how helping buildings in the Indian market aligns with BTO's domestic energy goals. One reviewer praised expected deliverables from this project to help the target audience (building officials, architects, building owners and developers) make informed decisions on energy saving products.

Reviewers questioned the lack of information presented on overcoming cost barriers as well as not properly addressing phase change material (PCM) characteristics: toxicity, melting point, auto ignition temperature, flammability, and volume change during phase change. Reviewers recommended sharing additional details on how PCM characteristics were measured and validated as well as defining a cost per square foot for the proposed materials. Other reviewers were positive about leveraging Indian investment for U.S. market benefit and the computational simulations and experiments conducted by the project team.

Reviewers expressed uncertainty about accomplishments with comments on a lack of clarity with respect to measurement of PCM characteristics, that it was too early to assess any market impacts, the limited usefulness of the results to BTO's goals, and oversimplification of modeled systems. By contrast, reviewers were generally pleased with project collaboration and integration with a strong and well-balanced team as reflected in field experiments and joint papers.

Reviewers recommended that the project incorporate additional modeling efforts to ensure the project has significant impact, as well as increased collaboration with Indian partners to ensure all project partners understand the challenges and critical barriers in India. Reviewers also recommended a detailed plan for measuring PCM thermo-physical characteristics and creation of anticipated quantitative and qualitative targets to evaluate project success.

Weighted Average: 3.08 # of Reviewers: 6
Relevance: 3.00[1] Approach: 3.25 Accomplishments: 2.92 Project Collaboration: 3.25 Future Work: 2.83

Program Response:

CBERD projects are intended to promote scientific research collaboration for diplomatic and technical objectives that provide mutual benefit to the U.S. and India. To that end, while the portfolio on the whole seeks to balance those benefits, some tasks and sub-tasks might be more weighted towards benefits for the U.S. or India. As an example, the PCM project will likely have greater application in India, where natural ventilation and mixed-mode building operations (i.e., using natural ventilation in conjunction with mechanical HVAC systems) are far more common and PCMs can help improve performance in those operating regimes. The treatment of the PCM characteristics noted above is somewhat limited given the budget constraints of the U.S. side of the project, but the challenges of PCMs have been communicated to the Indian research partners.

While it might not have been conveyed fully, the U.S. and Indian partners have been in close collaboration to ensure that the work conducted is consistent with the nuances and challenges of the Indian market and building-related industries. This sensitivity is aided by the fact that the bulk of the work is being conducted by the Indian research teams.

[1] Score not included in weighted average.

EMERGING TECHNOLOGIES
SENSORS & CONTROLS

Project # 31490: Equipment Health Monitoring with Virtual Intelligent Sensing

Presenter: David Fugate, Oak Ridge National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project to BTO's goals, noting that the project's potential for improving building system efficiency and reliability through low-cost fault detection was directly aligned with BTO objectives, particularly if it could be done without installing expensive sensing and control equipment.

Overall, reviewers expressed that the project's approach – which was focused on fault detection in HVAC systems – had merit, but also that it faced several significant risks. Reviewers commented that the approach had a lot of promise, especially when combined with other fault detection techniques. However, one reviewer cautioned that using power signature identification for energy loads was difficult, as many combinations of devices could produce similar signatures. Reviewers acknowledged that the basic software capability had been validated in test buildings, but they warned that translating this success to real buildings would be challenging.

One reviewer noted that aging effects and variance in equipment can change a device's power signature from building to building, and that figuring out how to establish a good baseline for a specific building was going to be difficult. This reviewer felt that the project's technology might not be able to implement successful HVAC fault detection on its own, but instead it could be a powerful addition to other sensed data, some of which was already present in existing control systems. Another reviewer commented that actual fault detection data was not yet available, but would be important to generating more confidence in the project.

A third reviewer noted that if it the project's fault detection software could be used reliably, it could be deployed to buildings immediately because there would be little cost in terms of new investment. However, another reviewer commented that, while the software could work well in smaller buildings with limited HVAC loads and no adequately trained maintenance staff, larger buildings with multiple HVAC units would not be good candidates.

Reviewers agreed that the project appeared to feature only light collaboration, though one reviewer surmised that additional collaboration may not have been needed based on scope. One reviewer offered further comment that the limited collaboration appeared heavy on academia and consultants, and recommended that the project team consider also partnering with manufacturers and businesses.

Overall, reviewers expressed mixed feelings on the project's proposed future work. One reviewer believed that limitations were presented and progress was shown with timelines for the next milestone, while another reviewer felt that the project lacked a strong vision going forward. One reviewer noted that it seemed like a preliminary software package would be ready for real building tests soon, and that the outcome of this testing would determine the readiness of the proposed solution. This reviewer expressed concerns, however, that if the software package did not work well in a real-world setting, no fallback solution was presented for salvaging the analytical techniques developed.

Weighted Average: 2.80 # of Reviewers: 4
Relevance: 2.75[1] Approach: 2.75 Accomplishments: 3.00 Project Collaboration: 2.38 Future Work: 3.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 31491: Transforming Ordinary Buildings into Smart Buildings via Low-Cost, Self-Powering Wireless Sensors and Sensor Networks

Presenter: Philip Feng, Case Western Reserve University
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to DOE's goals, describing that self-powered sensors would be an excellent addition to building systems in terms of monitoring and controlling energy use. Reviewers also generally agreed with the project's approach, though with certain reservations. One reviewer noted that people would definitely be interested in cheaper and low/no-maintenance sensors, while another commented on the novelty and relevance of the piezoelectric energy harvesting idea.

However, one reviewer flagged that the sensor was limited, in that it had to be co-located with a vibration source, while another highlighted that the approach would have benefited from a consideration of sample frequency and the application of a model predictive control strategy that could enhance sensor lifetime. One reviewer felt that the project demonstrated no real innovation, however, and instead merely integrated an established piezoelectric harvester with existing sensors and communication packages.

In terms of accomplishments, reviewers highlighted that the project team had successfully built a prototype sensor, exceeded original impact goals, and received several awards from outside agencies. However, one reviewer flagged that most of these accomplishment were primarily related to student activities and demonstrated little actual technology development. This reviewer further commented that they were not satisfied with the small amount of data that was shown to support the work of the sensors, given that the data presented were exclusively related to power consumption rather than sensor reliability, detection failures, communication failures, etc.

Reviewers agreed that the project appeared to have very little outside collaboration, including very little industry involvement, and that the project was primarily an effort of a single university and a spin-off company. Further, one reviewer commented that the project team's presentation demonstrated that they were not familiar with the requirements of the building controls or HVAC industry, signaling that some real industry partners would be valuable.

Looking forward, reviewers noted that with testing of the fundamental apparatus complete, further miniaturization of the device and the pursuit of venture capital made sense. However, one reviewer commented that, because the sensor's wireless functionality still had to be tested and fully implemented, the project team was still in the product development phase, rather than the "commercialization" phase described in the presentation. Another reviewer recommended that the project team should continue to investigate whether improvements can be made to the underlying technologies (e.g., piezoelectric (PZE) harvesting, form factor) to add value beyond the project's current strategy of packaging together existing technologies.

Weighted Average: 2.73 # of Reviewers: 4
Relevance: 3.00[1] Approach: 3.00 Accomplishments: 2.75 Project Collaboration: 2.25 Future Work: 2.75

Program Response:

The second budget period will focus on testing the performance limitations of the PZE harvesting technology and the initial laboratory prototype.

[1] Score not included in weighted average.

Project # 32611: Low-Cost Wireless Sensors for Building Monitoring Applications

Presenter: Teja Kuruganti, Oak Ridge National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed that the development of printable low-cost sensors aligned well with BTO's goals. Reviewers commented that low-cost sensors could help make energy management systems more affordable, and therefore more attractive to install, and that solving wireless integration issues was both relevant and needed. Reviewers also generally agreed on the project's approach, alternatively describing the approach as solid and effective in reaching its goal. One highlighted that difficulties in printing sensors were well documented, that all barriers were identified, and that the project's designs appeared to address most of the issues. Another reviewer warned that some of the sensors might require geometry beyond two-dimensional (2D) and noted that better integration of foreign parts or the use of three-dimensional (3D) printing might be helpful. A third reviewer highlighted that key issues like sensor accuracy and drift were not addressed, but acknowledged that these issues might be irrelevant due to sensor price and short service life.

Reviewers felt that the project had achieved good results thus far. They highlighted that the nature of the work and the accomplishments were directed more at solving a fundamental problem, and described that the project team was on a good path in this regard. Another reviewer was impressed with the almost-to-market quality of the project's sensor prototype. One reviewer was pleased that the functionality and cost of the sensor's various integrated parts were detailed, but thought that the Peer Review presentation was heavy on antenna-related elements, whereas additional performance data on sensor component would have been valued. Overall, reviewers felt that the project had great promise to release a low-cost sensor to market within the next couple of years. In this vein, one reviewer encouraged the project team to drive toward completion in order to compare the project's final deliverables with the state-of-art.

In terms of collaboration, reviewers remarked that the project team had worked very closely with partner Molex on the development of the sensor product, and the fact that Molex was able to produce such a high-quality prototype spoke to the quality of this collaboration. One reviewer did note, however, that there did not seem to be significant collaborations beyond Molex, noting that the project might have benefited from also partnering with an end-user who could deploy the sensors. However, this reviewer acknowledged that perhaps the project was primarily focused on producing the sensor, not testing it.

Looking to the future, reviewers noted that the project team's plans to wrap up the project seemed well within reach. One reviewer noted that it was likely that the inclusion of humidity and temperature sensors would be tricky, but that all signs pointed toward the challenge being solved. However, this reviewer remarked that because there was no plan to actually test sensors in real buildings, nor to perform any lifetime assessments, the project team will not know how long the project's sensors will last.

Weighted Average: 3.10 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.00 Accomplishments: 3.25 Project Collaboration: 2.88 Future Work: 3.25

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

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, by providing commercial buildings with additional capability for building energy savings – particularly in small and medium-sized commercial buildings – this project was well aligned with BTO's goals. In contrast to the project's relevance, however, reviewers appeared split on the project's approach, its progress and accomplishments, and its collaborations.

For its approach, some reviewers commented that the project's energy management system appeared to be moving forward, that the software platform offered good attention to interoperability, and that the project team's composition allowed it to focus on both market conditions and product development. However, one reviewer felt that the energy management software's reliance on a hardware platform was a questionable decision, and another thought that the project team had misidentified the critical market barrier as the "inability to communicate" between devices, whereas the actual barrier was "too many languages for one platform to communicate to all" or "the refusal by some devices to communicate." This reviewer also thought that the project team had pushed "openness" as the project's innovation, whereas the reviewer thought that the device-driver portion of the project was most important.

In terms of progress and accomplishment, one reviewer felt that the project had good management, leadership, and had experienced excellent project execution; while another reviewer thought that the project's accomplishments were good overall, but thought that the project team should have focused on finalizing the software before field testing it in three buildings. In contrast, a third reviewer commented that the project team's demonstration of what could be done with the system was very rudimentary, noting also that the team had done a poor job of differentiating the project's software from existing open-protocol systems.

Some reviewers felt that the project had pulled together a great team of collaborators, and thought that the compatibility of the project's energy management software with DOE's VOLTTRON platform was a positive sign. However, some reviewers felt that the project's integration with commercial companies needed attention, particularly because the project team discussed needing to spin off a company to upkeep the platform. In addition, reviewers commented that the project's need to spin off a company was indicative that the effort was not really any different from other startups in home automation or building control systems.

Reviewers were in general agreement that the project's proposed future work was lacking. One reviewer commented that they were apprehensive about the future work, while another noted that while adding Demand Response functionality was a positive development, concerns remained about the cost of the energy management service compared to other systems already in production. Finally, another reviewer commented at length regarding the project team's apparent belief that the job was done following completion of the integration platform; this reviewer believed that even if a company were spun off to keep the software going, the project team was underestimating the actual software development required, including around energy management and control logic and maintaining interoperability with a range of devices over time.

Weighted Average: 2.58 # of Reviewers: 4
Relevance: 3.25[1] Approach: 2.75 Accomplishments: 2.50 Project Collaboration: 2.75 Future Work: 2.00

Program Response:

Reviewer comments will be utilized to improve the work plan and development of both VOLTTRON and BEMOSS moving forward.

[1] Score not included in weighted average.

Project # 94151sc: CBERD: R&D Integrated Sensors and Controls

Presenter: Christian Kohler, Lawrence Berkeley National Laboratory
DOE Manager: Karma Sawyer

Brief Summary of Reviewer Comments:

Reviewers were split on the relevance of this U.S.-India Joint Center for Building Energy Research and Development (CBERD) project towards BTO's goals. While reviewers agreed that the work could result in benefits for the Indian market and power grid, they did not see value for the work in the U.S. market unless there was a better interface to control price or power demand. Reviewers generally were positive towards the project's utilization of the VOLTTRON platform and the approach for the Indian market, but they worried that due to prevailing norms in the U.S. HVAC industry this project's approach and lack of cost data would never result in widespread, global impact. Reviewers were also concerned that the project would require a significant amount of education and behavioral change to be included in the work to enable cutting individual loads on and off, given that plugging a non-dimmable load into the wrong outlet will burn out the load.

Reviewers praised the demonstration and product development work for the Indian market, noting that should the technology be developed at the envisioned low price-point, it could be industry changing. Reviewers were generally positive on the Indian partnership involved in the project, with one saying the high degree of U.S. – India collaboration "is the shining part of this effort" and said such internationally collaborative projects in the future could have a major impact.

Many of the project reviewers' criticisms centered on the impact of the technology in the U.S., with reviewers noting it remained unclear how the project demonstrations could impact the U.S. market. Several reviewers noted there was no real U.S. industry participation and recommended reaching out to more U.S. industries for their perspective on market development. Reviewers were concerned across categories as to the lack of this project's articulated value to the U.S. and the DOE.

Reviewers also expressed skepticism on elements of project management, with concerns centering on unrealistic timelines, a lack of planning, and insufficient budget for the scope of work to no behavioral change component in an effort that requires user education. One reviewer remarked that the project appeared to lack a unifying theme, worrying the project team was unwilling to coalesce around a single technology research project and working more on technology integration issues. Finally, one reviewer recommended looking for any technology transfer from India to a U.S. manufacturer.

Weighted Average: 2.19 # of Reviewers: 4
Relevance: 2.50[1] Approach: 2.13 Accomplishments: 2.00 Project Collaboration: 2.75 Future Work: 2.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

EMERGING TECHNOLOGIES
BUILDING ENERGY MODELING

Project # 31590: A New Hybrid Approach to Energy Modeling

Presenter: Tianzhen Hong, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers differed in their opinions on this project's relevance to BTO's overarching goals. On one hand, some reviewers expressed that this project's work represented a very innovative attempt at merging measured data with modeled data, supporting BTO's goals by helping practitioners estimate and implement energy conservation measures more accurately and effectively. On the other hand, some reviewers noted that BTO's ultimate goal was to provide substantial reductions in energy consumption, where these reviewers felt that the project's potential for substantial energy saving was questionable.

Reviewers agreed on the appropriateness of the project's approach. One reviewer commented that the project team was employing well-established methods and processes to solve a clearly understood problem. Another reviewer noted that using Lawrence Berkeley National Laboratory's (LBNL's) FLEXLAB for model and simulation validation was a significant step forward in energy modeling, and that overall the strategies presented made sense and were valid. A third reviewer highlighted that the project recognized that energy modeling practices needed more accuracy in the descriptions of buildings' physical characteristics and operations, and was working to help reduce the differences between model estimates and measured values, beginning with infiltration and thermal mass.

Reviewers identified some deficits in the project team's approach, including that it did not provide techniques for integrating the proposed hybrid modeling with existing design tools, and also that it failed to identify how to isolate the specific uncertainties of infiltration and thermal mass from other potential sources of uncertainty. One reviewer recommended that the project could be improved by extending the testing of the hybrid modeling approach to a real world/as-constructed building, and also that it was important for the project to identify what type of standardized and BTO-advised building data collection, storage, and model integration techniques would be needed to facilitate the proposed modelling process.

One reviewer highlighted the project's demonstration of a two-step validation approach – using prototype models and EnergyPlus followed by field validation via FLEXLAB – as a clear accomplishment, identifying the approach as one that should be used by all researchers investigating improvements to EnergyPlus.

Beyond this approach, however, reviewers expressed mixed feelings about the project's potential impact. One reviewer felt that once tested and implemented, the project's hybrid modelling approach could lead to significant energy savings by enabling existing-building retrofit analysis. In contrast, a different reviewer expressed doubts about the project's estimation of energy savings potential, recognizing how difficult it is to make accurate estimations for modeling tools. One reviewer believed that the project would contribute significantly to achieving the Emerging Technologies (ET) Program's interim market goal, but a different reviewer though that contributions to the ET Program's interim market goals would be marginal, due to the hybrid approach adding complexity to the current workflow of energy model development and calibration.

Reviewers generally agreed that the project team had pursued appropriate and effective collaborations, but also identified additional stakeholders to whom outreach would be valuable. One reviewer expressed that the project team had done an exceptional job of working with collaborators, including the EnergyPlus team, while another highlighted the value of the project's collaboration with FLEXLAB.

However, reviewers noted certain deficits, including that there had been little discussion around collaboration with potential end users to better understand their restrictions and workflow expectations. One reviewer observed that the project's collaboration with the California Energy Commission (CEC) PIER (Public Interest Energy Research) demonstrated the project team's basic understanding of key stakeholders, but another reviewer recommended that the project should collaborate with stakeholders outside of California to develop impact. A third reviewer highlighted that collaboration with the National Renewable Energy Laboratory (NREL) should be pursued around the integration of EnergyPlus with OpenStudio.

Reviewers generally agreed with the project's next steps, with one reviewer describing them as simple, relevant, and on point. Another reviewer expressed that proposed future work was not particularly creative or innovative, but allowed that the nature of the project did not leave room for doing much more than integrating the approach with EnergyPlus and disseminating findings. One reviewer noted that the project team's future plans failed to highlight technical risks or risk mitigation strategies, while other reviewers recommended developing a framework to get possible industry partners to deploy the hybrid approach and prove user acceptance, as well as instructional/educational resources.

Weighted Average: 3.03 # of Reviewers: 5
Relevance: 2.60[1] Approach: 3.30 Accomplishments: 2.80 Project Collaboration: 3.00 Future Work: 3.20

Program Response:

This is a successful research project that will be integrated into EnergyPlus before the end of Fiscal Year (FY) 2016 and into OpenStudio in FY 2017 and FY 2018. The goal of the project was to allow EnergyPlus to leverage increasingly available outside data sources--specifically time series indoor temperature data from smart thermostats--to improve modeling of existing buildings. Initial results were quite positive and additional testing will be done in FY 2017, especially in the context of calibration algorithms. OpenStudio Server provides a natural deployment channel and will make this feature available to EnergyPlus client applications.

[1] Score not included in weighted average.

Project # 35510: EnergyPlus

Presenter: Mike Witte, GARD Analytics
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers gave EnergyPlus high marks for its relevance to BTO's mission and goals, with one reviewer describing it as an "indispensable" energy modeling engine that is the "basis for almost every technology evaluation in the BTO mission." Similar sentiments were given in reviewers' assessment of the program's strengths with one reviewer writing, "As 'best in class' software for determining predictions of energy usage, EnergyPlus remains a core component in DOE's strategy for providing platforms for software vendors to build off of." Other reviewers remarked that EnergyPlus was now an "international tool" with a "great" performance testing framework that "continues to become more and more useful and accurate as time goes on." Reviewers praised the integration with OpenStudio and with other DOE tools and programs.

The lowest overall score was for project approach, mostly due to reviewer's disagreeing with the relevance of the evaluation criteria for EnergyPlus' mission and impact. One reviewer noted that addressing "critical market barriers" is not applicable because it is an ongoing effort to improve a piece of software, while another wrote that EnergyPlus itself is designed to overcome the major market barrier of the capability to analyze energy performance with a high level of accuracy.

A third reviewer viewed insufficient energy model control design integration as a critical market barrier and noted that no activity was proposed on how to support EnergyPlus energy modeling under actual building operations. This reviewer specifically pointed to key needs such as "taking into account the stochastic behavior of occupants" and how to handle improving the model's capabilities for "integrative/batch simulation purposes required for population-based probabilistic numerical optimization and uncertainty-sensitivity analysis." However, when the stochastic question was raised during the question and answer (Q&A) session, the presenter replied that EnergyPlus was developing occupant behavior models "integrated through co-simulation."

Reviewers were generally pleased with the EnergyPlus team's collaboration with industry, though a few were concerned with the relationship between DOE and one major industry user of the tool, potentially giving the appearance of supporting a single company more than others. Overall reviewers were impressed with plans to continue to build out functionality (recent accomplishments including LaTeX, C++, JSON input, and code compliance check), use-cases, and a second-generation version of the tool (Spawn-of-EnergyPlus) and pointed to the past success and the growing number of downloads under DOE hands with ensuring quality and rigor.

However, some reviewers were concerned with the ability of the EnergyPlus team to accomplish all of its planned improvements in the coming years with its current level of support. Reviewers pointed to a lack of formal management plans and procedures for addressing bugs, prioritizing and adding new functionality, the availability of overall software user documentation (specifically, how components interact with each other), and the transition between EnergyPlus and Spawn-of-EnergyPlus as project weaknesses in accomplishing the multitude of proposed future projects. One reviewer, however, did note that that a flexible management approach is key for EnergyPlus to be responsive to market needs. Another reviewer proposed creating a formal advisory board that is focused on market-needs to help prioritize improvement needs.

One suggested a different evaluation mechanism from the Peer Review might be useful for EnergyPlus that split the review into a half day devoted to technical experts and a half-day with market representatives such as architects, engineers, developers, and facility managers.

Weighted Average: 3.27 # of Reviewers: 5
Relevance: 3.80[1] Approach: 2.90 Accomplishments: 3.60 Project Collaboration: 3.30 Future Work: 3.00

[1] Score not included in weighted average.

Program Response:

EnergyPlus is a long running project that will continue into the foreseeable future. In response to prior year reviews, the team has created a better and more transparent process for collecting and incorporating user feedback and synthesizing requirements. That channel (implemented via the UserVoice site http://energyplus.uservoice.com/) is being put to the test in the Fiscal Year (FY) 2017 planning process. DOE and the EnergyPlus team has also established tighter communication channels with third party vendors.

Concerns about the unknown aspects of the large impending Spawn-of-EnergyPlus transition are legitimate. DOE and the team are well aware of them. To mitigate risk, the team is pursuing a somewhat parallel development strategy for a number of years before completely switching over. The OpenStudio software development kit also mitigates transition risk by acting as a mediator between EnergyPlus and client applications and users.

Empirical validation of existing and new EnergyPlus models is an important task, but it is not a part of the EnergyPlus project proper. It is addressed in two other projects, "ASHRAE Standard 140" and "Empirical Validation and Uncertainty Characterization," neither of which were reviewed this year. Related education and community collaboration projects were also not reviewed. Suggestion for alternate peer review structure for EnergyPlus (and maybe other large long-standing projects) is well taken and will be considered for implementation next year.

It is difficult to attach traditional performance metrics (i.e., the types of metrics that are attached to physical widgets such as light-emitting diodes (LEDs) and windows, in particular, installed cost and lumens-per-watt or U-value) to software projects as well as to account for energy savings. Rather for software, DOE focuses on deployment and use metrics. Current DOE metrics for EnergyPlus (and OpenStudio) use the American Institute of Architects (AIA) 2030 Commitment reporting data to measure use in design and energy savings over code-baseline. DOE will investigate other potential metrics and sources of data for tracking EnergyPlus use.

COMMERCIAL BUILDINGS INTEGRATION

Project # 22296: Significant HVAC Energy Savings enabled by Practical, Low-Cost Air Treatment Technology

Presenter: Udi Meriv, enVerid
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, recognizing the deployed technology's potential to reduce HVAC energy use while improving indoor air quality (IAQ). However, they expressed concern that technical issues could limit market adoption, and therefore the project's potential impact on energy use. These technical concerns included that the sorbent material's ability to perform reliably over its useful life was unknown, that the process for integrating the technology into most existing building control systems had not been well defined, that the installation and servicing network has not been well defined, and that the need for an exhaust vent for the air flush could be an impediment in many otherwise appropriate applications.

One reviewer remarked that there appeared to be a strong technical team in place, and a good product with significant energy savings potential, but that understanding of the real and substantial market barriers to getting beyond a very small number of pilot projects was not demonstrated. This reviewer observed that the first pilot installation appeared to be delivering substantial savings, but expressed concern that there also seemed to be significant installation and practical barriers to wider acceptance and use of this new technology. Despite these concerns, reviewers acknowledged that, though slightly behind schedule as of the time of this Peer Review, the project did have one system successfully installed, and appeared to be on track to monitor system performance, analyze the energy savings, overall economics, verify IAQ improvement, and achieve its interim market goal.

Reviewers noted that the project's linkage with utilities and Johnson Controls was useful, but also that it seemed that many more partners and case studies would be needed to get beyond niche market penetration. As mentioned previously, reviewers felt that development of an installation and servicing network was also lacking, noting that project success would require relevant trades to be engaged and encouraged to accept this technology. One reviewer expressed a desire to see a roadmap for the installation and servicing of this technology.

Reviewers acknowledged that the project's future plans called for addressing some technical concerns, which would contribute to increased technology cost-effectiveness and wider applicability. However, while they felt that the outlined technical work seemed appropriate, reviewers thought that more work was needed on market assessment, barriers, and a realistic commercialization plan, given that this was a demonstration and deployment project.

Reviewers recommended that the project could benefit from having a market research analyst help to identify barriers to wider market acceptance, which seemed critical to move toward any significant market penetration. They also recommended planning now for the installation and servicing network, as well as surveying various code jurisdictions across the country to be sure that the technology did not run afoul of some jurisdictions that limited the project's ability to flush the pollutants to the atmosphere.

Weighted Average: 2.35 # of Reviewers: 2
Relevance: 2.50[1] Approach: 2.50 Accomplishments: 2.50 Project Collaboration: 1.75 Future Work: 2.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 22297: Advanced Retro-commissioning Technology: Predictive Energy Optimization (PEO) and Automated Demand Response for Commercial Building HVAC

Presenter: Michael Nark, BuildingIQ
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed that the project was relevant to BTO goals, and that it held significant promise for cutting energy use and peak demand. Furthermore, they remarked that if the project were successful in overcoming the critical barrier posed by buildings managers' inability to optimize operations of their buildings, the opportunities for improving building energy efficiency will be enhanced, and will result in utility bill cost reductions.

However, reviewers felt that the project did not demonstrate a strong understanding of barriers to wide-scale implementation, with one reviewer observing that the project team did not acknowledge that many building owners and operators are skeptical about energy savings from an unproven concept. This reviewer noted that having project partner Lawrence Berkeley National Laboratory (LBNL) provide monitoring and verification of savings could substantially address this "new concept" barrier, and that bringing utilities on board to offer incentives could also help mitigate "risk adverse" concerns.

Reviewers commented that the project team identified other barriers that would limit the ability to reach certain building types, including commercial buildings controlled via real estate investment trusts (REIT), but one reviewer explained that this market barrier would only limit future penetration of the technology, not prevent the project's success. Another reviewer remarked that the project's current focus on U.S. General Services Administration (GSA) and other government- and university-owned buildings was not representative of the broader commercial building market, and that marketing the project to skeptical building owners on a one-off basis would be more difficult.

Reviewers expressed mixed opinions on progress achieved. One reviewer thought that the project seemed significantly behind schedule, that the schedule appeared to be unrealistic, and that it was unclear what results and impacts would be demonstrated at project end. In contrast, another reviewer felt the project was progressing as planned, but explicitly highlighted the risk posed by the ongoing difficulties integrating project technologies into GSA facilities. Finally, a third reviewer felt that the project had met performance goals identified in the timeline.

One reviewer felt that the project team demonstrated a good understanding of those stakeholders necessary to move its technology into the market, while another highlighted that the GSA Green Proving Ground and the District of Columbia Department of General Services (DC DGS) were useful partners, but that it was not clear how much these partners were being engaged. Further, this reviewer felt that certain other partners' roles were entirely unclear.

One reviewer felt that the project's plan for future work seemed reasonable, but that the planned project schedule would need to be extended given the delays experienced already. This reviewer also thought that the plan to roll out the project to all GSA buildings was well conceived, but felt that it would only be effective if the GSA building data barrier could be resolved. Another reviewer recommended that the project's best market opportunities were in the healthcare and higher education sectors, given the likely limited penetration into REIT-controlled offices and the current challenge posed by GSA systems.

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

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 22298: High Efficiency Motors for Refrigerated Open Display Cases

Presenter: PJ Piper, QM Power
DOE Manager: Charles Llenza

Brief Summary of Reviewer Comments

Reviewers overwhelmingly agreed on this project's relevance to BTO goals, its approach, its market integration, and its plans for future work. One reviewer went so far as to call this project a "success story for BTO," based on the project's strong support of BTO's goal of reducing building energy use and its success in tackling and overcoming potential installation pitfalls for its technology through forward-looking product design.

Reviewers referred to the project's approach as very sound, highlighting in particular the project's responsiveness to customer and stakeholder input early in the deployment and demonstration process, as well as its focus on critical market barriers. They described the project as having successfully developed a commercially- and retrofit-ready deployable product that was delivering significant energy savings, was reaching strong market penetration in a very short period, and had already obtained UL certification. Reviewers agreed that the project was on time, on budget, and ahead of near term installation targets, and was therefore likely to make a transformative contribution to or exceed the interim market goal.

Reviewers felt that project staff demonstrated an excellent understanding of the key stakeholders necessary to move this technology to market. They noted that while there did not seem to be a large group of stakeholders involved, the project was extremely responsive to what worked best for customers, adapting the product offering to make it easier for retrofits and simple installations. Therefore, reviewers concluded that the level of integration and collaboration met the needs to have a very successful project, with strong ongoing market prospects and energy savings.

Overall, reviewers agreed that proposed future work appeared very reasonable and would continue to build upon and substantiate performance and energy savings; they anticipated that the project would thus avoid nearly all potential risks that could impede full deployment of its technology.

Weighted Average: 3.82 # of Reviewers: 3
Relevance: 3.67[1] Approach: 3.83 Accomplishments: 4.00 Project Collaboration: 3.50 Future Work: 3.67

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 22299: Commercial Advanced Lighting Control (ALC) Demonstration and Deployment

Presenter: Gabe Arnold, Northeast Energy Efficiency Partnership
DOE Manager: Charles Llenza / Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, noting that the project was working to commercialize technologies that BTO had supported for many years through research, development, and demonstration (RD&D). Reviewers commented that the project was advancing a complex and confusing technology, where BTO had correctly identified a need in the market. Reviewers also noted that there was potential for substantial savings in the solid-state lighting (SSL) controls arena, and further that the project was taking some much needed steps in the right direction, but that no one could expect all SSL lighting issues to be solved with this project.

Reviewers agreed that the project's overall approach seemed very sound and well thought out, but warned that barriers to advanced lighting controls were significant and should not be underestimated. Reviewers remarked that the project team had correctly identified market roadblocks and had formulated a good approach to begin moving SSL lighting controls into mainstream utility program offerings. However, one reviewer felt that while the project's focus on training installers would contribute to increased cost-effectiveness, this reviewer was left wondering how the project would address the high cost of equipment.

In terms of progress, one reviewer thought the project appeared to be running a bit behind, while another thought that the project was making good progress towards its goals. One reviewer noted that while there was a "systems based energy efficiency program offering" that was described as being completed in December 2015, no information was available on the project website; this reviewer was concerned that project outputs were only being made available to project partners and not the broader public and marketplace.

One reviewer commented that the project was taking a holistic approach by engaging so many stakeholders in the process, and another remarked on the project's very broad and impressive group of collaborators, which the reviewer thought was the result of the project team's success with other technology initiatives in recent years. One reviewer made note that the project team's pre-existing relationships with manufacturers could be a powerful tool, but cautioned that it remained to be seen how past experiences would translate to advanced controls deployment, which required a systems versus individual product approach. Another reviewer remarked that there appeared to be a large number of utility partners involved, which might help define a course for utility programs to advance SSL controls adoption.

Reviewers thought that proposed future work seemed reasonable, and remarked that completion of pilot training and other energy efficiency programs by the end of 2016 should provide time for analysis of the results before the project end date. However, reviewers did feel that there should be more requirements that project materials be made publicly available, and also recommended that the project team should be sure to focus on control solutions that were incredibly simple and user friendly.

Weighted Average: 2.97 # of Reviewers: 3
Relevance: 3.33[1] Approach: 3.00 Accomplishments: 2.83 Project Collaboration: 3.17 Future Work: 3.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 222100: Demonstration of micro-CHP in Light Commercial Hot Water Applications

Presenter: Kris Jorgensen, A.O. Smith Corporation
DOE Manager: Charles Llenza

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO goals, and also on the technical potential for project outcomes to achieve significant energy savings, but there was disagreement on reviewers' expecations for the success of the technology and the ultimate impact of project activities. One reviewer expressed serious concern that market and technical barriers would prevent large-scale adoption of micro-combined heat and power (CHP) technology, thus limiting its impact. Another reviewer was optimistic that the potential and promise of micro-CHP technology was sufficient to drive market adoption, provided certain obstacles could be overcome (e.g. development of a plug-and-play model, ability to cost-effectively meet stringent state-level emissions standards, development of a strong network of installation and servicing contractors); however, even this reviewer highlighted the real threat posed by these obstacles to the project's success.

One reviewer felt that the project appeared to be well positioned to contribute to BTO's interim market goals, but others felt that no significant progress or impact had been made outside of the identification of a few demonstration project sites. Reviewers agreed that opportunities were missed for engaging with key partners and stakeholders who might support or contribute to the project – notably the natural gas industry and relevant engineering, mechanical, electrical trades – and recommended that outreach to these groups be a priority. Reviewers did commend the depth of collaboration with existing partners in the water heater industry, but agreed that partnering with a well-established water heater manufacturer was a mixed-proposition that did not guarantee successful market impact.

Reviewers agreed that future work plans were at least adequate, with one reviewer noting that future plans did a good job of mitigating risks. However, here too reviewers remarked on the risks posed by certain market barriers and technical obstacles to successful product deployment and wide-scale market adoption.

Weighted Average: 2.55 # of Reviewers: 2
Relevance: 3.00[1] Approach: 2.50 Accomplishments: 2.50 Project Collaboration: 2.75 Future Work: 2.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 222101: Financial Management for Retail Energy Efficiency

Presenter: Eric Hiatt, Retail Industry Leaders Associations
DOE Manager: Holly Carr

Brief Summary of Reviewer Comments

There was agreement among reviewers that this project was relevant to BTO goals and objectives. However, one reviewer remarked on the modesty of the project's goals, while another expressed concern that there was not a clear metric – nor any estimate of magnitude – for measuring the project's contribution toward BTO's energy savings targets.

Reviewers disagreed on the appropriateness of project's approach. One reviewer commented that the project's approach was well thought out, noting in particular that the project did a good job of addressing keys issues involved in financing retail energy efficiency improvements. Another reviewer, however, expressed concern that the project was too limited in scope, did not describe how relevant information would be diffused to retailers outside of the Retail Industry Leaders Association's (RILA's) membership, and did not address certain other and important market barriers. A third reviewer was concerned about the lack of specificity on certain approach details, while another noted that the project offered no real innovation, focusing instead on activities that are routinely carried out as part of other BTO projects and programs. One reviewer recommended that the project team consider Strategic Energy Management as a comprehensive framework that participating companies could use for goal setting, and implementing measures over time.

In regards to project accomplishments, one reviewer lauded the project's success in developing implementation models and securing commitments from its membership, but other reviewers felt that no significant direct program accomplishments were presented, remarking furthermore that RILA was working under the assumption that their implementation models would work without demonstrating that this was true. One reviewer felt that industry partnerships and collaboration were a strength of the project, given how it was bringing together the largest retailers to discuss industry-leading practices. However, another reviewer saw partnerships and collaboration as a weakness, noting that key stakeholders like landlords, contractors, governments, and utilities were omitted from the project's analysis.

Looking forward, reviewers were mixed on their evaluation of the project's stated future plans. Some reviewers felt that the project had potential to be influential in this market, expressing that a clear path forward was presented. However, one reviewer stated that project offered little-to-no information on if and how it would build upon the successes of the BTO-funded program, while another was concerned that no explanation was offered on how the project would ensure that diffusion of information and demonstrations would lead to actual energy-savings activities on the part of retailers.

Weighted Average: 2.63 # of Reviewers: 4
Relevance: 2.50[1] Approach: 2.75 Accomplishments: 2.38 Project Collaboration: 2.88 Future Work: 2.75

Program Response:

DOE has requested that RILA report the following metrics for energy projects implemented by retailers where available:

- energy savings as energy use intensity (EUI) in thousands of Btu per square foot (kBtu/SF) for 12 months before and after a project's completion;
- greenhouse gas (GHG) reductions (metric tons);
- number of buildings retrofitted or impacted;
- private sector dollars invested in project;
- workers trained as part of project; and
- jobs created as part of project.

[1] Score not included in weighted average.

Building energy use and project information is to be reported to the Building Performance Database if available.

Implementation Models (i.e., case studies) developed by RILA with market leaders (adidas, Regency Centers, etc.) will be replicated with other retail partners through the Environmental Defense Fund (EDF) Climate Corps fellowships. Additional best practices uncovered during these fellowships may also be turned into Implementation Models which can be used during subsequent years of the project by Climate Corps fellows working with retailers.

Implementation Models are publicly available for all retailers to access through the Better Buildings Solution Center. All project resources will also be publicly available through a Retail Energy Management website to be created as a part of the project. RILA will be sharing outcomes of the initial work with retailers through the EDF Climate Corps fellowships with their membership with the intention to expand adoption of these practices across the industry.

Project # 222102: Putting Data to Work

Presenter: Julie Hughes, Institute for Market Transformation
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, noting their expectations that the project's activities would expand energy efficiency programs, and lead to more efficiency investments in the two pilot cities. One reviewer noted that it might be difficult to attribute city-wide efficiency improvements to this project, highlighting the importance of monitoring and evaluation, while another recommended the project focus more on substantiating any progress made toward its goals. Overall, many reviewers were optimistic about the potential for this project to have a positive impact in New York City, Washington, D.C., and other cities, although a few questioned whether the project's activities could be effectively replicated *across the country*.

Reviewers expressed mixed opinions about the project's approach and accomplishments, though some attributed a negative appraisal to the project's nascence. Reviewers commented that the project's activities were a good first step to reduce energy consumption in existing buildings, and that the project was adequately making progress given its early stages. However, reviewers highlighted several concerns about the project's planned activities, notably that project did not fully or adequately identify market barriers to energy efficiency in the multifamily and commercial buildings sectors, nor did it explain how these barriers would be overcome.

Other reviewer concerns included that reviewers uncertainty with how the project would make building performance data any more actionable than they already are; whether the toolkit would be effectively disseminated to the proper organizations in other pilot cities;, and – importantly – how energy audits would be completed so as to lead to the completion of energy efficiency retrofits. In regards to the toolkit that will be developed as party of this project, some reviewers felt that its details remained unclear, that no firm implementation plan had been presented, and that there was risk that the toolkit would not be properly distributed.

Reviewers felt that the project was connecting with some of the right people in pilot cities, including government officials and utility providers, but also that some important stakeholders in the private sector were being left out. Though project staff expressed their intention to collaborate with the private sector, reviewers felt that no clear-cut next steps were provided in this regard.

In terms of future work, one reviewer felt that there was a clear path forward for the initial 3 years. However, others remained concerned that, unless incentives were addressed by the project, building owners would likely not take action on their own to reduce energy consumption. Another reviewer stressed that the project needed to clarify how its toolkit would add value over and above the data already collected by energy efficiency programs.

Reviewers recommended that the project had to effectively share its best practices in order to help other cities jump start their own programs, and also that the project should focus its deliverables according to target markets, noting that officials in different cities need very different resources and solutions.

Weighted Average: 2.87 # of Reviewers: 5
Relevance: 3.00[1] Approach: 2.70 Accomplishments: 2.80 Project Collaboration: 3.30 Future Work: 2.80

Program Response:

Given some of the challenges that were expressed by the reviewers, the project will likely include a new Go/No-Go decision point to encourage incremental progress in both the development of the toolkit and the articulation of the value that this data can provide to program implementers. Steps will be taken to gather feedback on the toolkit throughout the duration of the project, leveraging new and existing networks through DOE and the Institute for

[1] Score not included in weighted average.

Market Transformation (IMT), will support the effort to distribute and implement the final version of that toolkit that will provide an easily replicable solution for cities looking to gain value through leveraging their data resources.

Project # 222105: SoCal Edge

Presenter: Ben Stapleton, Los Angeles Cleantech Incurbator
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers agreed on this project's relevance to and alignment with BTO goals. However, one reviewer was not clear on what innovation was being introduced by the project's work plan, and another reviewer was concerned that the project's premise was based on very broad and unproven assumptions: that a technology which demonstrated energy savings in a U.S. General Services Administration (GSA) demonstration project would perform the same in a different building application.

One reviewer noted that the project team did a nice job of identifying an "on-ramp" market adoption strategy for emerging technologies, but another warned that conducting a handful of pilot projects may not be enough to develop a single "on-ramp" process. Furthermore, a reviewer cautioned that if the "on-ramp" strategy cannot reliably deliver predictable energy savings from the commercial buildings it is targeting, its value is low. One reviewer lauded the important barrier being addressed by project's development of technical specifications for equipment and buildings, but another felt that the project's activity was modest, and that certain critical barriers were not being considered, notably the potential lack of an installation and servicing network.

Reviewers highlighted that because the project had operated for less than a year, there have not yet been significant accomplishments or impacts. However, they also noted that the project had already met key milestones and appeared on track to meet stated goals and accomplishments.

One reviewer felt that progress was difficult to assess because the specific technologies being pursued in demonstration project were not identified, while another felt that the project lacked a practical roadmap to accomplish its goals. A frequent reviewer comment was that the planned project timeline of 2 years would be insufficient to complete project activities and accomplish project goals. Finally, a third reviewer noted that the project's plan (i.e., to identify best-in-class technologies, leverage DOE performance specifications, and engage utility partners to deliver reliable and repeatable energy savings) was a significant undertaking. Being unfamiliar with the project team's testing, analysis, and deployment expertise, this reviewer was unsure if the project could reliably and repeatedly accomplish its goals.

One reviewer though that the project demonstrated good local engagement, while another highlighted the project's creative matching of interested and motivated building owners with an incubator of new, innovative technologies. One reviewer did express concern that, for a project focused on leveraging partnerships, the project was not leveraging the Design Lights Consortium's Qualified Products List for light-emitting diode (LED) lighting.

One reviewer thought that the project's future work plan appeared sound, if not a little ambitious, and identified no major red flags in planned work. However, another reviewer was concerned about the lack of clear metrics for measuring success, while another was not clear on how the project's planned approach would continue after DOE funding has concluded.

Weighted Average: 2.54 # of Reviewers: 4
Relevance: 2.50[1] Approach: 2.63 Accomplishments: 2.38 Project Collaboration: 2.75 Future Work: 2.50

Program Response:

The objective of SoCal Edge is to create a regional model to increase the conversion of technology demonstrations to larger regional adoption, thus providing local "boots on the ground" to scale up energy savings across regional buildings. Piloting this process includes screening and vetting tools, approaches and developing strategic networks to expand the program's reach, like the Los Angeles Department of Water and Power and major building owners.

[1] Score not included in weighted average.

DOE will look for program replicability and sustainability as the project moves forward over the longer term. In the next budget period, the Los Angeles Cleantech Incubator (LACI) and the L.A. Better Buildings Challenge (BBC) will be exploring the benefits of expanding its deployment reach by focusing more engagement with the L.A. Department of Water and Power to use demonstration project results to inform incentive program development. LACI and L.A. BBC will identify the best in class approaches to achieve the project's impact objective: 100 buildings adopting technologies that achieve 20-50% savings per project.

Project # 222106: Envision Charlotte Project

Presenter: Sean Flaherty, Envision Charlotte
DOE Manager: Priya Swamy

Brief Summary of Reviewer Comments

Reviewers described this project as highly relevant to BTO, with one noting that there was a clear and direct link between Envision Charlotte's well-articulated and measurable efforts on one hand and BTO's goals on the other. One reviewer warned that because the project was very targeted to one region, it might be prevented from having a significant dent in BTO's nationwide objectives; however, this warning was tempered by a note that the project's replicability could lead to broad impact.

Overall, reviewers felt that the project was a great model for the reduction of resources by end users, and recommended that the project should share its experience with other cities to help maximize the project's impact in other parts of the country. In particular, reviewers recommended exchanging notes about their processes with the City of Milwaukee, who is implementing a similar, well-regarded project.

Reviewers felt that the project's approach was very well thought out and focused on critical market barriers. However, reviewers also noted that the City of Charlotte had the luxury of being home to many forward thinking businesses, which helped the program to both succeed and grow. One reviewer noted that while the project's design appeared effective, it relied on slightly unproven strategies and did not have a clear plan for scaling. Another reviewer highlighted that the approach was not entirely clear in all aspects, including around how energy efficiency measures would be financed and what occupant engagement strategies would be used.

Reviewers felt that progress was being made towards project goals, and expressed every confidence that the project would move ahead as planned. One noted that project activities appeared to be moving well toward BTO performance goals, but that a little "tuning" might be necessary to achieve BTO targets and to scale the project's activities to other cities. Reviewers felt that all parties involved – including Duke Energy, key city partners, and the University of North Carolina (UNC) – were actively engaged and steadily working towards the project's goals. One reviewer noted that the project team showed a strong understanding of the diverse networks of city and utility stakeholders, but could do a better job of interfacing with the private sector to drive creative energy efficiency solutions and business models.

Reviewers felt that it was too early to know how well the project's proposed future work had been designed, but that efforts appeared to be headed in the right direction. Some concern was noted regarding work on behavioral change, citing that those types of programs are very difficult to apply effectively; reviewers counselled project staff to carefully consider what behavior change can realistically achieve. Another reviewer noted that scalability may be difficult because the approach was tailored to specific building stock, but another noted project's efforts to expand the program within the city, and that the project's success was evidenced by Duke Energy wanting to move the program to elsewhere in its service area.

Weighted Average: 3.44 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.63 Accomplishments: 3.38 Project Collaboration: 3.38 Future Work: 3.25

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 222109: Accelerate Performance

Presenter: Adam McMillen, Seventhwave
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Overall, this project was very well regarded by reviewers, who felt that it was well thought out, supported BTO's long term goal of reducing energy use intensity (EUI) in commercial buildings, and provided an excellent opportunity to demonstrate that new buildings can be built to consume 50% less energy than code. Reviewers noted that the project did a good job of simplifying innovation and implementation, and that it wisely leveraged existing energy efficiency programs and their related resources.

Reviewers felt that interim goals appeared achievable, though they expressed concern that the project's energy savings targets were imprecise, potentially rendering progress difficult to track. Reviewers also noted that anticipated energy savings might not materialize until after the 3-year, BTO-funded performance period had closed, suggesting that a longer period of performance may be required for long-term goals to be achieved.

Reviewers highlighted that the project was heavily focused on a critical barrier to energy-efficient commercial construction – namely, that business customers are not asking for high performance buildings, and that energy efficiency is not being considered in new construction until too late in the process – but also pointed out that there were other important barriers which the project failed to address, including financing, measurement and verification, and the long duration between design and measured savings.

Furthermore, one reviewer was concerned that the project's solution for the barrier of interest (i.e., tapping utilities to be lead in promoting the project's procurement model) had its own myriad limitation. This reviewer highlighted that until highly energy-efficient construction was no longer cost prohibitive, it would need to be heavily incentivized; this reviewer found it difficult to believe that utility funding would be able to finance all project activities, recommending that project staff should consider a utility energy services contract (UESC) approach to financing new work where appropriate.

In terms of partnerships and collaboration, reviewers felt that this was an exemplar project, featuring close collaboration between project staff and energy efficiency programs and other stakeholder in the regions being targeted. One reviewer noted, however, that while stakeholder engagement was particularly impressive in Illinois, additional work remained to gather stakeholders on the ground in Minnesota, Colorado, and Connecticut. In all locations, one reviewer made note of the project's failure to collaborate with banks and other financial institutions, an activity which could help address financing shortfalls that arise.

Some reviewers thought that the project's future plans were good, at least within the scope of work presented, but others remained concerned that activities and impacts would need to take place beyond the project's 3-year period of performance.

Weighted Average: 3.24 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.13 Accomplishments: 3.25 Project Collaboration: 3.38 Future Work: 3.25

Program Response:

Accelerate Performance has produced very promising initial results. Seventhwave has successfully integrated a pipeline of projects and owners in three different, regionally diverse utility territories. Performance-based procurement and utility program development is well underway with regulatory approval moving forward. Problems and barriers with programmatic development are often proactively identified and addressed as the project moves forward. Useful approaches and lessons learned will support replication by in other projects and regions. DOE shares concern with the term of the project considering the length new building construction and the time necessary

[1] Score not included in weighted average.

to verify post-construction performance. However, Seventhwave is progressing ahead of schedule and has met all milestones to date. Resources and practices to support replication will be developed within the three year project timeframe. DOE will be looking for monitoring and verification protocols to support utility program development, as well as regulatory approval of pilot offerings by at least one utility, in the next budget period.

Project # 222106: Better Buildings Challenge - Milwaukee

Presenter: Eric Shambarger, City of Milwaukee
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers remarked that the project's energy efficiency upgrade plan for commercial buildings was in exact alignment with BTO's goals. One remarked, however, that the project's problem statement and direction were relatively open-ended and ambiguous, and recommended that the problem statement be tied directly to specific metric-based goals that linked to BTO targets. Another reviewer observed that the relevance will be on target once the project is a bit more mature, though at the time it was too much in its infancy stages.

Reviewers agreed that the project's approach seemed to be on target, given its early stages, and further that the project was moving in the right direction to get its program off the ground. One reviewer remarked that project staff appeared to have given thought to nearly every potential barrier that could impede progress toward overarching goals. Another noted that the project's design appeared to address the market barriers identified at face value, but that it was difficult to see whether the project was taking clear action toward its objectives. For the age of the project, reviewers felt that project staff had a good base of knowledge and direction, and also that there appeared to be a clear plan for the project to deliver progress toward the relevant goals. However, reviewers felt that it was far too early in its timeline for the project to have had identifiable progress to report.

Reviewers observed that the project has an impressive array of partnerships, and that, as it was early on, it was still engaging others to participate. One reviewer remarked that the project appeared to coordinate well across a large field of stakeholders, and demonstrated an ability to properly utilize stakeholders, as necessary, while leading a process that appeared uncomplicated to its users. Another reviewer felt that once the project was more established and had a proven track record, other businesses would also want to participate.

In terms of future work, reviewers felt that the overall approach to the full project cycle was very thorough, and gave thought to the degree of attention that each step required. One reviewer commented that there had clearly been a lot of good input in the project's design, and that the project team appeared have a clear handle on what the next steps were. However, another noted that the proposal for future work presented only a "broad strokes" vision of what the project should look like, whereas the reviewer would have liked to see more details.

One reviewer recommended that the project team reach out to Envision Charlotte team to have a conversation on lessons learned from Charlotte's successful program.

Weighted Average: 3.30 # of Reviewers: 4
Relevance: 3.25[1] Approach: 3.50 Accomplishments: 3.13 Project Collaboration: 3.38 Future Work: 3.25

Program Response:

Milwaukee will continue outreach through partners, training with auditing tools, and trialing the customer management tool to identify improvements. In the next budget period, DOE will be looking for the establishment of a new work study program and testing of the customer management tool with 30-50 buildings in multiple commercial building sectors.

[1] Score not included in weighted average.

Project # 25136: OpenStudio

Presenter: Larry Brackney, National Renewable Energy Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed on the relevance of this project to BTO's goals, remarking that it provided a critical resource and key infrastructure tool that allowed for the free-market development of applications, strongly supported performance-based building design and transaction approaches, and helped a range of stakeholders to effectively understand and incorporate the value of energy efficiency into the commercial building market. Several reviewers noted that the concept of "market barriers" was not as applicable to this project, as the project represented an ongoing effort to continually improve a piece of energy modeling software for which market barriers to its adoption and use were long ago identified and overcome.

Reviewers noted that the project team had a clear way of organizing its work flow to focus on bug fixes, user requests, and longer-term developments, and that the project team continued to focus its workflow on those features that the industry found useful. However, reviewers did identify a few features they felt were missing from the tool, including a lack of design-decision support tools dedicated to net zero energy commercial buildings and a lack of focus on high-impact technology applications.

One reviewer felt that the project's deliverables have significantly contributed to BTO's impact goals, commenting that continued support, improvement, and expansion of the tool was one of the critical functions that DOE has provided over the years. Another reviewer felt that, by widely supporting other DOE programs, this project's accomplishments would ultimately be a great deal more than the sum of all direct applications of the tool. Regarding this impact, however, reviewers expressed a desire to see more measurement and reporting efforts, commenting that it was difficult to directly relate project outcomes to BTO's quantitative goals and performance targets.

Reviewers thought it was clear that the project team collaborated with an extensive network of DOE and external stakeholders, with one reviewer remarking that no stakeholders appeared to have been omitted. While the stakeholders were well known, however, reviewers would have liked to hear more about the many roles played by these stakeholders in the development of the project's tool. One reviewer also felt that some thought should be given to the needs of end-users of derivative products built from the tool, a function that was currently being left to third-party developers. Another recommended that the project might consider pursuing increased industry cost share, given its slew of successful partnerships.

Reviewers generally agreed with the project's future plans for new features and updates for the tool, and also remarked that the project team appeared to have clearly thought out its method for prioritizing its work. However, one reviewer thought that future work was not spelled out with sufficient detail, while another thought that future plans should prioritize efforts to identify cross-over functionality between the project deliverable and other major tools (e.g., Asset Score).

Weighted Average: 3.21 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.13 Accomplishments: 3.25 Project Collaboration: 3.38 Future Work: 3.00

Program Response:

OpenStudio is a long-running foundational DOE project that will continue for the foreseeable future. The project is laser-focused on software industry needs and collaboration with industry and other stakeholders (e.g., utilities, state energy agencies) will continue to be an important aspect of the project.

It is difficult to attach traditional performance metrics (i.e., the types of metrics that are attached to physical widgets such as light-emitting diodes (LEDs) and windows, in particular, installed cost and lumens-per-watt or U-value) to

[1] Score not included in weighted average.

software projects as well as to account for energy savings. Rather for software, DOE focuses on deployment and use metrics. Current DOE metrics for OpenStudio (and EnergyPlus) use AIA 2030 Commitment reporting data to measure use in design and energy savings over code-baseline. DOE will investigate other potential metrics and sources of data for tracking OpenStudio use.

Suggestion for alternate peer review structure for EnergyPlus (and maybe other large long-standing projects) is well taken and will be considered for implementation next year.

Project # 25150: Building Energy Asset Score

Presenter: Nora Wang, Pacific Northwest National Laboratory
DOE Manager: Andrew Burr

Brief Summary of Reviewer Comments

Reviewers agreed that this project was relevant to BTO's goals, with multiple reviewers remarking that the project was either critical to achieving the goals or would have a significant impact on BTO's ability to achieve its goals. Reviewers believed that the project team adopted a good approach to the development of the Asset Score tool, and liked in particular the tool's simplified interface; its flexibility to operate with rudimentary information or with additional, increasingly precise inputs; and, its ability to identify efficiency-improvement opportunities based on the user-defined energy performance of a building.

Reviewers thought that the market barriers the project aimed to address were useful and relevant, and that the project appeared to be working towards appropriate solutions. However, one reviewer thought that the project was failing to address certain barriers related to the usefulness of the tool which could prevent key stakeholders from adopting it. In addition, while reviewers acknowledged that this the tool was different than the U.S. Environmental Protection Agency's (EPA's) ENERGY STAR Portfolio Manager tool, reviewers were concerned that differences were not immediately obvious; reviewers recommended coordinating closely with EPA to appropriately market the different tools.

While reviewers identified a number of the tool's features and technical accomplishments to illustrate progress to date, many reviewer comments focused on the future of the project. At worst, reviewers warned that this tool could become just another optional assessment tool for government buildings. At its best, however, reviewers remarked on the tool's potential to transform the real estate market. One reviewer described the tool's potential to significantly impact the BTO's performance goals, but only if it were to reach enough of the market; this reviewer expressed concern that the project's target of reaching only 1% of commercial buildings by 2020 was too low.

Reviewers generally agreed that the project team demonstrated a deep understanding of key stakeholders in the market, noting that the project was working with the proper stakeholders and using them very effectively. One reviewer lauded the project team for creating a complex tool with a great deal of consultation and collaboration, though another reviewer commented that it was difficult to identify how close the level of collaboration was with different stakeholders. One reviewer referred to the project's partnerships and collaborations as a good start, but thought that more outreach was needed, including with larger real estate companies.

In terms of future work, reviewers thought the project's work plan would add functionality to the tool and be effective at overcoming current market barriers. However, while some reviewers felt that the project was poised to overcome obstacles related to technical implementation, others felt that the project team did not sufficiently identify potential technical risks. In addition, one reviewer thought that the project team should focus more on working with key industry stakeholders to ensure the tool was meeting these stakeholders' needs. Another reviewer recommended that the project team focus more on increasing the tool's connectivity and integration with other DOE tools (e.g., the Standard Energy Efficiency Data (SEED) Platform and Buildings Performance Database).

Weighted Average: 3.19 # of Reviewers: 6
Relevance: 3.50[1] Approach: 3.42 Accomplishments: 3.08 Project Collaboration: 3.17 Future Work: 3.00

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 25301: Assessment of Advanced Measurement and Verification Methods (M&V 2.0)

Presenter: Jessica Granderson, Lawrence Berkley National Laboratory
DOE Manager: Cody Taylor

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project to BTO's goals. One reviewer remarked that the project was well positioned to provide valuable measurement and verification (M&V) of energy efficiency improvements, while another described the project as critical to the success of BTO's overall goals and the energy efficiency market at large. However, reviewers also pointed out that while savings verification are core to BTO program goals, this project's tool would not directly produce energy savings, and therefore would not directly contribute to BTO's quantitative performance targets.

Reviewers agreed that the project's approach addressed a significant market barrier (i.e. skepticism of building owners about investments in energy efficiency measures), with one reviewer describing the project as being "laser-focused" in this regard. Other reviewers remarked that the project's approach seemed reasonable and valid. Reviewers agreed that the project had been successful in solving technical issues related to its objective. However, they expressed concern about how the project's outputs would be adopted or seeded into the community in a manner that supported longer term functionality, and recommended that the project team focus more on the infrastructure and support networks required to see this work continued.

Another point of reviewer concern focused on the question of uncertainty, noting that if the project team wanted to see successful future deployment of the tool, they would need to help bound the maximum level of acceptable uncertainty in energy-savings M&V.

Reviewers made note that, to date, the project's progress was in line with its goals, commenting specifically that the project had demonstrated achievement of near term goals and was well positioned to deliver intermediate goals. However, reviewers expressed concern regarding the project's ability to achieve its long term goals. This concern revolved around the two issues referenced above: (1) whether the team will provide formal guidance on the acceptable level of uncertainty for M&V tools; and (2) whether the team can find a permanent solution for sustaining its project deliverables beyond the project period.

Reviewers felt that the project team demonstrated good understanding of market players and the M&V tools available, and engaged in significant collaboration with an impressive list of partners, including proprietary tool developers, industry stakeholders, utilities, and end users. However, one reviewer questioned why regulatory stakeholders did not have a formal collaborative role earlier in the process.

Reviewers agreed that the project team presented a logical and achievable set of tasks for the future, with some commenting that momentum existed to carry the project forward. However, other reviewers thought that next steps were unclear, that some risks were not fully considered, and that the future of the project's tool had some uncertainty, because an appropriate entity had not been identified to whom stewardship of the project's deliverables could be transferred. One reviewer felt the project team appeared focused on tying up these questions, however, and expected the team to be successful.

Weighted Average: 3.15 # of Reviewers: 7
Relevance: 3.43[1] Approach: 3.07 Accomplishments: 3.29 Project Collaboration: 3.21 Future Work: 2.71

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 25480: Better Buildings Workforce Guidelines

Presenter: Roger Grant, National Institute of Building Sciences
DOE Manager: Charles Llenza / Amy Jiron

Brief Summary of Reviewer Comments

Reviewers generally agreed on the relevance of this project to BTO's goal, remarking that project deliverables filled a clear need in the market and provided a tool that would help boost the energy-efficiency-improvement economy. One reviewer expressed reservations about the number of existing credentials that may already meet market needs, but even this reviewer acknowledged the project's value-add.

Several reviewers felt the project had successfully identified a key market barrier (i.e., the lack of national guidelines for energy-related professional credentials), and agreed that the project's approach was appropriate for addressing market needs. However, one reviewer was concerned that many barriers discussed were barriers to building energy efficiency rather than barriers to workforce development, and that the project had moved forward assuming that development of new workforce guidelines would have a conclusive and significant impact. Another reviewer expressed concern over the assumption that accredited workers save energy, noting that this claim should be validated and widely communicated to overcome skepticism in the construction industry. A third reviewer would have liked to hear more specifics on the market demand for workers in this field, to get a better understanding of the future job market for workers trained for clean energy jobs.

One reviewer felt that the project had met key milestones, and had identified long term outcomes which appeared achievable, while another had no concerns about the project team's ability to meet its goals. In contrast, one reviewer commented that the project's achievements had made little progress toward meaningful program-level goals, and was concerned that the project should have had more concrete progress to report as it neared its end. Another reviewer projected that the project had a greater likelihood of supporting BTO program goals in the future, once the first group of workforce professionals were trained. Finally, one reviewer recommended that the project team develop metrics to measure the success of their workforce training once it was implemented.

In terms of collaboration, reviewers remarked on the project's success in reaching out to key public and private sector stakeholders, and on its effective coordination with existing credentialing programs. One reviewer would have appreciated more detail on the project's collaboration with its stakeholders, particularly its collaboration with government agencies. Another reviewer was concerned that no major architecture, engineering, and/or construction firm was represented on the project's board of advisers, believing that designers were critical to engaging educated professionals on a construction site.

Looking forward, one reviewer felt that the barriers that remained had been identified, and another felt that most of the project's difficult tasks were complete. However, one reviewer was concerned about the project team's ability to complete its work and provide enough support to partners to carry on the work beyond the funding period. Another reviewer recommended that the project team prioritize its efforts to educate others about the certification and its associated titles, as organizations that are unaware of the certification will not put enough emphasis on these titles.

Weighted Average: 3.30 # of Reviewers: 6
Relevance: 3.17[1] Approach: 3.17 Accomplishments: 3.25 Project Collaboration: 3.67 Future Work: 3.17

Program Response:

Since the Peer Review, two additional certifications have received DOE recognition: Certified Energy Auditor from the Association of Energy Engineers and the Certified Commissioning Professional from the Building Commissioning Certification Board. Work is also underway to create a certificate program for a Better Buildings Workforce Guidelines (BBWG) job - the Building Operations Professional (BOP). The subject matter experts (SME) committee has been formed and the Board has been organized. Scales for each task and knowledge, skills,

[1] Score not included in weighted average.

and abilities (KSAs) for the BOP has been developed. The scales have been provided to SME for review and validation. Finally, a survey has been developed and disseminated to stakeholders in the industry regarding the BOP.

RESIDENTIAL BUILDINGS INTEGRATION

Project # 11119: Healthy Efficient Homes Research & Standards Support

Presenter: Iain Walker, Lawrence Berkeley National Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers agreed that this project is relevant to BTO's portfolio since healthy efficient homes are an important and often misunderstood aspect of low energy development. They agreed that indoor air quality (IAQ), especially in low-load homes, was an important area that builders needed to consider and homeowners needed to understand. There was general consensus among the reviewers that this project took an appropriate approach in addressing IAQ by conducting the right research and development (R&D), although one reviewer commented that cost impacts were not discussed. One reviewer commented that this project was filling information gaps that have the potential to lead to changes in industry standards, while another claimed the results are still too developmental and do not indicate clear cost/benefit solutions. Reviewers agreed that key stakeholders were actively involved in the project, though one reviewer commented that builders were not adequately represented.

Proposed future work was well thought out, built well on work already completed and addressed many of the concerns mentioned in the review. The reviewers agreed that this project had strong R&D capabilities, well qualified staff and engaged partners to develop market solutions. One reviewer found that the major weakness with the project was the lack of builder partners. Another did not see the level of risks clearly demonstrated. One reviewer acknowledged staff participation in IAQ standards committees to enable them to quickly move the results of the project into a position to impact the market.

A third reviewer focused more on broader communication, claiming many in the industry simply do not understand what the potential risks are and therefore will likely fight the adoption of new requirements that cost dollars, so this project needs to find a way to better educate all in the chain to home owners, including homeowners.

Weighted Average: 3.41 # of Reviewers: 4
Relevance: 3.75[1] Approach: 3.63 Accomplishments: 3.13 Project Collaboration: 3.63 Future Work: 3.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 11122: Buildings America Envelope and Advanced HVAC Research

Presenter: Jeff Munk, Oak Ridge National Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers felt the relevance of this project was limited due to similar already commercialized products on the market, limited market appeal, and limited applicability. In regards to approach, reviewers agreed that market penetration and homeowner and contractor awareness should be addressed, possibly through demonstrations. One reviewer commented on the lack of information provided on the potential cost to operational savings. Additionally, there were testing concerns since field tests were performed in Alaska, and reviewers felt they should be supplemented with testing in more typical zones for these systems (such as the Midwest). Finally, regarding approach, one reviewer wanted to see more assessment of needed training/technological barriers to full scale implementation.

One reviewer saw success more likely with the integrated hot water system because it would serve the area of the country that most new homes are built. Another reviewer thought this technology was premature to be included in the RBI portfolio until there was preproduction/production models available to be tested in homes. Reviewers concurred there was a good level of manufacturer involvement, the main stakeholder at this stage in the project. One reviewer was impressed with the potential for these technologies, but commented that non-technical barriers should be addressed in the research program moving forward. Another reviewer concurred with the performers plan not to propose further work on this project upon completion of field testing in 2016.

Reviewers agreed that integrating HVAC and hot water systems was a creative solution, as long as the equipment were close to each other. One reviewer mentioned this project could be an important tool for utilities to have when seeking additional ways to shave peak demand loads, and that using existing technology means little additional training for a ready workforce. There were overarching reviewer concerns of market adoption due to market gas prices, advances in mini-split system manufacturers and installers, applicability especially in the retrofit market, and the two compressor system versus traditional one compressor systems. One reviewer recommended performing a study to determine the benefits of retrofitting the advanced variable speed air-source integrated heat pump (AS-IPH) product to each type of HVAC system as this may greatly increase its market potential. Another reviewer commented that HVAC systems sometimes run into challenges with working over the long term, and thus testing of environmental stress and operational stress must also be demonstrated to gain builder acceptance. Another noted the dehumidification aspect needs to be clearly understood.

Weighted Average: 2.55 # of Reviewers: 4
Relevance: 2.50[1] Approach: 2.50 Accomplishments: 2.38 Project Collaboration: 2.88 Future Work: 2.75

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 12204: Energy Savings with Acceptable Indoor Air Quality Through Improved Air Flow Control

Presenter: Larry Brand, Gas Technology Institute
DOE Manager: Eric Werling

Brief Summary of Project

Reviewers felt this project was relevant to the BTO portfolio, and an important issue in existing homes. However, two reviewers expressed concerns about the overall impact of the project in the residential market. Reviewers generally agreed that the accuracy of combustion safety testing could be improved, and that this study contributed valuable knowledge that may help the market reduce the potential for false positive combustion safety tests. While one reviewer noted that this project was successfully completed, the others agreed that the number of test homes was insufficient to have a meaningful impact. Reviewers concurred that key stakeholders were generally well represented, and collaboration with industry and relevant partners was apparent and benefitted the project. Reviewers agreed that though the project was complete, the researcher had identified pertinent areas of further study to expand upon this project.

One reviewer commented that this study was the first of its kind to address reducing false positive combustion safety tests and that it found, through field testing, that many failures are due to system install deficiencies, not exhaust ventilation. The study scratched the surface of the potential for improving false positive combustion safety test results. Another reviewer thought the project's strength was that these results are being integrated into standards and best practices, while a different reviewer felt that addressing the important issue of energy savings impact was the project's strongest aspect. Reviewers recommended broadening the field test in general to increase the number of homes tested, but also to include greater house diversity. The narrow sample size was the main concern of the reviewers throughout the review, and thus for any future studies, their primary suggestion focused on increasing and broadening the sample size.

Weighted Average: 2.86 # of Reviewers: 4
Relevance: 2.25[1] Approach: 3.13 Accomplishments: 2.63 Project Collaboration: 3.00 Future Work: 2.75

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 12205: A "Plug-n-Play" Air Delivery System for Low-Load Homes and Evaluation of a Residential Thermal Comfort Rating Method

Presenter: Ari Rapport, IBACOS
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers agreed that this project is relevant to the Residential Buildings Integration (RBI) Program roadmap, with the potential to change the industry if this work is successful. Reviewers agreed that most barriers and limits to implementation were well addressed and that the overall approach of this project was well thought out and implemented. However, one reviewer pointed out that at this stage of the project, a more advanced understanding of how to overcome plastic ductwork fire code barriers or significant progress towards that end would be expected, as well as an assessment of the energy needed to operate such a system. Another reviewer commented that code barriers are larger than the technical barriers, so solutions that can address the need for smaller diameter ducts systems should focus on materials and performance acceptable in the code.

Most reviewers agreed that the potential for this project if it is successful will have a large impact on the design and installation of HVAC duct systems in low-load homes and improve overall indoor air quality (IAQ). At this stage in the project, the majority of reviewers felt that project integration and collaboration was appropriate, with the exception of the lack of some builder and manufacturer engagement, even on a test level. Two reviewers felt the proposed future work was well thought out and appropriate, while the other two reviewers thought more needed to be addressed. One thought zone dampers were a huge opportunity to build into future demonstrations. Another asked what other system solutions are possible, such as ducted mini splits. One reviewer commented that this project represents a potential and relatively simple solution to a long-term vexing problem of good HVAC duct design and conditioned air delivery.

Reviewers wanted to know more quantifiable information, such as the potential per home savings compared to traditional ducting. Another reviewer wondered when this equipment would be broadly available in the market for this type of system.

Weighted Average: 3.15 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.00 Accomplishments: 3.25 Project Collaboration: 3.00 Future Work: 3.50

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

Project # 15116: Advanced Technical Solutions for Zero Energy Ready Homes

Presenter: Tim Merrigan, National Renewable Energy Laboratory
DOE Manager: Sam Rashkin

Brief Summary of Reviewer Comments

Reviewers agreed that this project is relevant to key issues identified in Residential Buildings Integration (RBI) Program roadmaps and the BTO Multi-Year Program Plan. A reviewer commented that better defining the latent and sensible load control needs of low-load homes is critical to the future of low-load home construction. Relatively little information has been developed over the years and this research program squarely addresses this lack of information. However, one reviewer questioned whether a new modeling tool will result in a change to building practices since we have known how to build low-load passive homes for 40 years, noting concerns about the high cost of developing modeling tools to confirm what is already known.

Reviewers agreed that this program addresses gaps in knowledge regarding low-load homes, especially regarding properly sizing equipment and evaluating moisture absorption and buffering. However, one reviewer thought there was much to be done before it can be used by a building designer or HVAC contractor. Reviewers agreed that project integration and collaboration was generally appropriate for this stage, but suggested including more manufacturing partners, as well as working with Oak Ridge National Laboratory (ORNL) and Lawrence Berkeley National Laboratory (LBNL) staff who work in the same or related areas. Reviewers agreed that the heavy reliance on computer modeling needs to be kept in check, by using as much real world experience and data as possible, especially through trades and builders. A reviewer highly recommended evaluation of the thermal buffering capacity of the house and consideration of changes to materials used to increase both moisture and thermal capacity in low-load homes as a way to decrease the number of hours the house operates outside of the comfort range without the need to increase HVAC size and complexity. Another reviewer approved of the focus on the ACCA manual J and S practices, but wanted to see some assessment of the size of the market not using ACCA manuals and how to approach that market.

Weighted Average: 3.49 # of Reviewers: 4
Relevance: 3.50[1] Approach: 3.63 Accomplishments: 3.63 Project Collaboration: 3.13 Future Work: 3.25

Program Response:

No Program Response Provided.

[1] Score not included in weighted average.

RAW REVIEWER COMMENTS

EMERGING TECHNOLOGIES
SOLID-STATE LIGHTING

Project # 31111: Advanced Light Extraction Structure for OLED Lighting

Presenter: Zhiyun Chen, Pixelligent
DOE Manager: Jim Brodrick

A. Relevance

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

- The gradient index substrate could potentially improve OLED lighting which is part of solid state lighting. The solid state lighting can potentially offer 217 terawatt-hours energy saving in the U.S. by 2015, corresponding to $21.7B annual savings.

- The overall goal of this project, namely a 70% light extraction efficiency, is consistent with BTO's objectives. Because this team is composed of three commercial partners, it is likely that the lab-to-market transition receives considerable attention, advancing BTO's objectives.

- High-extraction efficiency is a key to achieving more efficacious solid-state lighting and is in line with the roadmap.

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 stable scatter/nanocomposite formulation via scalable slot-die coater is promising for low-cost manufacturing.

- The project is fully focused on overcoming a well-defined technical barrier, reach the stated efficiency goal (2.9X light extraction) and to do so with an eye on commercial implementation, incorporating the new developments into the existing manufacturing processes.
- There seems to be some deviations from the original plan, which normally would envision significant computations and simulations early on. These are essential to guide the development. The project has apparently made progress without the computations but one wonders if the current formulation (integrating nanocrystals of appropriate size, size distribution, optical attributes, concentration, orientation, etc.) to create the gradient index layer sought is close to optimal.

- The goal of choosing a process with an eye towards manufacturability is appreciated.

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 has demonstrated up to 2.1X improvement in EQE and compatibility with OLED manufactured process. The company also launched Gen 1 and Gen 2 products especially for OLED markets.

- Experimental developments (introduction of scatterers in such a way that an appropriate gradient index film is formed) is seemingly on track, and the work is probably consistent with the company's on-going effort in this area meeting the efficiency target and paving the way for quick entry into the market place.

- It's a little difficult to judge the full impact of the progress since so little data was presented. The actual % extraction efficiency towards the goal of 70% was not given for example.

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) **3.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Pixelligent Technologies have worked closed with OLED manufacturers such as OLEDWorks to market their products.

- There PI and its key partners are well suited for this work and it appears that they work well together. From the written report and the presentation it is not very clear who does what, however, the project seems on track.
- In the report, it is stated that computations were proven to be intense and difficult to implement. No computational results were provided. Was Peterson Advanced Lithography (one of the partners) tasked with this effort? Given the importance of modeling and computation to arrive at a good solution prior to implementation, it would be appropriate to explain what the issues are, which computations were not done, how important they are, and if the situation can be helped.

- Pixelligent is working with a key leader in the OLED field.

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 proposed to continue improve process for gradient film manufacturing using a slot-die coater and continue to optimize the scattering layer configuration and processing, and perform more device tests using 4" by 4" substrates at OLEDWorks. The future plan is rather vague. More specific challenges and solutions would be more convincing.

- It seems that the team is close to accomplishing the development of the 4" device with 2.9X light extraction. It would be interesting to know how 2.9X was selected in the first place, and if that can be revised upwards based on what has been learned.

- Description of future work is rather generic.

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

***High*: 3** reviewers
- The substrate with index gradient with scatters for better light extraction fit well with the OLED lighting market.

- The deliverable would represent an improved product for the market. Some marketing plans would be useful, more specific that provided in the report under "project integration."

- All stakeholders want to see higher extraction 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

- The project has good integration and collaboration with potential customers.
- *None*

***No*: 1** reviewer

- Based only on the report and the presentation, it seems that at least some of the necessary computations and simulations have not been performed, and thus it is hard to tell whether the design of the gradient index layer, which is a significant part of this project, is optimal. It may be far from it?

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project seems to have good commercial prospect.
- The project's strengths are its key partners and their ability to come up with processes that can be implemented commercially. This cannot be underestimated.
- Use of natural diffusion processes to generate the GRIN layer is interesting and seems manufacturable. This detail came out of the verbal discussion but is not present in the slides.

2) **Project Weaknesses**

- The descriptions on technical aspects are rather vague.
- The report and the presentation were somewhat vague in comparison with the other project reports, making this project more difficult to review. Lack of specific information in the report might be due, at least in part, to the IP issues. In such cases, a closed door review might be helpful allowing reviewers to ask and the PI to answer questions. It is a bit difficult for the PIs to discuss details in front of their competitors.
- Hard to extract without more data, which may be intentionally withheld due to the public nature of the presentation.

3) **Recommendations**

- The team should have look into R2R manufacturing.
- In the absence of clear documentation of the actual measurement results showing improved light extraction I had to rely on the statements of the PI.
- Would like to see more experimental comps to benchmarks.

Project # 31112: ITO-free white OLEDs on Flexible Substrates with Enhanced Light Outcoupling

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 aims to improve out-coupling of OLED lighting. In 2012 SSL was responsible for saving 71 tBtu, roughly $675 million in energy expenditures.
- This solid lighting research program (and others like it) are well aligned with BTO's efficiency targets and the market needs. While the solutions and the devices developed here address the needs of a segment of the solid state market, projects such as this, collectively, help BTO meets its targets.
- High-extraction efficiency is a key to achieving more efficacious solid-state lighting and is in line with the roadmap.

B. Approach

This project was rated:
1) **3.67** 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 use of voids as non-absorbing scattering centers in high-index, low-cost plastic substrates is promising for making low-cost flexible substrates with enhanced light out-coupling.
- This project has correctly identified a market need, increasing white organic LEDs. There is a permutation of approaches to achieve this higher efficiency, and this project has selected a path based on several proven concepts and developing advances.
- As with 31119, market barriers include such key issues as manufacturability and cost impact which weren't mentioned in the presentation. The reviewer realizes that a full market evaluation is beyond the scope of the project. A quick comment on these issues would have been welcomed however.

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 has successfully demonstrated 1.6x enhancement using porous substrate and 1.9X enhancement with Ag NW-embedded PI and porous PI combination.
- Although I have not reviewed this project before, it appears that it is on target, accomplishing most of the steps it set out to do as of now. A clear list of milestones is provided and they seem to be on track. The next few months are critical but I feel the team is well positioned to meet its targets.
- The achievement of 1.9x light extraction is impressive, but there is still a relatively large gap in getting from 1.9x to the goal of 3x in the final few months.
- Also the measured result of 32 lm/W is far from the stated program goal of 130 lm/W. It's not clear to me if the 3x light extraction is consistent with this value.

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.

- The team could certainly benefit from close collaboration with industrial partners.

- The team set up by the three PIs is handling the project effectively, evidenced by the accomplishments so far. It would have been helpful if the roles of each participant was identified, particularly to see who will be responsible for system integration where all the parts have to come together in a single device later on in the course of this project.
- With an eye ultimately on the transition from lab to prototype and production, the PIs might benefit from having a suitable collaborator from the industry on board, who might help identify processes that are scalable and those that may not be.

- No industry collaborators were mentioned, but it is expected that sufficient industry contacts and communications will be exercised in order to ultimately commercialize this.

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.

- The plan for future work is not clearly presented.

- The project seems well planned and executed so far, and based on the report provided, there is no reason to believe the future work would be any different.
- However, solutions at component level must now be all combined at the device level. As noted, having an industrial collaborator would be an asset at this stage.

- I may have missed a description of next steps in the oral presentation.

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

***High*: 2** reviewers

- The team has successfully show 1.6X EQE enhancement using porous PI substrate.

- Any method for increasing light extraction by 1.9x is of value to the industry. Ideally this can be show to be cost-effective as well.

***Average*: 1** reviewer

- Reviewer 44: If successful, a prototype WOLEDs with 3X the light output is significant. The question then to be addressed relates to how to transition from lab to factory and to 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*: 3** reviewers

- The research activities are well aligned with the program's objectives.
- Research wise, the path seems clear; it might be a suitable time for the team to seek additional collaborators, funding, and industrial partners for the next steps.
- *None*

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The idea of using porous substrate is promising low-cost approach to make enhanced light out-coupling substrates.
- The strength of the project is in its detailed examination of each of the components of the device, and plans at improvements, one at a time, with the goal of an overall of 3X more light extraction. From the report it appears that the team has the expertise and the tools to successfully execute the project.
- The use of spontaneous controllable voids in a polymer system is an innovative approach to improving light out-coupling, and the initial result is promising. Glad to hear also that a patent has been submitted.

2) **Project Weaknesses**

- It is not clear how easily the phase inversion process for making the porous substrates can be transferred to large scale manufacturing.
- From the report, I do not see the path forward after the completion of the project. The fact that there is a market out there does not mean that there are entities waiting, willing, and able to take this on. Some effort on the part of the PIs would be great, especially if done in such a way that their IP rights are not affected.
- Unclear to me why the 32 lm/W result is so far from the 130 lm/W goal. Is it simply that the material is not state-of-the art?

3) **Recommendations**

- Large scale demonstration of high throughput production of porous PI seems necessary.
- The roughness and the wavelength of the corrugated surfaces could be important, and the latter adjusted optimally.
- There might be an optimal solution for substrate-trapped light with scatterers of proper size, size distribution, and concentration, and that could be determined computationally. Would the absorption be significant?
- Some additional information on the micro lenses and their efficacy and contribution would be helpful.
- In the next report, it would be great to include barriers that the team feels exist on the path to commercialization.
- *None*

Project # 31113: The Approach to Low-Cost High-Efficiency OLED Lighting

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 aims to develop an integrated plastic substrate to replace indium tin oxide transparent anode, glass substrate for OLED lighting. OLED lighting reach 200 lm/W by 2020 for a projected annual energy savings of 395 TWh by 2030.

- The main goal of this project, that is the development of flexible large-area white organic LEDs with 150 lm/W, is consistent with BTO's target of reaching 200 lm/W by 2020. The design simplification leading to reduced manufacturing cost is also a significant aspect of this proposal.

- This project mostly addresses cost which has been the primary barrier to high-adoption rates of OLEDs in solid-state lighting, and is consistent with the roadmap to increase lm/$.

B. Approach

This project was rated:

1) **4.00** 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.

- A scalable, low-cost process to fabricate an OLED substrate that integrate high surface conductivity, low surface roughness, and high light extraction efficiency in a plastic sheet using Ag NW is promising. The ALD process might be too expensive for large-area, low-cost application.

- Increasing efficiency and simultaneously reducing manufacturing costs are the twin targets of this proposal. The approach is the development of a flexible polymer layer with imbedded silver nanowires replacing three of the layers in current OLED designs with a target price of $20/m^2.
- These objectives, put all together, will overcome some significant market barriers, providing improvements in performance, cost, and efficiency.

- Cost barriers and market adoption are the primary goals of this effort.

C. Accomplishments/Progress/Impact

This project was rated:

3) **4.00** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
1) **3.67** 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 a flexible OLED with 80 lm/W efficacy at 1000 cd/m2 using the integrated plastic substrate.

- The data provided shows that the project is on track, has achieved significant milestones, reaching 81 lm/W in a simple and flexible design.

- Very good results so far, with resistivity equivalent to or better than ITO and light output substantially better than the control case.

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.

- The team has worked closely with OLEDWorks to the level of process integration.
- This project seems to have the necessary expertise and partners (university and industry). As the report indicates, input from industrial partners has been used to modify some of the processes. This is excellent. The contributions of various partners are clearly stated in the report.
- Valuable collaboration with industry is included in this effort.

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.

- Barriers and potential solutions to reach 150 lm/W at 1000 cd/m^2 target are clearly described.
- The next steps are clearly outlines and there are two major ones: increasing efficiency and improvements in the flexible substrate. It would have been helpful to this reviewer if more details about the path forward were included in the report.
- Identification of the reason curve 4 is so much better than the others in slide 11 should be targeted. This result needs to be reproduced.

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

***High*: 3** reviewers

- The deliverables are well aligned to reach flexible OLED market.
- Successful implementation of the stated goals and the involvement of the industrial partner will help pave the way for creating significant IP and the potential to bring the product to the market.
- Excellent results with potential cost 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 activities focus on reach the target OLED performance.
- The project is well planned and executed so far.

- *None*

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The team has made impressive progress to fabricate OLED on the newly developed integrated flexible substrates.
- The project has superb goals, appropriate partners, and the necessary tools and skills.
- Compelling approach with a focus on simultaneous performance and cost improvements, with great initial results.

2) **Project Weaknesses**

- ALD process might be too costly for low-cost, large area manufacturing of integrated substrates.
- As noted, some information on the planned path forward to go from 81 lm/W to the target value of 150 lm/W, and to mitigating other technical issues (e.g., substrate flexibility) would have improved an otherwise excellent and clear report.
- Disappointing that the PI did not know why the one standout result was so much better than the others. Also I have some concern about the tarnishing of silver over time--not sure if that is a possible issue or not however.

3) **Recommendations**

- N/A
- This is an excellent project.
- Show reproducibility of the one outstanding result.

Project # 31119: CMU- Novel Transparent Phosphor Conversion Matrix with High Thermal Conductivity for Next-Generation Phosphor-Converted LED-based Solid State Lighting

A. Relevance

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

- The project aims to improve the thermal conductivity of the encapsulants for pc-LED. No potential energy benefits were discussed.
- The 20-30% of the energy absorbed by phosphors that is lost to heat, instead of light is rather significant, and the efforts to reduce this are consistent with BTO's goals. A reduction in this loss will additionally provide for cooler and longer life LED systems.
- High-thermal conductivity encapsulants designed to replace standard silicone in LED packages provide clear and measurable benefits to LEDs used for lighting.

B. Approach

This project was rated:

3) **3.33** for the degree to which it focuses on critical market barriers, and
1) **3.33** for the degree to which the approach addresses the market barriers identified.

- The approach to use surface polymerization to improve interface for better thermal transport and dispersion has potential.
- Although having some losses, as is the case in the current LED devices, does not constitute a market barrier, effort at reducing thermal absorption - especially in the low cost volume cast design - can lead to higher efficiency and longer device life, both of which can help marketing of mid-power pc-LEDs.
- Market barriers include such key issues as manufacturability and cost which weren't mentioned in the presentation. The reviewer realizes that a full market evaluation is beyond the scope of the project. A quick comment on these issues would have been welcomed however.

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.

- The improvement on performance is limited at this stage.

- The first five tasks that the performers had set up for themselves have been carried out leading to the synthesis of hybrid siloxanes with improved particle dispersion, reduced scattering, and increased thermal conductivity (which is still below the 1 W/m-K) goal.

- The goal of 1 W/m-K is an aggressive one, and the best result to date appears to be about 0.6 W/m-K. It's not clear if the gap can be closed, but the 0.6 W/m-K number result may well be sufficient to provide most of the desired benefits, judging by the figure on slide 3.

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) **3.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The team work closely with OSRAM.

- It appears that the project stuff work effectively together and with OSRAM, both parties having an interest the outcome. It would be helpful to clarify in the report the roles of various parties, the funding each receives (or contribute), and the tasks they would carry out.
- I would have liked to know OSI's view of the progress and whether the approach being pursued is likely to be adapted for manufacturing and production.

- The collaboration with a key siloxane manufacturer as well as a major LED manufacturer gives the proper input and perspective to the project

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.

- It is not clear what needs to be done to close the performance gap.

- The project is already more than half way through and it seems that the performers are following the path they set for themselves. Happily, it seems that some of the proposed work had been accomplished prior to the award (8 invited presentations and 4 students graduated) enhancing the chances of accomplishing the major tasks going forward.

- The key parameters that need to be measured here are LED package performance and reliability, the latter indicated by the photo-thermal stability measurements. This will provide an initial approximation of LED package reliability which otherwise requires significant testing by the LED manufacturer.

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

***High*: 2** reviewers

- The nanocomposite is a promising approach to improve the thermal conductivity of encapsulants.

- The goals of this program are of interest to all LED and silicone manufacturers.

***Average*: 1** reviewer

- There are several approaches to increase conversion efficiency and life span of LEDs. It is not clear to me that even if we achieved 100% of what we set to accomplish here, the present approach will necessarily be adapted for manufacturing. Some discussion on this issue with the industrial partner would be helpful.

***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

- Improve the interphase is a promising approach to improve thermal conductivity. However, there may be other areas that need attentions as well.
- It seems that the project is progressing as planned.
- *None*

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The approach to improve NP and polymer interface is promising.
- The team work closely with OSRAM.

- The strength of the project is on its promise, and accomplishments so far, to develop thermally conductive transmissive medium without increased light scattering. Proper coordination with OSI (assuming IP issues are settled) would have immensely helpful.

- The strength of this project is the focus on the details of covalently bonded ligands for integrating the nanoparticles into the siloxane, rather than simply adding untreated particles as any lab could do. Also, the inclusion of the siloxane manufacturer and the LED manufacturer into the project are important to validating its ultimate viability. The success of the surfactant to disperse the particles is also impressive.

2) **Project Weaknesses**

- The thermal conductivity improvement is limited. It is not clear what exactly need to done to close the performance gap.

- I do not see any negatives in this project.
- One concern that I have is that with increasing number of particles there will come a time where scattering also increases reducing transmissibility, and also the ability to produce particles of precise size without much variations Fig. under Accomplishment 2 shows that the scattering cross-section is rather sensitive to particle size.

- My main concern is that PMMA is not as thermally stable as silicones and there might be an unacceptable sacrifice in photo-thermal stability of the combination as a result. I wonder if this could be validated earlier in the project.

3) **Recommendations**

- Thermal modeling at the nano- and microscale might be necessary in addition to the molecular level models.

- The article by one of the collaborators, Tchoul et al. in 2015 (Polymeric Materials in Phosphor-Converted LEDs for Lighting Applications: outlook and Challenges) is rather interesting and puts the current research in a broader context. Would the result of the current project have bearing on any of the other conversion layer architecture?

- A comment on the effect of the ligands, surfactant, and particle loading on the curing rate and degree of cure of the silicone would be valuable. This is a potential reliability/manufacturability issue.
- It may have been useful to test with LEDs some compositions of the matrix during the course of the program, not just at the end.

EMERGING TECHNOLOGIES
HVAC, WATER HEATING, & APPLIANCES

Project # 30002: Advanced Hybrid Water Heater Using Electrochemical Compressors

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project is perfectly aligned with the BTO's goals and it presents one of the key technology of the BTO portfolio. The presented ECC technology may very well serve as a viable cost-effective and cross-cutting one for targeted reduction in buildings energy use

- *None*

- Project supports DOE BTO goals of reducing energy consumption of water heating compared to electric resistance while also eliminate need for high GWP refrigerants. It is not clear if project will save energy compared to "conventional" heat pump water heaters or if it saves energy on a primary energy basis compared to natural gas/propane fired heaters. However presumably quiet operation could spur additional adoption of HPWH.

- This project is aimed at developing an advanced pump based water heater that uses electrochemical compression rather than more traditional mechanical vapor compression. This is highly relevant for the DOE BTO program mission, both in terms of the advancing of innovative enabling technologies as well as the potential energy savings.

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.

- ECC is a transformational technology for the cooling/refrigeration cycles. Current effort is focused to implement ECC into heat pump for water heating application to meet the BTO's metrics and satisfy the market targets. Close cooperation with the market leaders such as GE enable the project team to identify the critical barriers for the technology and focus on their overcoming. Low pressure operation and target cost are the most critical for the technology deployment.

- *None*

- Project clearly identifies barriers (cost of components, long term performance, system integration) and has laid out and achieved a good plan to address each of these barriers. In particular, the close collaboration with GE is noted as a strength.

- Water heating remains an essential and core need for nearly all residential and commercial entities. However the vast majority of water heaters do not make the most potential of the energy they use, and typically suffer from poor efficiencies.
- The project has identified these critical market barriers, assessed them quantitatively, and has oriented the product research and development to make significant improvement in the existing state-of-the-art such that, if developed successfully, the potential exists to develop a product that would be competitive with current technologies, while offering a notable improvement in device efficiency.

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 reported project is rapidly approaches its final stage - Commercial Scale Testing in June 2016. The accomplishments are as per approved SOW. Membranes and MEAs are commercially available now and demonstrated the superior performance over the competing off-shelf products. Design tooling and testing resources/protocols are established. Production capacity and cost are established (compelling economics - low CAPEX of <$500 at lower OPEX over gas-fired systems). ECC prototype is delivered (estimated cost <$70). Commercial scale 50 Gal water heater system is in the final stage of evaluation (assembly and testing).

- *None*

- As most of project is complete, it is likely that project will achieve desired goals. The willingness of GE as an OEM to dedicate unfunded resources shows confidence of external entity in the technology and market potential.
- Project progress to date has been good. The team appears to have a solid understanding of the physical mechanisms and principles associated with the electrochemical compression process, have identified several near-term target goals, and are making progress both on the analytical and experimental fronts.

- Based on the progress to date, the indications are good that future work by the team will continue to progress towards the program goals. A COP greater than three is a challenging target however the technology is innovative enough that this is not unreasonable.

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.

- Very impressive collaboration and integration of the presented effort. Being a world leader of the ECC technology the Xergy team has been extensively collaborate with the leading players on the targeted marketplace - GE, DOE, OEMs, strategic suppliers, etc. Such a fruitful and active cooperation along with a numerous papers and patent applications as well as extensive number of presentations and exhibits will ensure the project success.

- *None*

- Very strong project collaboration including, GE, other water heating companies and other DOE funded projects. Potential for developed compressor technology to enable other energy efficient technologies is attractive.

- The teaming with GE Appliances is a particularly strong relationship. As a world leader in appliance manufacture, with a long history of bringing new technologies to market, the team will benefit substantially by having this expertise.

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.

- Project team outlined a clear action plan for the successful technology deployment and commercialization. Developing an advanced integrated ECC+MHHX system and cooperating with the leading OEMs such as AO Smith, Rheem and others will enable this promising technology for a cross-cutting application spectrum.

- *None*

- Proposed future work is to complete long term testing of 50 gallon unit. There are no indications that final tasks will not be completed.

- Moving forward with laboratory demonstrations and a working prototype, even at a 2 gallon level, would be a substantial milestone. The team is aware of this and has arranged its tasks and objectives to meet these milestones.

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

***High*: 4** reviewers
- The technological challenges were mostly resolved, favorable economics was established, the pre-commercial testing is underway.

- The presentation of the cost analysis was somewhat missing and discussion was minimal. The presentation did not show how a premium price reduction was obtained.

- *None*

- Water heating is an essential resource for the entire country.

***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 reported technology has been considered, characterized and evaluated from the all possible aspects dictated by such a competitive market as water heating.

- The resilience of the system to contamination, especially when operating under below ambient pressure, and air fouling needs to be addressed.

- *None*

- The task distribution and emphasis is well-balanced for the program targets.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Build upon the strong prior work and expertise of the project team members the presented work has demonstrated the initially anticipated benefits and successfully approached its final stage meeting the established metrics. Most of the market and engineering hurdles have been overcome and the project team set a sounded action plan for the follow-on technology commercialization and substantial market penetration.

- Novel concept and unique compressor technology approach. Good resources and strong background to complete the project

- Strengths
    - Clear and well defined work plan
    - Strong partners and collaboration
    - Ability of developed technology to enable other new systems

- This is an innovative, interesting and potentially game changing technology for watering. It is understood that electrochemical compression is a new and relatively unexplored area, however advances made may also benefit other related technology areas.
- The intrinsically low DC voltage available from the system may complement systems that have solar power installed, as solar powered systems also have low DC voltages and the appropriate hardware to generate higher voltages required for the household operation.

2) **Project Weaknesses**

- The developed technology is not considered for the current systems' retrofit. Long term performance of the seals is needed to be evaluated.

- The presentation lacks showing the experimental results at the system level that would generate confidence with the achievement of the target performance and target reliability levels.

- Weaknesses
    - Still some uncertainty regarding durability.
    - While product is designed for hermitic sealing, some investigation of effect of NC over time is warranted for system under vacuum.

- The presence of non-condensable gas may present an issue in terms of long-term performance. The system appears to be hermetically sealed, which will help in this regard, and certainly other refrigerant-based systems are hermetically sealed and work for many years without issue. The project team however is encouraged to keep this in mind moving forward to ensure that nonconventional gas remains a non-threat.

3) **Recommendations**

- In some cases, the cyanogen (CN)2 may be produced at the electrodes that should be taken into safety consideration. Engage the certification agency (such as UL, CE or similar) into the pre-commercial design and testing ... Their input and recommendations at early stage may prevent the OEMs from the follow-on design adjustments at the market deployment stage.

- *None*

- *None*

- *None*

Project # 30003: Heat Pump Water Heating Using Solid-State Energy Converters

A. Relevance

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

- *None*

- The idea of an add-on heat pump is a very good idea. And the development to achieve 2/3rds of the efficiency of vapor compression is a good development if it stands up.

- Easy technology to implement onto existing water heaters, enhancing market penetration.
- A very straightforward technology, with a high probability of market success, if past HPWH lessons are learned.

- The concept of using TE to transfer heat from the surroundings to a water heater has outstanding relevance.

- The project aims at demonstrating a home water heater product with affordable and reliable solid-state heat pumps with a COP greater than 1.1. The project includes development of high cooling power thermoelectric modules as well as development of bottom-mount 4-engine and 8-engine heat pumps. As such, the project is critical to the BTO and fully supports BTO's goals.

- No non-vapor compression HPWH are currently on the market; this technology has the potential to go on the market at a low price point. So it seems highly relevant.

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.

- Investigators seem to have identified some assembly methods and associated barriers that could make this a more acceptable technology.

- Shifting the project to an add-on external heater is a good and logical approach. Marketing might be something of a challenge, but if the price is right, it could become quite popular.

- The core technology, thermoelectric modules, has been addressed very effectively.
- A partner like AO Smith, or especially a consultant like Dr. Carl Hiller, P.E. (Applied Energy Technology - AppliedEnergyTech.com), could teach the researchers about the history of HPWH technology, and mistakes that industry has made in the past.
- There were a lot of mistakes made throughout the history of HPWHs that should not be repeated, and some simple but unintuitive control techniques and improvements to HPWHs` implementation that should be observed.

- The critical market barriers have been identified and they are being addressed in an outstanding manner.

- Using the thermoelectric modules is a brilliant idea in the design.

- It is difficult to identify market barriers missed by the team, but it is unclear if the design can address all market barriers. I'm thinking specifically of WH manufacturer's reluctance to change the tank design.

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.

- Technical abilities proven, but not clear that a path to the market in the U.S. is opening
- Good concept but not likely to have a great impact since the coordination with the water heater may limit its usefulness.
- Good likelihood of major market impact if above comments are observed regarding learning from HPWHs' past mistakes.
- The TE heat pump water heater project strongly supports the program's performance and market goals. COP values from 1.3 to 1.7 exceed the targeted COP, which is greater than the 1.1 value.
- The investigators presented strong qualitative and quantitative support for their work. The technology could be transformative.
- If the last barriers can be overcome, it has outstanding potential.

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.

- *None*
- Collaboration appears to be primarily with foreign manufacturers whose products are not likely suited for the U.S. market, but if the heat pump can perform as advertised it should have a number of applications here
- Suggest that PI become acquainted with past and current electric utility company HPWH promotions. Contact PNNL for experiences implementing GE and AirGenerate HPWHs.
- There is outstanding synergy between the project and stakeholder as evidenced by Whirlpool's involvement.
- The investigators are partnering with Whirlpool Appliance as a consultation for specs.
- The consultation with Whirlpool is a good start.

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.

- Investigator stated that one of the future plans was to "become a leader in high volume manufacturing" of this technology, a great high level goal, but not entirely proven that there was a path to do this within the U.S. market

- Next step (commercialization) is not well defined but the broad approach would seem to fit this development

- Progress has been excellent at developing the high power thermoelectric modules.
- The challenging next step is to effectively mate the modules with water heaters and implement a control system.

- The project is focusing on the future barrier of obtaining funding to support marketing and production.

- There are plans for commercialization and contacts have been initiated with Whirlpool both in the U.S. and India. They plan to become the leader in high volume manufacturing of efficient thermoelectric heat pumps for refrigeration, water cooling and water heating. They also plan to develop self-controllers for modular heat pumps and extend the plug-in capabilities for variety of cooling/heating applications.

- The new manufacturing process looks very promising.

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

***High*: 4** reviewers
- The core technology has been well developed.

- Energy use will be potentially reduced.

- Project is potentially transformative.

- Again, the possibility of a significantly better efficiency at a low price point has a high value.

***Average*: 2** reviewers
- *None*

- Seems OK.

***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
- *None*

- It appears the resulting heat pump meets what was desired

- Research areas have been addressed well. Deployment will be the next challenge. Suggest working with GE or AO Smith for marketing and distribution.

- Yes, research areas are relevant to program objectives.

- Project is very relevant to BTO's program goals.

- The project's activities seem well-balanced. Yes, it would be nice if there were a WH-manufacturer partner that is more committed/interested in bringing this to market.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good technical progress showing a focus on overcoming the challenges associated with manufacturing.
- An inexpensive heat pump device with no moving parts will find applications in the industry
- Module development has been outstanding.
- The strength of the project is that significant COP's have been achieved in a very innovative project.
- Project is potentially transformative.
- The main strength of the project is that it can deliver an intermediate-efficiency water heater at a very favorable price-point. It seems like this has the potential to be the low-end of the market. (Where the low-end is substantially more efficient than the current standard approach.)

2) **Project Weaknesses**

- Slight weakness in showing how this technology will break into the market
- Not certain the heat pump HW heater is the killer app needed for this
- PI has a lot to learn about HPWH history and implementation, and about product costing, but should be successful if the right people are consulted.
- I think the PI mentioned that he thought the add-on system could be sold for $70; was I wrong? The pumps and fan together would cost more than that, and the mark-up from factory to retail customer might be 4X the out-the-door price. One pump might possibly be eliminated by use of heat pipes, but the other pump, fan, and power supply costs should still be reviewed.
- The project's challenge is future funding for manufacturing and licensing this product.
- None that I know of.
- The biggest weakness is that the project team has not yet located a committed WH-manufacturer partner.

3) **Recommendations**

- *None*
- Recommend DOE watch to see if the product lives up to advertised low cost and good efficiency. Let's see what the firm can do with the seed money.
- After more careful review of retail cost, a comparison should be made with the one remaining add-on HPWH (the Nyle Geyser), for efficiency and payback. That will reveal if the presumed-lower cost, lower-efficiency HPWH has a faster simple payback.
- None.

- Very good project.
- *None*

Project # 30005: Manufacturing Competitiveness and Supply Chain Analysis

A. Relevance

This project was rated **3.17** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- It seems important that the BTO (and other bodies) have a tool like this at their disposal, so the relevance of this work should be high.

- This is important to gain an understanding of industry issues as a part of a program to achieve more efficient equipment and systems.

- Project goals were to determine the following:
  - Current and future opportunities for thermal non-vapor compression heat pumping technologies in comparison to conventional systems.
  - What drivers (market, regulatory, technology, or cost) are most impacting the adoption of these heat pumping technologies today in the U.S.
  - Are there unique, value-adding, or enabling portions of the heat pumping technology supply chain that the U.S. already has, or could capture?
- I can't see that any of these objectives have been addressed in this presentation. (Maybe they were in a final report?) This presentation discussed conventional heat pump manufacturing - except on Slide 13 which discussed ductless HPs.

- The development and promotion of non-vapor compression heat pumping technologies is critical to BTO's goals.

- The goal of the project is to help BTO identify research, development, and demonstration (RD&D) needs at points along the value chain. It supports BTO's goals of increasing the deployment of energy-efficiency technologies through evaluation of market and cost barriers. It also identifies the key factors behind manufacturing location decisions.

- This project indirectly supports BTO goals by leading to a better understanding of heat pump manufacturing.

B. Approach

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

- I believe that the approach focused too much on air source heat pump manufacturing capabilities being independent of air conditioning manufacturing. The results presented may have been different, or differently interpreted if they had been linked in a more realistic manner.

- Looking at how the industry operates and what and were products are and will be built is good background to help determine where R&D support can best be applied.

- Perhaps the barriers to normal manufacturing (steel, shipping, etc.) might apply to non-vapor compression technologies, but this wasn't stated. Some of these non-VC systems might use more steel and less copper, for example.

- The primary emphasis of this project is to overcome barriers, hence the reason for a high score in this category.

- The approach deals with assessing the global supply chain, performing a comparative cost analysis, and performing analysis of the impact of other factors (such as policy, quality, and shipping). Some of the key questions involve identifying the current and future opportunities for thermal non-vapor compression heat pumping technologies in comparison to conventional systems; identifying the drivers (market, regulatory, technology, or cost) that are most impacting the adoption of these heat pumping technologies today in the U.S.; and possibly enabling portions of the heat pumping technology supply chain that the U.S. already has.

- Project is not likely, in and of itself, to overcome barriers, but it does provide useful information about the state of the industry.

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) **2.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The approach shows that, with the right set of assumptions this could contribute to work BTO is doing and how it can select work in the future.

- This is a start, but I think more understanding of the industry is needed to project how a transition to non-vapor compression might occur.

- My "good" rating in item 2 is a hopeful response.

- The analysis of non-vapor compression technologies has been completed and the focus is now on magnetocaloric refrigeration, whose development would be a transformative contribution to program market goals.

- Accomplishments so far include the following: (1) defining the global demand of conventional heat pumping technologies; (2) mapping manufacturing production and capacity; (3) mapping global trade; (4) identifying areas of highest cost contribution (materials); (5) calculating global cost for manufacturing key components; and (6) identifying non-cost factors that could contribute to manufacturing competitiveness and greater market deployment.

- Again, the project is not aimed at directly meeting BTO goals, but does provide support for the goals and for longer-term decision making.

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.

- It can be a very difficult task to get the information that this program was trying to compile, but if more OEM's had been involved, the fidelity and resolution of the data could be improved

- It would be helpful to reach out to manufacturers to determine their views on such a transition.

- The project didn't directly address stakeholders in non-VC heat pump manufacturing, so far as I can tell. Did they actually talk to any of those specific manufacturers? I can't see where the presentation addressed the 2nd and 3rd points at all.

- The stakeholders in heat pump technology and magnetocaloric refrigeration have been identified and in many cases contacted directly.

- CEMAC staff have received data and market characteristic inputs from the U.S. HVAC industry, and used it in the analysis. Researchers from ORNL and NREL have provided market and technical guidance on issues such as electric air-source heat pumps, adsorption non-vapor compression heat pumps, absorption non-vapor compression heat pumps, Vuilleumier non-vapor compression heat pumps, and magnetocaloric refrigeration.

- I'm not sure these aspects can be evaluated for this project in the same way as for other projects, but it appears that the project team has consulted with industry at some level, though I think it would be useful if industry personnel would review the 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.

- *None*

- There are several competing paths the heat pump technologies may travel. I'd like to see a more encompassing approach to the potential future.

- N/A. Project report is finished.

- The future work is focusing on magnetocaloric refrigeration, which still requires technology development and market promotion.

- Current and future work will focus on magnetic refrigeration.

- Future direction seems fine.

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

***High*: 1** reviewer
- The technology developed could be transformative to the target audience.

***Average*: 4** reviewers
- Not sure that the input assumptions were entirely correct or would have ranked as excellent

- We're starting to get data, but now we need to analyze it to find what is important for the future we want to help realize.

- The project is interesting but I am not sure how crucial it is to the BTO program.

- Again, the deliverables can't be compared directly with other research projects.

***Low*: 1** reviewer
- As noted, the delivered data (as seen in this presentation) did not meet the report's stated objectives.

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

***Yes*: 5** reviewers

- *None*
- Knowledge is power and this project is all about developing better knowledge of the industry that is a key to more efficient buildings
- Yes--the appropriate research areas are being emphasized.
- The investigators are doing their best with a tough project.
- In general, the research and deployment activities needed are receiving sufficient emphasis.

No: 1 reviewer

- Comment as above.

H. Additional Comments and Recommendations

1) **Project Strengths**

- A good tool for examining manufacturing and market barriers for emerging technologies.
- This is a good start to understand how this segment of the industry operates.
- The data presented was interesting, but not relevant specifically to non-VC technology.
- The project strength is that it evaluates and promotes transformative technologies.
- It is an interesting study and should be of benefit to the BTO.
- The main project strength is that it provides information about manufacturing and trade of heat pumps that is not otherwise available.

2) **Project Weaknesses**

- Relies very heavily on input assumptions/data that may be hard to compile accurately.
- The project scope is necessarily limited, but it is important to focus on the key drivers of change and what is required to trigger such change. That has not been developed yet.
- See previous comment.
- The project investigates technologies that are somewhat high risk – which may be a weakness but also a strength.
- The objectives seem a bit elusive and the degree of the project success is a bit hard to quantify.
- Two weaknesses (at least weaknesses as perceived by me):
    - 1. I understand that it does not include ground source heat pumps, a technology that can already meet BTO goals.
    - 2. I'm really skeptical of the North America manufacturing capacity for heat pumps only being 200,000 per year. (Slide 7 in the presentation). I couldn't believe the number was that small, especially as manufacturing a heat pump is very nearly the same process as manufacturing a

central air conditioning unit. So, as I completed the review, I looked at AHRI statistics. According to this December 2015 report:
    - http://www.ahrinet.org/App_Content/ahri/files/Statistics/Monthly%20Shipments/2015/December_2015.pdf
- U.S. manufacturers shipped in 2015:
    - 4.5 million central air conditioners.
    - 2.3 million air-source heat pumps.
- This is an order of magnitude higher than the results presented in slide 7. I think the methodology used needs to be reviewed.

3) **Recommendations**

- *None*

- I'd like to see some continuation of this work focused on identifying key drivers for change.

- This is my personal sensitivity regarding graphs, not a technical shortcoming of the work:
    - When using 2 Y-axis scales, as on page 6, both scales' values should align with the grid-lines. That is, if the right scale is 0 to 1600, the left scale should be 0 to 8000 (a multiple of 5). Thus the two scales align with the same grid lines. 0 to 8000 in 1000-increments, and 0 to 1600 in 200-increments.

- None.

  None.

- Please review the AHRI data.

Project # 31290: Natural Gas Fired Air Conditioner and Heat Pump

A. Relevance

This project was rated **3.17** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Good demonstration of unique approach that could elevate performance
- This is an interesting system, but the flexibility between heating and cooling appears to be limited so there will be potentially extensive periods in which heating or cooling will have to be synced to obtain the ratio needed. Add to that the COPs which are not
- If this were a horse race, this horse would have 100 to 1 odds.
- Competition will be stiff from other more developed or mature gas heat pump technologies. Outstanding competitive benefits vs. the competition would have to be shown.
- The project focuses on reducing energy consumption for heating and cooling, along with hot water-all are relevant to BTO program goals.
- The aim of this project is to develop a Vuilleumier heat pump (VHP) which includes novel improvements that will yield higher performance than the already high COP results of previously developed VHP. The heat pump will use natural gas to provide heating, cooling, and hot water with a single device. As such, it aligns very well with the goals of the BTO's program.
- This project, if successful, will exceed DOE performance goals. It's not clear at this time that it can meet DOE first cost goals.

B. Approach

This project was rated:

1) **3.17** 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.

- System is significantly different than traditional systems and there seemed to be some lack of effort into how such a technology would be enveloped into the market place and accepted by users/installers
- This is a very complex product to be marketed to the residential market. It is not likely to be at all an easy sell. And the total package to capture and use the heat in residences will be expensive.
- It is probably premature for this project to address market barriers, since the technology has not yet even approached the Alpha-test stage. It appears to still be in the "making the prototype work" and "trying to achieve desired efficiency" stage.
- It is impressive that a large number of utilities and other organizations have expressed interest.
- I can't recall that barriers or technical challenges were discussed.
- The critical barriers to achieving project success have been identified and are being addressed. A large team has been assembled with diverse talents
- The investigators are attempting to modernize a proven Vuilleumier cycle device for heating, cooling, and hot water. The end product will be a single 20kW natural gas-driven device for residential and commercial applications. Engineering development is focused on incorporating innovative improvements, optimizing device performance, and reducing the complexity and manufacturing costs. Key Issues include designing a novel electromechanical drive, optimized heat exchangers, and ways to deal with the high temperatures and pressures involved.

- This a different and highly complex type of heat pump. Whether or not it can be manufactured at an acceptable cost remains to be seen. Based on the presentation, the project team is moving in the right direction.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.83** 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.

- Good technical accomplishments, but not clear how they would translate to meeting market goals

- Good work has been done and some developments point to potential improvements. But this product is unlikely to have any measurable impact on the program's goal because, as stated earlier, of its cost and complexity.

- Progress appears good, in that the bench top / breadboard unit is reported to be working. Lots of component manufacturing techniques have been developed. The page 4 chart indicated that there is a ways to go between the tested prototype and the V-Cycle Production Target. Thermolift expects to sell 5000 units in the first year, and 15,000 in the second. This is too ambitious. There will inevitably be unexpected issues with early production units, and troubleshooting or replacing failed units over a wide geographic market area would be costly enough to bankrupt the company.

- The overall project requires a significant amount of work and effort. Much has been accomplished, which already is impactful, but as described in future work below, significant effort remains.

- Very good progress has been made that includes building and testing second generation prototype, re-designing numerous improved components, and developing baseline simulations for tuning, validation, and future enhancements.

- The likely impact depends strongly on whether or not it can be manufactured at an acceptable price point. Also, given the high internal pressures, there is some risk (albeit small) that one or two dramatic failures could set back market acceptance.

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.

- Good demonstration of integration of utility and regulatory stakeholders, but missing manufacturing/installation stakeholders

- Work has been done to reach out to certain technical expertise, but those who would sell, install, maintain, or buy such a product have not been included. This is the weak point for this product. It may be that if the product is successfully completed and demonstrated, the developer will find that an entirely different market has to be approached in which to sell it.

- While the project has an impressive number of "advisors", it was unclear to me how much contribution to the product development came from those outside Thermolift. Are they getting engineering and manufacturing guidance or mostly cheering and funding?

- The project has received support from numerous entities, both institutional and industrial and investor. This large interest by stakeholders is an indication of the project's value.

- Excellent integration and collaboration that involves Oak Ridge National Laboratory, Gas Technology Institute (GTI), National Grid, Star Gas, Par Group, FalaTechnologies, LoDolce, MicroTube, HandyTube, and Bruce Diamond.

- Project collaboration is good for this stage of the project.

E. Proposed Future Work

This project was rated:

1) **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.

- *None*

- I agree with the plan for further technical development, but more attention must be paid to a potential market for the product. The residential heating market is not a reasonable one.

- Every component of the V-Cycle device has been built from scratch; not one major part appears to be commercially available, off the shelf. This means that the product developers must design, test, and optimize every component. Progress to date on component design has been impressive, but I would say there is a long way to go.

- Future work involves pilot plants and tests, along with improvements in analysis, technology, manufacturing, and system integration.

- Future work involves developing a further optimized design. Analysis of improved heat input, investigating joining technologies for high pressure sealing, developing a simplified manufacturing design, performing system integration and improved modulation, putting emphasis on cost reduction and durability, and carrying out full scale demonstration/Pilot tests.

- Future work is appropriately aimed at commercialization, though there are a number of steps to get there.

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

***High*: 2** reviewers

- *None*

- Potentially transformative

Average: 4 reviewers

- *None*

- A (nearly) working model has been developed and lessons have been learned and shared.

- Difficult to rate this.

- While this project has a lot of potential, there is little in the way of deliverables that would benefit the public if the team is not successful in bringing this to 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*: 6** reviewers
- *None*
- No qualms with the technical development. I think it has been well organized, but realistic applications that are cost effective are missing.
- Technical development appears to be progressing well.
- *None*
- Research areas and deployment activities are in concert with BTO's program goals and objectives.
- Project plan and emphases are appropriate at this stage of development.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Achievement of very difficult technical goals.
- Project team has strong technical capabilities and appears to have made good progress.
- The greatest strength is the developer team's dedication to success.
- The project strength is its breadth and potential for reducing nation-wide energy use with innovative technology.
- Project strength is in the novelty of the concept and the qualifications and diversity of the team members.
- The project aims to deliver a novel gas-fired heat pump. It is quite different from any commercially available heat pump technology and operates internally with quite high pressures and temperatures. On the up-side, it offers the possibility of high performance.

2) **Project Weaknesses**

- Not clear what the path forward is to integrate into an easily usable/adoptable platform
- Much development remains and a better application needs to be found.
- I have four concerns about this V-Cycle device:
    - I really question whether it can be manufactured and sold at a market-competitive price since every part must be manufactured by Thermolift.
    - I wonder if sufficient efficiency or comfort advantages can be shown vs. "traditional" absorption heat pumps, go warrant significant higher cost.
    - The operating fluid is Helium. I'm concerned about whether it can be contained within the system over its lifetime, or whether frequent recharging will be necessary.

  - The high temperatures required may be very stressful on various components. This would lead to short component lifetimes and the need for component modules to be replaceable in the field.

- The technology used in this project is complicated and potentially expensive. Which presents a challenge.

- None that I know of.

- The project aims to deliver a novel gas-fired heat pump. It is quite different from any commercially available heat pump technology and operates internally with quite high pressures and temperatures. Risks include: possible high cost of manufacturing; complex internal controls may be difficult to make robust; one or more dramatic failures might set back market acceptance.
- In short, on the scale of DOE projects this is a higher risk/higher payoff project.

3) **Recommendations**

- *None*

- I think it is well and good that DOE has participated in the basic development but it's now time to see what can be done to complete and find applications for this. The benefits of this product are at present generally overstated when compared to other heating options. Electric heat pumps will be far less costly and compete well, even on source energy COP when combined cycle and renewable sources are considered as part of the electric generation matrix. This continues to highlight the obvious conclusion that for the foreseeable future, electricity is likely to be (and from an environmental standpoint, should be) the fuel of choice for building heating. Let's not exclude gas heating technologies as possibilities, but realistically, focusing on an environmentally sustainable electric generation and distribution network, along with system and building efficiency must become the priority for the building sector future.

- I recommend a much more cautious introduction to the market. The first 100 units in the field should be monitored and watched carefully. There will be a lot of failures that were not seen in the first few carefully built prototypes. Failures could be components, or due to installer carelessness or misunderstanding of the equipment. Controls and internal sensors have been problematic in lots of new HVAC and WH products.

- None

- Very good project with very good potential.

- *None*

Project # 31291: Natural Refrigerant High-Performance Heat Pump for Commercial Applications

A. Relevance

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

- *None*
- This project has some pretty good claimed potential. But it is unlikely the technology will be adopted quickly and the applications may be limited.
- Quite unique system (compressor, expander) design. (Assuming the system lives up to its expected efficiency!)
- Impressive turn-down ratio should help maintain efficiency by reducing cycling losses.
- The technology being developed for heat pump applications in this project does not involve HFC's plus the result could be reductions in energy use, both are relevant to BTO program goals.
- The project is aimed at demonstrating a natural refrigerant heat pump prototype using S-RAM technology that is capable of achieving 50% energy savings, meeting DOE's cold climate COP targets, using air (R-729) as the refrigerant (ODP=0 and GWP=0), being cost effective with a payback period smaller than 4 years, being commercially available in less than 4 years, and is manufactured in the U.S. As such, the project is very well aligned with the BTO's program goals.
- Air as a refrigerant has some unique advantages for certain applications.

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.

- Nominally, the market barriers are being addressed, but very hard to see the path toward application on this technology. Is it with CO2 or Air cycles?
- It appears correct in the shift from CO2 to air but it is not clear how this will be configured and applied in real world applications.
- Could be rated 4 if the regenerator had been successfully tested. (This is not a complaint. I understand work is ongoing.)
- The approach is innovativeness, especially the expander/ compressor unit technology.
- The approach section is not described in enough detail to be able to assess. But overall, it seems that the investigators got it under control.
- To some degree, the market barriers are pretty low level at this point (e.g. development of a suitable compressor) and the project is appropriately focused at overcoming these market barriers.

C. Accomplishments/Progress/Impact

This project was rated:
1) **2.83** 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.

- Investigators demonstrated a technology that has strong potential and that they can make it work.
- Has not yet shown to be effective and also needs to demonstrate that compressor will be durable and long lived.
- This rating assumes that efficiency predictions are verified.
- The project progress is significant considering the sophisticated nature of the technology and approach used. A test stand has been built and key components and concepts have been evaluated.
- The investigators have made very good progress in developing some key components such as the S-RAM compressor. The CO2 compressor test stand is being built at Purdue University. The variable CO2 compressor has several attractive features including high volumetric efficiency and good isentropic efficiency.
- Development is still at an early stage to contribute to program goals; I expect the contribution will increase in the future.

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) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- *None*
- Short on industry partners - need to identify and pursue an initial application that will succeed.
- This rating is premature. The technology is not yet ready to be shared with manufacturers.
- The stakeholders have been identified and collaborators are being approached. Most of the collaborations to date are institutions involved with developing the technology.
- Investigators are collaborating well with Purdue University in modeling component testing, ORNL in system testing, and S-RAM Dynamics and ReGen Power in design and fabrication.
- Excellent project team that is a good fit 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.

- *None*
- Testing of the compressor and the cycle is the critical next step. This may help determine what application best suits the system.
- (Premature for me to speculate on this.)

- I hope there will be continued focus on reliability and manufacturability of the compressor system.
- The focus in the future is component testing and heat pump system testing, along with modifications.
- Plans for next quarter includes completing heat pump component testing, fabricating modifications to heat pump, completing heat pump testing, and performing final testing at Oak Ridge National Lab.
- Results of proposed testing are critical, and future work is highly appropriate.

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

***High*: 4** reviewers
- Very innovative work.
- *None*
- It could be transformative if successful.
- Since suitable compressors in particular aren't commercially available for heat pumps using air as the working fluid, the value of the deliverables produced by the project are high.

***Average:* 2** reviewers
- *None*
- Development seems to have progressed well.

***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
- *None*
- Maybe. The cycle itself appears to be coming along in development. But translating the development into a worthwhile product is of some question.
- At this stage, fundamental design work is appropriate.
- *None*
- Key research areas and deployment activities are receiving enough emphasis.
- Project is appropriately focused.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Great technical accomplishments.

- Promising improvement in efficiency.
- As presented, the development of this air-refrigerant system looks very promising. The proof will be in the details of the manufacturing, control design, etc.
- The strength of the project is in its goal of reducing heating/cooling energy use without HRC use.
- Strength of the project lies in its promise in using air as a refrigerant in a novel heat pump design and in the strength of the team and collaborators.
- Unique project that has high potential for some applications; excellent project team.

2) **Project Weaknesses**

- Not a very clear path to immediate application.
- New compressor technology needs to be tested for durability and regenerator for effectiveness. These could diminish effectiveness of concept.
- I would like to know how "manufacturable" the compressor/expander system is. This would have an influence on cost-effectiveness.
- None observed.
- The approach could have been better described.
- Project is running behind so performance can't yet be evaluated.

3) **Recommendations**

- *None*
- This should be considered a high risk technology that does not have at this time a widespread effective application. The listed applications need some vetting. Perhaps it can be applied in heat recovery chillers. Recommend settling on initial applications as a next step.
- None.
- None.
- Very promising project.
- *None*

Project # 31293: ORNL- High-Performance Refrigerator Using Novel Rotating Heat Exchanger

A. Relevance

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

- *None*
- Refrigerators represent a significant energy consumer. However, the 12% improvement in efficiency comes with a significantly more complex system. The evaporator and fan in a typical refrigerator is the simplest part of the process.
- This type of technology development is in line with BTO goals of energy efficiency improvements for appliances. If this technology is successfully demonstrated in refrigerator applications, the rotating heat exchanger can be applied to other heat pump applications. Therefore this technology is desirable, because of its applications to the larger heat pump market.

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 authors plan to develop high performance refrigerator heat exchanger cost effectively, with higher efficiency for residential applications targeting 12% efficiency improvement with a simple payback of < 3 years. Air-Bearing heat exchanger technology is used.
- This project seeks to replace a simple finned tube heat exchanger and low wattage muffin fan with a much more complex sealed rotating heat exchanger with air bearings. For a product that is expected to last 20 years with no maintenance on the refrigeration side, there are too many things to go wrong with this system. It is not surprising that no refrigerator manufacturer is participating.
- The project goal is to attain a 12% efficiency improvement in refrigerator operation with a 3 year payback. That is significant advancement in individual appliance performance and translates to a large potential when applied across the refrigerator appliance 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) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project seems to have been developed already, and a quick web search shows a prototype in operation. The reviewer is not clear what engineering goal is to be accomplished now.
- Given the requirement for proof of concept demonstration, this project should be able to do that. The complications that this system will introduce regarding defrosting and system reliability likely won't be addressed in just delivering a working prototype. I will be surprised if a manufacturer picks up the ball on this one.
- Good progress to date. The overall concept is a rotating fin heat exchanger which disrupts the air boundary layer to deliver higher heat transfer. Another component is optimizing system design and operation to limit

frost formation. The research clearly identified several lessons learned and the team appear to be appropriately addressing issues and moving forward in a good direction.

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.

- The partnership between ORNL, SNL, and UMD looks robust.
- This project really needs a refrigerator manufacturer to be involved to emphasize simplicity and system reliability. This is a really neat research project that likely will have no acceptance for commercial development.
- Project team is ORNL and Sandia National Laboratories and the University of Maryland. At this stage of research, these are the appropriate players to be developing this technology. At a larger stage of development, the addition of a commercialization partner might be appropriate. The current team has demonstrated good progress in developing the technology.

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.

- Integrate frost collector is a small bite for a big budget. "Second generation" looks a good label for recycling, "run 1-month long un-interrupted" is not exciting new project.
- I was not convinced that the researcher understood the impact this system would have on the refrigerator defrost controls or the requirement that it must be able to start/stop perhaps a million times before failure. These issues won't be addressed in a prototype that is simply required to operate continuously for one month.
- The proposed future work is appropriate to advance developing this technology towards commercialization.

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

***High*: 1** reviewer

- See comments above

***Average:* 1** reviewer

- The milestone of having it work for a week has been met. However, that is a long way from having a robust evaporator replacement.

***Low*: 1** reviewer

- I admit I am not familiar with the progress of the previous work, but any duplication of tasks should be avoided, and a new proposal should stand alone in its own merit. Running the system for 1-month long un-interruptedly should not be charged as a research task.

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

***Yes*: 2** reviewers

- Refrigeration and heat exchangers are vital components of the HVAC industry, and they are relevant to the program objectives.
- See comments above

***No*: 1** reviewer

- No commercialization appears to be in the cards for this concept.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The idea of using rotating heat exchanger is novel and interesting.
- A unique concept.
- This is a solid technology concept to advance refrigerator heat exchanger technology. The projected energy savings result from improved heat transfer and defrost characteristics over existing HX technologies. The research to date shows positive results and the presenter demonstrated a solid plan for moving forward.

2) **Project Weaknesses**

- This project seems continuation of previous work. Unfortunately the project activities that are to be continued do not show strength. Not sure why integrating frost collector or fabricating a vaguely defined "second generation" is a worthy task in this round.
- Replaces a simple system with a complicated one that no refrigerator manufacturer seems to have any interest in, and which delivers at best a modest improvement in system efficiency.
- None identified. There are issues that need to be worked on. For example: ensuring baseplate design allows for good heat transfer and refrigerant distribution. These are not weaknesses, just identified items that need to be resolved. Overall the technology looks promising.

3) **Recommendations**

- Explain succinctly what new concept is to be added or incorporated to the existing system, and why is the task so challenging worthy of funding.
- Get a refrigerator manufacturer involved before the final prototype stage.
- *None*

Project # 31294: Univ. of Florida – A Combined Water Heater, Dehumidifier, and Cooler

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 develops a low-cost gas-fired water heat pump to meet the DOE MYPP 2020 target and double the energy factor from current 0.62 to 1.3. Additional dehumidification benefits are claimed.
- Integrated appliances should be a future trend in low energy houses.

- This project meets DOE BTO goals. The stated goal is to double the EF from current .62 to 1.3 in a gas fired water heat pump. There is a substantial existing gas water heater market in which this technology can be deployed. Currently there are no gas fired water heat pumps in the market.

B. Approach

This project was rated:
1) **3.67** 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.

- Using Membrane-based absorption technology with a novel cycle.

- An absorption system is well known. My concern is the size of the system and its cost. They did not compare this design to those that are currently on the market (or soon will be). No future schedule is shown.

- The gas water heating market area has substantial potential. Development of this technology definitely advances the state of the art for gas water heating.

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.

- Authors have developed capabilities to measure P-¬-T-¬-X, thermal conductivity and capacity, heat of absorption, density, viscosity, mass diffusion coefficient (using PFG-¬-NMR), and corrosion rate on ionic liquids for absorption chiller.

- They seem to have made good progress so far, but I will be surprised if they complete the project in November. This is a complicated flow system with complicated heat transfer processes that will take some time to work through.

- Project initiated in October 2014. Good progress has been made.
  - A demonstration unit has been built.
  - Good development and characterization of ionic liquids for absorption cycles.
  - Good progress in demonstrating EF goals. Current level is over 1.2 with a target over 1.3.
  - Good progress has been made in other areas of system development.

D. Project Integration and Collaborations

This project was rated:
1) **2.33** 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) **2.33** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- No mention of industry collaboration, just mention of communication on a continual basis.

- A nice university research project, but I am concerned that there are no manufacturers involved. Absorption systems for residential applications generally are not well received because of size, cost, and complexity.

- Presenter demonstrated collaboration among members. Partners include ORNL, University of Florida and Stony Brook University.

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.

- Planning to continue experimental study, fine tuning the ionic liquids design; improve their properties and absorption and desorption characteristics, first prototype is currently being fabricated.

- I think the schedule is overly ambitious to accomplish by November. Still a lot of design decisions to make.

- Future work is logical and on track with project goals. Next steps include:
    - Continued advancement of system component research and validation.
    - Continued advancement of System Performance.
    - Development of Prototype system.
    - Commercialization plan. Obviously dependent on demonstration.
- This plan demonstrates a solid path "to market approach."

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

***High*: 2** reviewers
- Low cost gas fired water heat pump - doubling the energy factor with additional dehumidification is a plus for the market.

- See comments above.

***Average:* 1** reviewer
- They seem to be making good progress 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*: 3** reviewers
- Heat pump and dehumidification are topics well within the project objective.

- But I think it will take them longer than they have scheduled to have their full working prototype.

- Good solid project with good results to date.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Solid plan, good idea.
- Absorption systems should be evaluated as a viable option for residential applications. A lot can be learned from this work that may be useful in a larger application.
- Good progress on developing the components of the technology, such as ionic liquids and absorption technology. Demonstration unit validates viability and targeted energy performance. Proposed future work builds on current demonstration success.

2) **Project Weaknesses**

- No industry collaboration has been identified and named.
- Absorption systems are tough to make cost effective for residential applications. GRI tried several different versions in the 1980s and spent many millions of dollars, but with no success. They could not hit their cost and size targets.
- None identified at this time.

3) **Recommendations**

- Contact and secure industry support, and involve an HVAC company.
- Try to get a manufacturer involved so they can provide useful input on practical constraints on cost and size targets before the design gets too far along.
- *None*

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

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Rotary Vapor Compression Cycle is a relevant aspect of HVAC.
- Air conditioning is a major energy user. While this technology likely cannot produce more than about 20% performance improvement, it may provide for a reduction in equipment size that could fit well with applications that are currently not foreseen with today's technology.
- Interesting project concept to take the heat pump system and build it into a rotating frame. There is potentially a significant energy savings associated with this technology. Quantifying exact savings potential is difficult since it's pretty early in the technology development process. The presenters propose a potential 21% reduction in system savings. This value should be taken with a large error band until additional research can refine the feasibility and real potential for this technology.
- The objective of the project is to investigate a new Rotary Vapor Compression Cycle that significant improvement over conventional systems that are limited by compressor efficiency a heat exchanger performance.

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.

- This is ongoing work - shown that heat transfer is enhanced in the rotating frame. Here, this approach is adapted to a larger scale for VCCs, where the evaporator and condenser are rotated, i.e., not entirely new concept.
- They have looked only at the easy parts so far (air side heat transfer). They have not addressed the compressor issue, how the fluid will be expanded inside the rotating blades, how oil will be returned to the compressor, and yet are scheduled to have a working prototype within a few months. I have little confidence they will meet their target schedule.
- This RVCC approach is not a new concept, and has been discussed for several decades, but as far as this reviewer is aware, this is one of the larger efforts to research and develop the RVCC technology.
- This project is more fundamental. The investigators are working to determine the ability of such a system can be built and if the performance potential could be achieved. If these are realized, a manufacturer should be added to the team that would assist in the detailed design.

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.

- A de-rotated imaging apparatus was developed and a rotating VCC was also developed for investigating phase change behavior in the rotating frame.

- They have done relatively little to address the refrigerant flow management inside the rotating elements. That will be a very complicated problem that I don't think will be solved by their September deadline for prototype development.

- The presenter demonstrated good initial investigation results and identified some technical challenges. One identified research area is the effect of centrifugal and Coriolis forces on refrigerants in a rotating HX.
- Refrigerant GWP reduction is an identified BTO goal. The chosen refrigerant for study in the VCC rotation research is R134a. It might be warranted to explore using very low GWP refrigerants for this study, so as the research moves forward, it has already incorporated low GWP refrigerant components.

- If the air-side and refrigerant-side heat and mass transfer enhancements be realized from the rotating technology significant energy savings would occur. This could result in a reduction in energy consumption of up to 21%. In addition, a major question that will still need to be answered is if the rotating vapor-compression system could be economically manufactured. This is why I suggest that in the next phase a manufacturer be involved.

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.

- Creative Thermal Solutions is taking the lead on the air-side heat transfer studies.

- Sandia and CTS are very good research organizations. Their shortcomings are that they don't manufacture products, and don't have a manufacturer involved in the project. They have done an elegant analysis of the air side heat transfer of a rotating blade, but which will have relatively little impact on the system performance improvement.

- Project partners are Sandia National Labs and Creative Thermal Solutions. At this very early stage of concept development, these are appropriate partners to move this project forward

- From the presentation the team has a long history in heat and mass transfer processes as related to vapor compression cooling. Also, I believe they have worked together in the past.

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.

- Well laid 6-year plan.

- I think they seriously underestimate the difficulties they will face in addressing the refrigerant side of the problem. Not to say that it can't be done, but likely not within the time frame they have allotted, nor within the budget that was agreed to.

- This is an emerging technology development project. . The presenter clearly demonstrates a multiple year time line to develop the technology.

- The next step if the rotating vapor-compression system is technically feasible then the manufacturability will need to be determined. The project team is well aware of this. I am just not sure if they will involve a manufacturer in the next phase if the concept is promising.

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

***High*: 2** reviewers
- As discussed above.
- The project is on track to determine if the concept is viable.

***Average:* 2** reviewers
- So far, the work has been more like a university research project, not a product development project.
- It's too early in technology development to rate the value or true potential of this concept.

***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
- Topic fits the program objectives.
- See above comments.
- The team have identified the key problems and tasks are to address these problems and to determine if there are any show stoppers.

***No*: 1** reviewer
- The compressor and refrigerant flow issues have been given inadequate attention to date.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Well-planned continuity, and novelty in the progress.
- Good research staffs and capabilities.
- This is a good concept. Early results show some promising potential. It's much too early in the development cycle for this reviewer to make a determination regarding commercial feasibility.
- The project tasks are well laid out and the scope of work is addressing the key technical and market barriers.

2) **Project Weaknesses**

- A 6-year long project should or could have accomplished goals set in this round by now.
- No manufacturer involved to provide practical input to the important design issues.

- In developing this technology there are and will most likely continue to be some significant research challenges. It is too early in concept research to call any challenge a physics based technical barrier or technical/commercialization weaknesses.

- I see no weaknesses, except that a manufacturer of vapor-compression cooling systems should be involved in the next phase.

3) **Recommendations**

- Move to the next step - may be marketing?

- I think you will need to make a decision about whether additional funding will be appropriate to continue the project beyond its early stages before a working prototype has been demonstrated.

- *None*

- A manufacturer of vapor-compression cooling systems should be involved in the next phase.

Project # 31296: Higher Efficiency HVAC Motors

A. Relevance

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

- High efficiency motors are relevant to BTO's program plan, [although] they have wider applications than strictly for this program, i.e., could be funded by other programs.

- Motors are a major energy user, so improving their efficiency is key to reducing the country's energy consumption. However, the project presentation never stated what its actual goals were other than to make a "higher efficiency HVAC motor". It can't be determined if the efficiency improvement meets BTOs targets.

- Project is to improve EE for motors ranging in size from ¼ to 1 hp. The key innovative improvement is in the electronics of an ECM motor. The feature is that the design allows for the electronics to drop out after the motor reaches synchronous speed thus reducing current draw when compared to other market ECM motors. This aligns with BTO energy efficiency goals.

- The project does align with BTO's goals of overall energy reduction. The project team indicates there is a potential to achieve 0.5 to 1 quads of primary energy savings if implemented in residential and commercial HVAC applications.

B. Approach

This project was rated:

1) **2.75** 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.

- With 90% or higher efficiencies, electric motors in the HVAC industry are [not a] bottleneck, However, the authors have a clear approach if this were to be addressed as a standalone issue.

- Motor requirements for torque, reliability, UL approval, and other standard design issues were not addressed so presume they are being covered. The presentation was very generic with no specifics given about anything, not even efficiency targets.

- The presenter indicated that current motor efficiency is 80.5% and this new technology is targeting a motor efficiency of 87%. Prototype is still not complete. There is no operation data from which to judge design efficiency and tangible performance. Work to date appears in line with project goals.

- From the presentation, the project team did not address what were the potential market barriers and how they would overcome them. I would suspect they would be cost and potentially size.

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) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- With the little margin for improvement, the project will likely not contribute significantly to the achievement of interim market goal. The project is indeed not about motor efficiency, it is about motor control:

  - "Higher efficiency Electronically Controlled Motors (ECM) that have become available have low power factors and thus give up much of their efficiency advantage in the form of higher current draw." In fact, the key issue is claimed to be "design and creating controls for the motor to operate at five speed/torque-controlled speed settings." In an era where VFDs have become common, why spend money and time on 5-speed control? Not clear.

- Without knowing efficiency targets or the efficiency of the small motor already developed, it is somewhat hard to know where they stand on their milestones. Gantt chart shows only future tasks, so past schedule, milestones, and accomplishments are unknown. Assume the small motor shown to reviewers is the prototype deliverable.

- The project approach appears sound. Presenter indicates a potential EE market of .5 to 1 quad. That's a substantial potential to justify BTO investment in this technology.

- The project team has design a 1/2 hp motor that incorporates the benefits of the IPM-PPMT and Q-Sync motor technologies and have initiated prototype manufacturing.

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.

- Engaged UTRC/Carrier to target specifications of the project, good collaboration despite it is not clear what level of collaboration is present under "engagement."

- Since UTRC employees were in the room, and they did not object to being listed as collaborators, it can be assumed that UTRC is providing some useful input. However, it is not clear that the collaboration extends beyond providing s set of motor specifications that they would provide for OEM requirements. UTRC is scheduled to verify motor performance once prototype is completed.

- Market partners are Carrier and UTRC. These are solid and key industry partners to help develop and deploy this technology. However, it is unclear if this technology will be limited to Carrier products or is it available to the larger market. BTO should clarify.

- Members of the QM team are UTRC and Carrier. This will enable market introduction of the higher efficiency motor in products.

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 plan to complete prototype fabrication and demonstrate/ validate the improved performance is understood. But given this is more of a control problem, not sure what 'manufacturing' entails.

- Scaling up to the half horsepower size seems to be straightforward enough. I would assume they have the resources to develop the hardware components as required.

- Proposed future work is designed to demonstrate motor efficiency and operation. In addition, project will provide a T2M manufacturing analysis. QM power has demonstrated successful motor development in BTO project 22298. Past success can be a good indicator for this project.

- If successful, the team intends to expand the product range to a larger market (1/4 to 1 hp) and to apply the technology to the compressor and pump markets.

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

***High*: 2** reviewers

- Project has not developed a working prototype. A working prototype is indicated as a near term goal. The partnership can then demonstrate and validate the motor operation and efficiency.
- The deliverables are to determine the projected efficiency improvements will be realized. This is appropriate.

***Average:* 2** reviewers

- There are competing technologies, and not sure if this will be superior and new.
- I presume the small prototype motor was acceptable, but no actual test results or performance details were provided.

***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

- Motors in HVAC are relevant to the project and program objectives, despite motors have much wider application and could be funded by other programs too.
- I presume the contractor understands what is needed to scale up the motor to 1/2 hp size.
- *None*
- Documenting the efficiency improvements so that the potential energy impact could be determined is important for the project. Also, the team should document the cost premium.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Most likely the project will address part-load issues through variation of speed, but not continuously as in VFD. Efficiency drops during part-load are serious challenges. But the project is not presented as such.
- Appear to have their first small motor prototype completed and ready to scale up to the 1/2 hp size.
- Good target market to focus on. Motors are good choice to develop EE improvements.
- The project is on track and they have designed, completing the fabrication of the prototype for testing. All of the tasks are clearly aligned to design, build and implement a new motor product.

2) **Project Weaknesses**

- It is confusing to understand what is to be accomplished - is it a novel design concept or a control problem which entails variation of motor speed?

- The presentation was very sketchy about the project details, specific objectives, and past performance. I presume that DOE staff are on top of the contractor's performance, schedule, and deliverables.

- None at this point.

- In the presentation, the team did not indicate what was the value of efficiency improvement (i.e., from x% to y%) for their technology.

3) **Recommendations**

- Clearly identify if it is a novel design concept or a control problem which then becomes more of system configuration and assembly.

- For future presentations, ask the contractor to provide more information about project details, schedules, and previous milestones/deliverables.

- *None*

- Quantify the value of efficiency improvement (i.e., from x% to y%) for their technology.

Project # 31297: Novel Ultra-Low Energy Consumption Ultrasonic Clothes Dryer

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 can potentially be significantly more efficiency than current technologies. Eliminating the need for a high flow rate and high temperature air.
- Clothes drying is a major energy user and this concept has the potential to significantly impact that energy usage.
- This is an excellent application of technology to demonstrate a completely new type of clothes dryer system. This fits well with BTO goal of reducing primary energy use as outlined on page 14 of the BTO Multi-Year Program Plan. The researcher has indicated an EF performance goal of >10. That is higher than any dryer on the market today.

B. Approach

This project was rated:

1) **3.67** 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.

- Plan to identify the right transducer, power signal, and modulating transducers ... implies work has significantly progressed. But then these are also listed as accomplishments!
- Perhaps too early, but demonstrated results on only a 14 square inch piece of fabric so far, which dried in 7.5 minutes, versus the 14 seconds that was stated at the outset. Must demonstrate concept with simple fabrics first, but the approach for a big batch of clothes was not convincing.
- The presenter did a good job of demonstrating good execution to a well thought out and planned research strategy. Results to date are excellent. Looking forward, this technology is not limited to the existing dryer drum and air flow design. The presenter is aware of this and the research team is planning to explore new dryer configurations.

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.

- Ultrasonic transducer selected, proof of the concept prototype developed.
- Schedule called for full scale prototype to be tested in Dec 2015, but still seems to be doing fundamental concept development work. Answers to questions about how complex fabrics with multiple layers would be handled were not convincing to me. A working prototype that handles multiple layer clothing is needed to convince skeptics about the viability of the concept..
- The project goal is to demonstrate a dryer technology capable of delivering an EF factor > 10. This performance surpasses any current dryer products. The presenter indicated that there have been other issues that the research team has experienced and dealt with such as amplification and synchronizing the nested piezoelectric units. This is to be expected in this novel cutting edge technology development.

- Interim results are good and if prototype development is successful, this project can radically advance clothes dryer technology and energy savings.

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.

- Weekly and monthly meetings between ORNL team members, ORNL/UF and GEA, and quarterly site visits by ORNL-GE.

- The presentation showed quarterly meetings with collaborators, but their input was hardly mentioned. GEs cost share is only 10% and they seem to have a very minor role in the development process.

- GE and UOF are partners. GE is an excellent partner with appliance research capabilities and manufacturing knowledge. One concern that may or may not impact the project is the sale of the GE appliance division.

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.

- Scale up and optimization. Evident that work on this project has progressed significantly, not sure if scale up is worthy of a new funding opportunity.

- Still no timetable presented for the full scale working prototype (scale up by June? Not sure what that means). Working with 1 square cm patches of fabric and vapor recovery issues. No clear concept of what form this would take in a full scale application.

- Presenter provided solid research results demonstrating optimization of drying performance, overcoming amplifier and piezoelectric component issues. Going forward, this technology does not need to rely on conventional dryer drum design. There is potential to radically reconfigure the appliance design to optimize for piezoelectric technology

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

***High*: 2** reviewers

- It is right on the eye.

- See comments above.

***Average:* 1** reviewer

- Demonstrated the basic concept, but is a very long way from drying a complex piece of clothing.

***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

- Cloth dryers are part of the project program objective.
- See comments above.

***No*: 1** reviewer

- Having a full scale prototype that can dry a complex piece of clothing will be critical to demonstrating the validity of the concept.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Great idea, feasible, seems passed proof-of-concept.
- Could be a disruptive technology.
- Well developed and executed research project.

2) **Project Weaknesses**

- Unfortunately, the writing gives the impression that this project is made to hang in there to attract more funding, little or no breakthrough is expected hereafter.
- Lots of questions about how it goes from small swatches of cloth to a full drum of clothes. Seems to be behind schedule on developing the full scale prototype. Little indication that GE plays an active role so far.
- No apparent weaknesses at this time. It's hard to say if this will result in a commercial dryer product, but so far so good.

3) **Recommendations**

- Go big, produce and market instead of meddling in small grant business, the field will offer more research ideas.
- Needs to demonstrate that the concept works equally well for multiple layer fabrics that are not firmly pressed against the piezo elements.
- None

Project # 31298: Novel Energy-Efficient Ventless Thermoelectric Clothes Dryer

A. Relevance

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

- Project is an attempt to apply innovative solid state heat pump technology to the dryer sector, helps meet the 2020 MYPP target of EF≥6 resulting in energy savings of 40%.

- Clothes drying is a major energy user and is very energy intensive. Modest improvements in efficiency can provide significant reductions in energy usage nationally. Thermoelectric options can provide incremental increases in efficiency for incremental increases in cost, so may be more widely accepted than more expensive options.

- This is an excellent application of technology to demonstrate a completely new type of clothes dryer system. This fits well with BTO goal of reducing primary energy use as outlined on page 14 of the BTO Multi-Year Program Plan. The researcher has indicated an EF performance goal of >6. That is a significant improvement over electric resistance dryers. In the market today, HP dryers currently have EF>6, but that comes with a significant cost addition over resistance dryers. This technology is attractive since the potential price point may be substantially lower than heat pump models.

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.

- First cost, long dry time, and perceived risk are listed as barriers, approach is laid out to mitigate these except the "perceived risk".

- Project has focused on how TEs can be incorporated into a current dryer footprint so that it will not be seen as a radical departure from current technology. They seem to understand what the limiting factors are for acceptable performance and product reliability.

- The researcher has defined a solid approach and demonstrated positive results. Obviously, there is more research work to do and a there are many opportunities to optimize performance, but the work to date is solid.

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) **3.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Did combined modeling/experimental test, designed and fabricated dryer for thermoelectric integration, and obtained preliminary test data on prototype.

- They have developed a reasonable prototype to demonstrate feasibility. Project ultimate success will depend on the ability of the TE manufacturer to meet their price and performance targets. Final product will likely require a mix of TE and resistance heat to provide acceptable drying times, but yield an efficiency better than resistance alone. It remains to be seen what the final incremental first cost impact will be until the TE units are finalized and mass produced.

- The research took two design approaches to the project. First was incorporated the TE units in the drum body and the second was setting the TE modules external to the drum. My understanding from the presentation is that research to date indicates better drying performance with the second approach.
- Researcher also indicated that there has been significant improvement in TE technology (independent of this project). One of these advances is moving from a ceramic substrate to a polymer substrate. This advancement in TE technology benefits a TE application project such as this. There is good evidence that this project can obtain its desired research goals.

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.

- Works with a U.S. manufacturer of thermoelectric modules. But the team is only negotiating with appliance manufacturers, no collaboration yet.

- Project seems to have good cooperation between ORNL and Sheetak. As a small company, Sheetak does not have the resources of a GE, but they may be hungry to establish themselves in this market. I am somewhat concerned that Sheetak is involved in several DOE projects yet has few different people assigned to these projects. It is difficult to really tell how much effort they are putting into the development processes for this application.

- Current partner is Sheetak, a TE module firm. Presenter indicated they are in discussions with appliance manufacturers. At this phase of project demonstration, a logical next step would be to include an appliance manufacturer to the partnership.

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.

- Work plan for improved control and on design changes to improve performance.

- There is no path forward beyond proof of concept. Neither Sheetak nor ORNL will manufacture dryers and no current manufacturer is currently involved for follow up work after the project is over this year.

- Presenter indicated several design optimizations that can provide performance improvement. Also indicated controls optimization to improve performance and drying time. The project has demonstrated successful potential application of this technology for use in clothes dryers. The next phase of work is warranted.

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

***High*: 3** reviewers

- But again, improvements in control and design modifications to improve efficiency are too soft for a fairly large funding such as this.

- The researchers have produced a working prototype to demonstrate concept feasibility. A manufacturer would be needed to take it to the next step in making a commercially viable model.

- Project results are positive.

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
- Application of solid state heat pump technology to the dryer sector to meet the 2020 MYPP target with energy savings of 40% is relevant to the project program objective.
- Activities are appropriate for proof of concept development.
- *None*

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Advances in the clothes dryer research are very promising - ultrasonic, IR, and thermoelectric. Which of these technologies yields the most ....? No doubt these are interesting research topics.
- Fundamentally simple concept that does not require a radical change in current technology to produce significant energy savings without pricing the system out of the market.
- This project has demonstrated the efficacy of applying TE technology to clothes dryers.

2) **Project Weaknesses**

- As a continuation, these tasks look like asking funding for a project that should have been out the door by now.
- There is no clothes dryer manufacturer that seems to be interested in pursuing this concept, so there can be no confidence that this system will ever be commercialized.
- No significant weaknesses are identified at this point in time.

3) **Recommendations**

- Improvements in control, or design modifications to improve efficiency are issues which will always be there, even after marketing. Lack of collaboration with appliance manufacturers at this stage of the project is a big minus.
- Get a dryer manufacturer on board as soon as possible.
- None.

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

A. Relevance

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

- Energy Efficient Clothes Dryer supports BTO's Multiyear plan.
- Clothes dryer market is a significant energy consumer where even incremental improvements in efficiency can have a significant impact in national energy consumption.
- The project supports the goal of improving energy efficiency in a major clothes dryer appliance. They propose a target EF of 6. This is better than the current EF of resistance dryers, which is about 4. The Clothes Dryer EF value is listed on the DOE site: https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/36
- The proposed EF of 6 is lower than some of the better performing heat pump dryers currently on the market.
- The objective of the project is to develop an efficient ventless closed-loop clothes dryer using advanced infrared heating and an electrostatic precipitator for humidity removal. Currently residential dryers have an efficiency of 3.73 lbs./kWh. This project is to enhance the efficiency to 6.0 lbs./kWh with a payback period of less than 5 years.

B. Approach

This project was rated:

1) **2.75** 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.

- Market barriers project addresses are not clearly stated.
- They seem to be applying rocket science to the simple process of vaporizing water. Very complex system being proposed with little success in even approaching milestone target. I would not be surprised if GE pulls the plug on this, partly as a result of them selling their appliance business soon.
- The project addresses the market barrier of improving the dryer EF factor with a proposed reasonable cost payback of less than 5 years. With a proposed EF factor improvement of 2 over resistance, the market cost increase has to be small compared to the better energy performing heat pump dryers. This technology has a number of market commercialization hurdles that may make it difficult to meet a market price point lower than current heat pump dryers.
- The approach is methodical and addresses the key market barriers. It is not clear from the presentation or at this point in the project if the size of the dryer will change.

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) **2.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Water extraction using the proposed technology has been demonstrated.

- Milestone target of 40% extraction efficiency, delivered efficiency was only 7.3%. Success does not look promising, not even accounting for the harsh operating (environment with abundant dust and lint) that it will be forced to operate in. Their proposed directions do not appear promising to achieve their targets.

- The presenter indicated that the electrostatic precipitator technology research has achieved a 13% efficiency performance. To achieve the project goal, the technology needs to achieve a 40% performance level. The overall process of the technology is complex. Not from a physics point of view, but rather from a mechanical implementation function for a residential appliance. A few potential issues include:
    - A submicron spray head is needed in the nebulizer to create sub-micron droplets. This has the potential for clogging and may require specialized filters and cleaning.
    - In the precipitator, arcing is an identified issue which poses a concern for a consumer product and UL listing.
    - In the precipitator and liquid collection area, lint and other foreign materials can create problems for system function. In a wet precipitator environment, lint can collect on the wall and reduce water collection functionality. The concern is that in the precipitator water collection area cleaning can become a maintenance and cost issue.

- The project currently is having problems of achieving the efficiency goals of the ESP/Exchanger. At the time of this report the efficiency of the ESP/Exchanger was 13% and 40% is needed to achieve the project goals. Also there are arcing issues in the ESP. These are critical problems that need to be overcome for the project to be a success.

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) **2.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Collaboration has been only with internal GE experts.

- GE is doing this all by itself. While GE has the resources in house to do it all, it also means that its corporate decision makers could pull the plug at any time since they have no contractual commitment to any other company.

- There are no identified partners, so there is no collaboration. This project could benefit by including a national research lab in addition to GE. This is definitely pre-commercialization research work.

- Since GE Global Technology is the contractor, this would enable such a product, if successful to easily enter their product line.

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.

- Optimization of Nebulizer parameters and increase efficiency.

- I was not impressed with the proposed solutions to resolve their shortcomings. I can't believe their own corporate management will be any more impressed than I was.

- There a numerous technical challenges that need to be solved in order to commercialize this technology. With a target EF of 6, this commercialized product needs to have a small price point increase over current

resistance dryers. Heat pump dryers already in the market perform at higher EF factors than this technology. To compete in the market, a dryer utilizing this technology needs the price point to be between the resistance and heat pump products. With the complexity of this technology, it will be very challenging to bring a commercial product to the market at a price point that works.

- The project team realizes that the efficiency of the ESP/Exchanger and issues of arcing must be addressed and overcome for the project to be a success. They are focusing their efforts on these issues.

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

***High*: 2** reviewers
- High EF, non-vented dryer with 5 year payback is a good start.
- The deliverables have identified the key issues and barriers and the team are addressing them.

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

***Low*: 2** reviewers
- Not even close to meeting their milestone performance target.
- See comments above.

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

***Yes*: 4** reviewers
- Clothes drying fits well within the program objectives.
- They are still working hard, but seem to be spinning their wheels on a concept that just has too many challenges to overcome.
- *None*
- Key issues and barriers have been identified and the team are addressing them.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Well-developed plan, excellent modelling and test approach
- The commitment of a company with the corporate resources of GE.
- See comments above.
- The team have identified key issues and barriers and are addressing them.

2) **Project Weaknesses**

- No collaboration, no market feedback, project may be ready for the next phase but still prefers to compete at a fundamental level.

- The complexity of the proposed solution and the lack of simple directions to meet their target performance. Since GE will soon finalize the sale of its appliance division, there would appear to be less willingness for them to continue funding the project.

- See comments above.

- I am concern that the ESP/Exchanger and the arcing issues cannot be overcome. This is not a weakness, rather a concern.

3) **Recommendations**

- Develop a convincing argument why application of IR (not new for heating btw), is a good fit for clothes drying, and how its efficiency will be better than other existing and emerging technologies including ultrasonic or thermoelectric ....

- I am not a clothes dryer expert, but I just cannot see this approach ever being successful in the dust and lint filled environment of a clothes dryer.

- This reviewer sees potential for other applications of the successful use of this technology. However the clothes dryer, may not be an appropriate application.

- None.

Project # 312103: Miniaturized Air to Refrigerant Heat Exchangers

A. Relevance

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

- *None*
- Heat exchangers are an important element of HVAC systems. This work may have some spillover to practical applications
- This project seems to be more a study of heat exchanger fundamentals, than one directed to yield a cost-effective, manufacturable product. Hopefully it contributes to better understanding of HX design for the industry.
- The development of miniaturized HXs is critical to BTO's program goals.
- The project aims at developing miniaturized air-to-refrigerant heat exchangers that are 20% better, in size, weight and performance, than current designs. The intent is to introduce these new design to the market place in five years. To that extent, the project is highly relevant to BTO's goals and fully supports them.
- Improving performance of heat pumps, air conditioners, refrigerators, water heaters and other devices require improved heat exchangers. Fundamental research like this is critical for supporting performance improvements across a wide range of energy-consuming devices.

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.

- Difficult to address all the market barriers as this study was focused more on what the potential of design optimization would be and this would likely drive a whole new set of manufacturing/market barriers if designs significantly different than the state of the art are identified.
- I appreciate that from an efficiency standpoint the direction is toward very much miniaturized components but in the HVAC industry we need understand the physical environment and contamination potential that cannot easily be contained. I'd like to see some recognition of the realities of this environment and while I don't discourage pursuing to some degree the ultimate, I would like to see some more effort focused on consideration of real life applications.
- This work seems to be rather fundamental research into HX design. It doesn't appear to be directly addressing practical shortcomings of existing HXs, except in terms of efficiency. I don't think the project is far enough along to look at market issues yet?
    - Is micro-tubing manufacturable to the required quality?
    - Can assembly be automated?
    - Can such a HX be make strong enough to tolerate the abuse that normal HXs get?
    - Will this HX require more cleaning? Will it clog with environmental crud easier?
- This project is focused on a major need in the area of energy efficiency, namely high performance HXs with reduced volumes and materials.

- The approach taken is sound and should accomplish the tasks on hand in an efficient manner. Almost all of the critical barriers have been identified. Investigators are very focused on ensuring that the approach is able to accomplish the tasks on hand.

- I suppose the answer to this depends on how you define market barriers at this stage of the research. My view is that, at this stage, the barriers are lack of knowledge of how to design this type of heat exchanger and even what designs work best (e.g., fins don't provide the advantage at this scale that they provide for typical HX in use today) and how to manufacture these ultra-compact HX. Obviously, the project has not answered all questions about manufacturing, but it has made significant steps towards overcoming market barriers.

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.

- Great work, but not entirely clear how to achieve the interim market goals

- It may be possible to apply some of the findings regarding tube shaping and flow patterns to practical products.

- It's too early to know if this work could lead to a manufacturable HX with greater reliability than current products. HX fundamentals have been explored very effectively in this work.

- The project has analyzed 15 or more heat exchanger geometries, developed new optimization methodologies, and fabricated/tested both 1kW and 10kW HXs.

- The project has gone a long way towards achieving its goals. The investigators developed a comprehensive multi-scale modeling and optimization approach to novel heat exchangers. They have emphasized small hydraulic diameter exchangers in their work, which is the more difficult task to tackle. They have analyzed more than 15 different geometries so far. They fabricated and tested three 1kW prototypes. They developed a system-test facility.

- I've rated this "Good" because I think it has excellent potential to help achieve a number of program goals. But it is too early to see exactly how long it will take to come to market.

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) **3.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- *None*

- It is not clear that there has been sufficient dialog to take what has been learned into viable products and applications. I'd like to see that more effectively addressed.

- The collaboration team is impressive.

- The project has numerous partners, subcontractors, and collaborators. Additionally, main industries affected have been consulted and included as advisors.

- The investigators have formed an excellent group of collaborators that include ORNL, Luvata, ICA, Wieland, and Burr Oak Tool Inc. ORNL is a subcontractor and is in charge of performance testing and advanced manufacturing.

- The project brought in a number of resources to help fabricate the heat exchangers and it also made good use of existing collaborations with manufacturers.

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.

- *None*

- I am not sure the upcoming tests will employ heat exchangers that are sufficiently durable to be practical in real life applications. This issue must be addressed at some point for the project to be successfully concluded.

- It's too early to say.

- The project is presently using the technology developed to build and test both condensers and evaporators.

- 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.

- Future plans are appropriate for dissemination of research findings.

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

***High*: 4** reviewers
- Well communicated process that could be used again in the future.

- HX users will find the deliverables of significant value to them.

- Developing analysis and optimization tools for heat exchangers with small hydraulic diameters is very important.

- New knowledge quantifying the performance of a miniaturized air-to-refrigerant HX and characterizing the performance of a number of different designs is highly valuable.

***Average*: 2** reviewers
- This is a good investigation with reliable results, but the direction is moving away from practical products.

- There is a lot of work still to be done between the current study and a useful product.

***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
- *None*

- *None*
- Sufficient emphasis is being place on relevant areas.
- The tasks performed so far and those on the list are relevant and key to achieving the goals of the project.
- Besides the high quality of the research and usefulness of the research, the team has done an admirable job of publishing the results in the open literature.

***No*: 1** reviewer
- The issue of durability is not being sufficiently addressed.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Great technical analysis.
- The project has identified issues that may be generally applied to improve heat exchanger efficiency.
- The work has been very effective at studying the limits of small HX channels.
- The main strength is that the HX research and development in this project is much needed and is approached in a practical, industry-friendly manner.
- The main strength of the project is the investigators and the teams working with them from ORNL and industry. They are solid in their understanding of the problem and in identifying the tasks and achieving them.
- Project has a number of strengths:
    - Thoughtful approach combining simulation (CFD) with experiments in order to get the most use out of a limited experimental budget.
    - Wide range of collaborations allowed fabrication of a number of innovative heat exchangers.
    - Good use of optimization to identify Pareto curves for different heat exchanger designs.

2) **Project Weaknesses**

- A bit removed from manufacturing, which may skew the attractiveness of some of the heat exchanger designs chosen as the "best" options.
- The configurations developed do not appear to be mechanically sound or sufficiently address air or hydronic contamination issues.
- Current A/C evaporators lately have been leak-prone. Could this technology (in production quantities), with greatly-more parts and brazed joints, be more leak resistant than current coils? The PI commented that it has been hard to control the quality (leak-integrity) of currently available micro-tubing.
- There are no major weaknesses.
- There are no weaknesses that I know of.
- I didn't find any substantive weaknesses.

3) **Recommendations**

- *None*

- Recommend there be a discussion with DOE and stakeholders to develop minimum mechanical and fluid constraints for the test modules.

- Please demonstrate that this type of HX will use less total copper than current copper/aluminum fin-tube HXs, in equivalent BTU capacities. Manufacturers are sensitive to the price of copper.
- It wasn't clear to me if the additive manufacturing process has been abandoned in favor of assembling individual tubes. Continued work needs to be done regarding air-side fouling with atmospheric dirt, lint, etc., and on condensate and frost management, due to the tight tube spacing. Current air-side HXs are such a commodity that significant benefits will have to be shown.

- None

- I like this project quite a bit and feel that it will be successful in achieving BTO program goals.

- Regarding the face area constraint problem - I've been trying to think of a good application that would allow a large face area heat exchanger to be used. It seems like there must be one! But none have come to mind yet.

Project # 312104: High Performance Commercial Cold-Climate Heat Pump (CCCHP)

A. Relevance

This project was rated **3.60** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Important work to move heat pump technology into colder climates and closely related to an OEM capable of building market share in these areas.
- A very sound and realistic approach to improving the heating efficiency. This is very relevant to DOE goals.

  This product was closest to market-ready of all those presented, since the project has been completed.
- There is a great need for high-performance cold-climate heat pumps, and therefore this project has great relevancy to BTO program goals.
- The project goals are certainly appropriate.

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.

- Baseline was not clear, is this competition to gas or electric heat? Makes a big difference in the likelihood of the technologies adoption
- Glad to see the realistic need to raise the supply air temp in cold weather. There appears to be a very strong attendance to market issues.
- Iterative design steps (slides 7 & 8) showed steady development.
- This project is spearheaded by major companies that manufacture and promote heat pump technology. As such, the project has addressed critical barriers.
- I will state here that this project is very difficult to evaluate as almost all of the information about the project is proprietary. The PI presented some performance testing that is promising, but beyond that, it is all a black box. As a result, this review was developed with a substantial information-deficit.
- The project team has identified some market penetration barriers for heat pumps in cold climates - low performance and "cold blow" and this project addresses both barriers.

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) **3.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- While investigators stated that target were met with their technology, very little of this technology was described making it difficult to determine the likelihood of success or the degree of accomplishment
- Capacity meets targets. COP is reasonable. Looks like a good development

- *None*

- There have been outstanding project achievements in the categories of accomplishments, progress, and impacts. All of the BTO's COP and capacity targets at cold temperatures have been more than satisfied.

- Performance tests come close to meeting project targets and if market resistance to heat pumps in cold climates can be overcome, this should have an impact.

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.

- As an OEM was involved, good collaboration with industry was demonstrated.

- I appreciate this is a proprietary product. None the less from DOE's perspective it does not meet this objective

- In-house collaboration with Carrier was sufficient.

- UTRC has integrated Carrier Corporation, which is the world's largest manufacturer of HVAC equipment, into the commercialization path for the new devices resulting from this project.

- As this is essentially an industry project by a corporation that has a large market share for commercial unitary equipment, the project integration and collaborations cannot be faulted.

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.

- It seemed as though the investigator was saying that they were now pursuing a very different design from what was developed as part of this project and neither the past approach or the future was very well technically described, making it difficult to judge the proposed future work

- I take some issue that further cost cutting will have to be employed to reduce the payback on enhancements to less than a year. I think for commercial applications a 2-3 year payback will sell.

- Future work should consist of introducing the product to the market.
- I suggest they pay close attention to defrosting at low ambient temperature.

- Future work will primarily be in the area of production, marketing, and distribution.

- Project is complete.

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

***High*: 4** reviewers
- *None*

- The product is nearly ready to be deployed and meets a real market opportunity.

- Nearly mature new product.
- The project deliverable will immediately be utilized by the target audience.

***Average*: 1** reviewer
- The nature of the project is such that very little information is available on what the project team did to meet the goals, so it may be of limited usefulness in raising the performance across 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*: 5** reviewers
- *None*
- Improving capacity and efficiency at low ambients are achieved in this product.
- Can't tell.
- The idea the new system will produce significant energy savings is known and receiving emphasis.
- Project emphases were appropriate, leading to a successful outcome.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Based on investigators statement, it seems things went very well.
- A product permits pretty good operating efficiency down to low ambients.
- Product appears to have passed environmental chamber testing. Size choice (20 ton, commercial roof top unit) is probably not a limitation; look at the roof of a Walmart. Just choose the area that 20 tons will serve.
- The project's strength is that it has successfully developed a system that exceeds BTO's program goals and an excellent path to production and marketing exists.
- Technology development project by major HVAC equipment manufacturer; appears to have met energy performance targets.

2) **Project Weaknesses**

- Little technical documentation to support the accomplishments.
- Further cost cutting to meet manufacturers ROI criteria could degrade efficiency and/or durability.
- As noted, defrosting issues at low temperature may not have been sufficiently addressed.
- No major weaknesses.

- Not so clear if they can overcome market resistance.

3) **Recommendations**

- *None*

- Let see if this and other similar products can make electric heat pumps a more viable commercial heating system

- Please present results of field tests at a future meeting!
- I would like to see some electric utility company comments on this system's performance under coldest conditions. Does it contribute to their winter peak load due to resistance heaters coming on at -10 degrees F? Installers will have to understand that under-sizing will contribute to the customer's demand charge being higher for the next year.

- None.

- *None*

Project # 312105: Low-Cost Gas Heat Pump for Building Space Heating

A. Relevance

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

- *None*
- The comparison with electric efficiencies appears to overstate the savings when considering the improved efficiencies electric systems have. Although the sales price is lower than gas units have been in the past it also requires more cost for the indoor components so cost effectiveness is in great question.
- More likely than the other gas heating approaches to actually be marketed successfully.
- Developing and promoting heat pumps based on gas technology rather than electrically-driven compressors should reduce world-wide energy consumption.
- The project is aims at developing and demonstrating a gas-fired absorption heat pump, with heating COP's greater than 1.0 at low ambients. Design simplicity and volume manufacturing requirements emphasized from conception. Achieving a projected 2-5 year economic payback to drive market penetration is a higher priority than ultra-high efficiency. As such, the project is in the heart of BTO's program goals.
- I'm not absolutely sure that the project is "critical" to BTO goals, but it does provide a path forward for residential-scale gas-fired absorption heat pumps.

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.

- Some of the market barriers around serviceability did not seem to be sufficiently addressed in this work
- No doubt that focusing on cost is critical to market penetration, but the cost is still not really competitive and without including cooling means additional cost is still required. A full home conditioning system based on this will be expensive and complicated.
- Wise design ideas:
    - Keeping it simple and hopefully reasonable cost; many components (i.e. coils) are commercially available or easily modified for the particular device.
    - Not striving for maximum efficiency in an introductory product
    - Focus primarily on heating
    - Modulating burner, to reduce cycling losses
- The critical barriers to the project's approach have been identified and the involvement of key gas industries such as A.O. Smith and GTI have been important for this endeavor.
- The approach has adopted sticking with several principles from the beginning. This includes employing a simple cycle optimized for cost and reliability; the use of common raw materials, processes, and scalability; focusing on total cost; optimizing evaporator coil; development of breadboard, then developing a packaged prototype. These principles are all good and conform with BTO's program goals.

- This project has an appropriate focus on cost with a target of $4500 per unit. The costs of installation, "hydronic furnaces", and separate air conditioning equipment may add substantially to the homeowner cost, though.

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) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- *None*

- It does appear that the performance goals are met, but the unit sales would have to become quite substantial before the cost objective can be achieved. Right now, there is no effective path to penetrating the market.

- My only hesitation - the prototypes have not yet reached efficiency goals.

- The project has successfully built and tested absorption heat pump prototypes that satisfy the program goals. This was accomplished with the support of key partners which should aid achieving market goals.

- Accomplishments so far include the following: (1) coming up with an optimized simple single-effect cycle that predicts target performance; (2) Breadboard Testing: 95% Performance Target and 4:1 Modulation Achieved; (3) Evaporator design model developed and verified w/experimental data; (4) Optimized coil ~25% cost reduction from original design; (5) Low-cost solution pump successfully scaled up by a factor of 10; and (6) Alpha 1 packaged prototype fabricated and lab tested: 97% target.

- Unit performance of the test units is very good.

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) **3.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- *None*

- The collaboration effort is focused on players that have already been pursuing gas heating. It would have been useful to bring some new players into the mix to get a more realistic approach to market entry. Perhaps builders in cold climates with high electric utility costs. And air handler/water heater manufacturers who could supply products ready made for this heat pump.

- I assume collaboration with AO Smith has been close.

- Two major players in gas technology, namely A.O. Smith and the Gas Technology Institute, are collaborating and advising on this project.

- The investigators have formed an outstanding team of collaborators that include AO Smith (OEM) which is responsible for providing component design, fabrication, testing support, market research, and cost share to the project; and GTI which is responsible for providing combustion system design and testing, system performance testing, cost share and gas utility communication.

- Project collaboration was pretty good, though I wonder if they would have been better off with a manufacturer of heating and air conditioning equipment rather than a water heater manufacturer.

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.

- *None*
- Project funding is complete. It is now up to the firm to find a way into the market. DOE should wait and watch. It is hard to imagine there will be any notable success with this product.
- Get the efficiency up to target!
- Future work is focusing on developing and testing more advanced units, along with markets and production.
- Beta 1-2 are being fabricated: Advanced testing and reliability. The investigators are ready for larger scale field tests sometime in the winter of 2016/2017.
- Plans for building beta test units seem appropriate.

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

***High*: 5** reviewers

- *None*
- Close to a successful product.
- The value of the deliverable to the target audience is high.
- The project aligns very well with BTO's program goals.
- Concept was realized in two test units that met performance goals.

***Average:* 1** reviewer

- It was a reasonably performed effort

***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

- *None*
- Project met performance goals but is not an attractive heating solution.
- SMTI appears aware of issues still needing attention.
- Yes, there is sufficient emphasis with the research areas.

- Investigators seem to be on top of the different tasks.
- Fabrication of units, laboratory testing and field testing are very relevant to meeting the project and program objectives and are receiving sufficient emphasis.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Great technical descriptions of technology and demonstration of collaboration with and OEM.
- The idea of a sealed power unit is a plus.
- This gas heating technology will be more successful and earlier to market than the others we looked at.
- The strengths of this project is that program goals have been satisfied, and prototypes have been developed and tested.
- Timely idea and good team.
- The project has made good progress with fabrication, laboratory testing, and field testing of two units, in addition to the "bread board" development. The $4500 price point seems achievable.

2) **Project Weaknesses**

- Perhaps not enough emphasis on serviceability to ensure that this technology could break into the market.
- The unit as reported will not be cost effective in most markets. It is hard to see how they will achieve market penetration.
- Defrosting control has not yet been fully addressed.
- A future challenge is developing a path to production and marketing.
- None that I know of.
- The only weakness that I see is the future: by the time extra costs for a hydronic furnace and air conditioning are added, and (likely) higher installation costs due to it being a specialty item, it may be difficult to achieve significant market share.

3) **Recommendations**

- *None*
- It’s recommended that no further funding go to this or other like projects. Cost and a lack of dollar savings over electric alternatives makes this unlikely to succeed. At present there can be some source GHG benefits, but as more renewables are employed in electric grids, this singular advantage will vanish.
- Defrosting at low outdoor temperatures will need special attention Please observe worst-cast defrost cycles personally. Put early production units into the field cautiously and watch for unexpected bugs. Problems will show up that you could not anticipate in the lab. Keep the first Beta and retail installations close to

home, so your engineers can make service calls along with the installers, who will need training on the particular product's features.

- None.
- Timely project.
- *None*

Project # 312106: High Efficiency Low Global-Warming (GWP) Compressor

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Demonstrate a high efficiency compressor design that is critical to enabling low direct-GWP high-efficiency small-commercial rooftop systems.
- It APPEARS to align with BTOs goals, but it is somewhat hard to say since they could not tell us anything about what they are actually working on.
- This is a GWP reduction project focused on HVAC refrigerant. BTO has identified this as a target research area.
- The UTRC teams plan to demonstrate a high efficiency compressor design that will enable low direct-GWP high-efficiency small-commercial rooftop systems. Projected primary energy improvements are projected to be 30%.

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.

- Combination of novel compression with low GWP refrigerant, high efficiency and system-level design optimization that is scalable for residential and light commercial HVAC systems" ... reasonable.
- I presume that UTC knows what they are doing, but since nothing specific could be said about it, I can'[t make any judgment about their approach.
- Target equipment is 4-5 ton RTU units. Presenter did not disclose exact GWP value or name of new refrigerant, but did indicate a GWP reduction of 75% compared to 410A.
- The team are very knowledgeable about the industry. The key issues for the project are to maximize compressor efficiency and reliable operation over a wide range of operating conditions while minimizing the system cost premium.

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) **3.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- A proof-of-concept compressor test done or to be done in Jul. 2016 to accelerate critical risk reduction.
- Similar comment as before. I really don't know anything about what they are actually doing.
- Presenter indicates there are EE efficiency gains achieved with the new refrigerant system design and additional EE savings from incorporating variable speed functionality.
- BTO should verify the 75% GWP reduction. This HVAC equipment designed to utilize the lower GWP refrigerant meets BTO program goals.

- The project will be wrapping up Phase 1 with a Go/No-go review in August of 2016. The project seems to be on track and key issues have been identified.

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.

- Excellent plan for project integration with Carrier.
- Since all work is proprietary and done in-house with plans to market through Carrier's distribution system, they would seem to have all the resources they need to commercialize the product.
- There are no key partners. This project is still in an early phase. The phase 1 go/no go decision is set for August 2016. Truthfully, there are not a lot of project results to evaluate at this stage. Presenter did not provide much insight into collaboration or research efforts to enhance project results.
- Since UTRC is R&D arm of Carrier the integration with Carrier is very good. In fact an additional proof-of-concept compressor test for July 2016 was added to reduce critical risk and improve the value proposition of 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.

- Phase 1 started in Sept 2015, not clear how this affects budgeting.
- Since nothing could be said about what is actually planned to be done, other than in just a general sense, I cannot comment on anything specific about their future work plans.
- Project is still in early compressor development stage. Overall project goal is to move from TRL 2 to TRL 5. Project goals indicate a 30% primary energy savings.
- After the Go/No-go decision point in August, the team clearly understands the performance needed for the market.

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

***High*: 3** reviewers

- The design of two compressor prototypes designed, fabricated and tested for a 5 TR rooftop advancing the TRL from 2 to 5, is feasible and admirable.
- These types of projects develop and advance current state of market equipment are important and relevant.
- The deliverables for the project address the key issues that must be addressed.

Average: 1 reviewer

- Based on Carrier's understanding of the marketplace.

***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 target audiences are mid-term light commercial rooftop cooling (3 to 20 TR) and long-term -residential systems (1.5 to 5 TR). I take these as well within the program objectives.
- Again, based on the supposition of Carrier's knowledge of what it takes to bring a new air conditioner to market.
- *None*
- Yes. The proof-of-concept compressor test will reduce risk and could enable easier market introduction.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Addresses HVAC system efficiency, - small building use R-410A with GWP=2088. Regulations driving industry to low direct GWP and higher efficiency systems. New low-GWP refrigerants require new approaches for compressor in order to achieve high efficiency.
- UTC and Carrier have a long history of developing successful HVAC products.
- GWP target reduction of 75% is good.
- The team is very knowledgeable of the market and have added a task to further enhance the possible introduction of the product to the market by Carrier.

2) **Project Weaknesses**

- The primary weakness is that the project seems to have started, and not sure how the project will benefit from DOE's funding.
- The proprietary nature of all their work limits anyone from outside the company from providing any possibly useful input to the process.
- It's too early in project to determine if the research method and results are thorough and will provide quality results. One identified weakness is the lack of key partners working on this project.
- None are seen at this time. The project is in its early stages.

3) **Recommendations**

- Readjust budget.
- DOE personnel should be provided complete access to their research work. This may require a confidentiality form, but is necessary to protect DOE's investment in the project.

- *None*
- None

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

A. Relevance

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

- The HVAC system is a relevant topic. However, the use of centrifugal compressor for ultra-small scale has traditionally faced serious challenges, and this proposal didn't make clear how it plans to defeat those challenges.

- An efficient compressor that can handle low GWP refrigerants is critical to future HVAC applications.
- TO has identified the advancement of low GWP refrigerants in vapor compression systems as a target research area. Target market is residential and commercial HVAC air-conditioning equipment.

- The team is designing and building a low-GWP HVAC systems that incorporates an ultra-small centrifugal compression. This project matches the goals of BTO to develop efficient low-GWP 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.

- The proposal outcome claims advancing "unrealized design potential of small centrifugal vapor compression in conjunction with advanced heat exchanger design". The concept of "advance" and "in conjunction" make the project a bit vague. "... to reduce environmental burdens" is also vague.

- Scaling down a centrifugal compressor will not be easy (it has been tried before unsuccessfully). However, the contractors involved should have the resources and experience to give it a good shot.

- Manufacturer is developing a centrifugal compression unit for a low GWP potential refrigerant for use in HVAC equipment. Presenter would not disclose the exact refrigerant GWP value or name, but did indicate that the refrigerant of choice had a 50% GWP reduction when compared to 410A baseline.

- The team have identified the key issues to be efficiency, system integration and cost. The team have identified that the early identification of system efficiency and cost are critical to success. A compressor efficiency greater than 78% is needed. System integration, where the use of a small centrifugal compressor in this range is a departure from current HVAC applications will be addressed secondly. Another one of the key aspects is that the new refrigerant is nonflammable. This is requirement of Lennox, one of the team members.

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) **2.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- However, this Reviewer is skeptical of the technology. There is no sufficient data to lend confidence that this will be a good investment. Promise to "refine" the design gives an impression that the task is not well articulated.

- Still too early in the project for significant results, but they seem to have gotten off to a good start. Some tasks are behind schedule.

- Project on track with stated goals. It's not clear if BTO set an initial project GWP target reduction. BTO's stated goal is refrigerant GWP reduction. To really move the market, BTO should focus on refrigerant projects with GWP reduction goals of 80% or greater over the 410A baseline.
- This project research appears thorough and well managed. Developing a compressor for use with GWP refrigerants with a 50% GWP reduction is good. But the target should have been set with a higher reduction goal.

- The team has methodically reviewed 12 low GWP refrigerants and have selected a blend.

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.

- A few companies (Lennox) are coordinating system design parameters which should be a competent team.

- They have all the right players involved, including an HVAC manufacturer that is aggressive about developing new technology.

- The presenter demonstrated a thorough knowledge of the procedure used to develop the compressor. Presenter also demonstrated that significant research and development rigor was utilized in this project.
- This project has only 2 partners. For this project there is not a lot of collaboration between groups.

- The team knows what is needed to make the product successful. The close integration of Mechanical Solutions, Lennox International and TURBOCAM International appear to be good.

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.

- Could use a more readable Gantt chart.

- The future schedule looks good. However, there are no deliverables shown on the schedule, just tasks and milestones. Milestone go/no-go decisions were not specified. Some tasks are already behind schedule.

- Project presenter clearly demonstrated good results to date and a clear path forward for future work.

- The proposed future work will lead to a mature product. These are: a 2-stage compressor, longer life cycles and more refrigerant options. This could make the design applicable to heat pumps, including cold climate heat pumps.

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

***High*: 2** reviewers

- To date the work results appear solid.

- The deliverables, as addressed by the project, will correctly determine the market potential and success of the system.

Average: **2** reviewers

- I see no strength in the claimed outcome, a concept that defies the status quo should be well-articulated as to why this "novel" approach has a chance.
- Very early in the process.

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

- In principle, HVAC systems, the compressor in particular, is a fair research subject that fits the program objectives.
- Very early in the process.
- The project objective is to create vapor compression systems that work with low GWP refrigerants. As stated earlier in the review, this review feels that the GWP target reduction should have been set at 80% rather than 50%.
- The project is on track and the key research areas are being addressed. The low gwp refrigerant has been selected, the compressor design (which will be oil free) is on track and the project is on schedule.

No**: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The idea of taking on uncharted territories (small centrifugal compressors) in itself should be commended.
- The mix of collaborators should have all the resources and expertise to tackle the problems that this design challenge poses.
- *None*
- The team is fully integrated addressing the key issues.

2) **Project Weaknesses**

- Not sufficient detail is given to justify why funding agency should take a risk on designing a small scale centrifugal compressor which are traditionally known to be inefficient in such flow regime.
- The schedule seems to be a bit fast for the scope of what needs to be done. I will be surprised if they stay on schedule.
- Presenter indicated a 50% reduction in GWP from an R-410A baseline. This needs to be verified before continuing with project funding.
- None to date.

3) **Recommendations**

- Explain precisely and succinctly how the concept will have superior efficiency than existing compressors, and outline the steps required to accomplish the goals more accurately.

- Lennox was involved with a similar project in the 1980s funded by the Gas Research Institute. Garrett Airesearch worked on the turbomachinery. Tried to use a small gas turbine to direct drive the centrifugal compressor. Needed that because of the high rotational speeds required of the compressor. Motor drive and gear box design will likely be tough.

- *None*

- None.

Project # 312108: Membrane Based Air Conditioning

A. Relevance

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

- Project objectives and milestones are well aligned with BTO's goals on development energy-efficient non-vapor compression air conditioning systems for the commercial sector.

- *None*

- Project is extremely relevant to BTO goals of reducing energy consumption and use of GWP fluids in HVAC equipment. The technology is also potentially one of the most promising to be a true competitor to vapor compression systems in the near term.

- This project is aimed at developing a membrane-based air conditioner rather than more traditional mechanical vapor compression. This is highly relevant for the DOE BTO program mission, both in terms of the advancing of innovative enabling technologies as well as the potential energy savings.

B. Approach

This project was rated:

3) **2.75** for the degree to which it focuses on critical market barriers, and
4) **2.50** for the degree to which the approach addresses the market barriers identified.

- Project approach is quite straightforward - using Dias' selective membrane and Xergy's ECC as key components - to package the roof-top air conditioner by engaging the resources of ORNL and ROBRADY followed by the experimental evaluation of the reported approach. The project is in its initial phase but there are still several major concerns in vision - fouling of the membrane, optimal vapor compressor performance and a cost-effectiveness of the entire system (the arrangement is too complicated and seems energy intensive). Stating across the presentation the technology is under development as "non-vapor compression", the project content includes ECC and mechanical vapor compressor as key components of the system... It is quite confusing.

- *None*

- The primary market barriers identified are increasing the TRL of the technology. Of technical issues, vapor compressor was identified as main issue. This in fact seems like the most critical challenge for the success of the system as proposed. It is not clear if project team has the right partners or approach to address this.
- While perhaps not within the scope of the project, the PI does not explicitly address some of the other myriad issues in membrane based system including mechanical and biological fouling, reliability, and service and support. Another market barrier/issue that was not addressed was adequately demonstrating the techno-economic feasibility of the technology in conditions far outside the AHRI rating condition.

- Air conditioning remains an essential and core need for many residential and commercial entities. The state-of-the-art in air-conditioning is based on vapor compression. This is a mature technology, however, that has likely seen the vast majority of improvements already made. In addition, with emerging mandatory requirements for new refrigerants, which may provide additional challenges to traditional performance, alternative technologies such as those being explored in this project are both timely and relevant.

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.

- Project started less than 6 months ago and certain limited progress has been reported:
  - partners were identified (assumable the partners should be identified at the proposal stage)
  - high level system design
  - membrane dehumidification modeling (Aqualyte is the underlying technology for the entire Dais line of products. It is a commercial product with quite known performance)

- *None*

- The project is very early in the period of performance. Accomplishments to date appeared to be in line with expectations. The critical item that may prevent project from achieving objectives is high uncertainty in vapor compressor component.

- Project progress to date has been good. The team appears to have a solid understanding of the physical mechanisms and principles associated with the membrane-based thermal and mass transport. The team has identified several near-term target goals, and are making progress both on the analytical and experimental fronts.
- Based on the progress to date, the indications are good that future work by the team will continue to progress towards the program goals. A 7.5 ton demonstration unit is a challenging target however the technology is innovative enough that this is not unreasonable.

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.

- Project team is well-qualified and equipped to undertake the reported effort. There is too early to discuss the progress and accomplishment of the team members however, Xergy's ECC is developed enough under other BTO programs.

- Need to involve at least an O&M in the work for assisting with the system level design and techno-economic for market penetration.

- Project has a good mix of industrial and academic partners, subcontractors and collaborators. Partnering with other DOE supported small businesses is a strength and encouraging to see. I would recommend a partner specializing in mechanical compressors/vacuum pumps to help mitigate vapor compressor challenge

- The teaming with Oak Ridge National Laboratory and Xergy are noted. ORNL is a world leader in the development of both traditional and next-generation heating and cooling systems, and represent an excellent program partner from a technical perspective. Xergy provides membrane technology critical to the project.

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.

- Next steps and future plans that are stated in the presentation include fabrication and testing of the prototypes followed by the evaluation of the market and selection of the initial target. It seems more

logically that the market evaluation and target selection should be made before engineering, design and fabrication steps.

- *None*
- Work plan is reasonable. Vapor compressor remains primary technical (and potentially economic) risk.
- Moving forward with laboratory demonstrations and a working prototype would be a substantial milestone. The team is aware of this and has arranged its tasks and objectives to meet these milestones.

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

***High*: 3** reviewers
- The presentation of the cost analysis of missing and discussion was minimal. Miss to discuss the risk mitigation strategies, if performance and/or reliability and/or cost target are not achieved by the next milestone.
- Overall I believe the project is technically achievable and represents the most realistic intermediate term competitor for vapor compression systems compared to other DOE supported technologies.
- Air conditioning is an essential resource for the entire country.

***Average:* 1** reviewer
- Fouling and cost might be serious barriers for this technology to hit the marketplace

***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
- Strong project team ensure all the aspects of this challenging effort to be adequately considered during the course of the project.
- The scheduled next steps seem to be crucial for the success of the project. What is the criteria used for comparing the performance of the individual components?
- The resilience of the system to contamination need to receive more attention. How to handle fouling and cleaning of the membrane should be discussed in more details.
- Need to involve OEM companies during the early stage of the project to understand the level of acceptance of this new technology and thus the prospective for penetration in the U.S. market by 2030.
- The PI should include a plan to disseminate the research and the project findings.
- *None*
- The task distribution and emphasis is well-balanced for the program targets.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- The use of membrane technology in the AC application is very promising in a wide spectrum of aspects including hot and humid climate zones.

- Novel concept for dehumidification technology approach. Good resources and good collaborations to carry out the project. This is an early stage project.

- Strengths:
    - Very relevant to BTO goals of reducing energy consumptions, reducing GWP fluids and displacing vapor compression
    - Past success and similar commercial products (ERV) give confidence that objectives can be achieved and technology can scale to realistic conditions
    - Ability for individual components to contribute to building energy savings independently or configured in different systems is appealing

- This is an innovative, interesting and potentially game changing technology for air conditioning. It is understood that membrane-based A/C is a new and relatively unexplored area, however advances made may also benefit other related technology areas.

2) **Project Weaknesses**

- Too many energy consuming components (fans, pump, compressor) in the overall scheme that compromise the system cost-effectiveness

- Need to focus on testing and provide experimental results that would generate confidence with the achievement of the target performance and target reliability level. Need to discuss the expected scale up performance derived from a 1D model of the membrane to an actual 7.5 ton AC system prototype before commencing the testing.

- Weaknesses
    - Risk mitigation plan for vapor compressor unclear.
    - Better understanding of system performance in varying conditions would be of interest.

- The currently configured system is complex, with a large variety of components. Air leaks that introduce non-condensable gas into the system may seriously degrade system performance, although there are provisions in the system to remove non-condensable gas through the roughing pump. The team has appeared to have done an exhaustive energy audit that ensures the system remains economically favorable, even given the various energy-consuming devices and component cost, which was good to hear.

3) **Recommendations**

- Consider Aqualyte membrane integration into advanced and/or state-of-the-art evaporative cooling concepts.

- The technology will need to operate in environments that has contaminants. Need to show how particle contamination affect the long term performance of the membrane. Coupling with electrochemical compression (for the vapor compressors motive force) adds complexity and cost. These addition should be carefully evaluated against BTO performance objectives.

- *None*

- Given the widespread potential for the technology, partnering with a large manufacturer of air-conditioning systems as the technology continues to mature would be helpful.

Project # 312109: Compact Thermoelastic Cooling System

A. Relevance

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

- The presented project is aligned with major BTO's ET Program goals - to accelerate the development of the innovative energy-efficient technologies for the buildings sector. Slide 14 clearly illustrates such a relevance. The project objectives are in the cost/performance target range.

- 1 kW cooling power is still fairly small and the weight and volume per kW cooling delivered is fairly large. Impact statement included in the slides of the presentation of the project seems quite ambitious for this early stage project.

- Project objectives of demonstrating a pathway to economical non-vapor compression cooling using thermoelastic materials is of direct interest to BTO program objectives. Project also reduces need for high GWP refrigerants. Impact of project COULD be large, but 50% penetration and resulting energy savings by 2025 is not realistic.

- This project is aimed at developing a cooling technology based on thermoelastic cooling. This is highly relevant for the DOE BTO program mission, both in terms of the advancing of innovative enabling technologies as well as the potential energy savings.

B. Approach

This project was rated:
1) **2.50** 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 project is its initial stage and mostly focused on the development and demonstration of the novel compression approach/mechanism of reduced footprint and weight. The project team has licensed the technology in 2012 mostly for the commercialization purposes and successfully completed proof-the-concept effort in 2015 under ARPA-E funding support. In the ongoing project MEST is exploring the "roller-belt" design and tested a few candidate materials. Due to a large number of the parameters to be simultaneously optimized - there might be more steps for design adjustment, including a shape of the thermoelastic material. The material selection and cost reduction may be a great challenge to this development.

- *None*

- There are several technical barriers to market adoption identified including (size), temperature lift, cost of materials, physical architecture of system (tension, compression, rollers, rods, etc.). The project team has designed their project to demonstrate a 400 W prototype of a complete system. The project plan as presented appears to show that the project PIs have down selected to the roller based design and the project will consist of optimizing this design. Additional risk mitigation strategies would be beneficial.

- Air conditioning remains an essential and core need for many residential and commercial entities. The state-of-the-art in air-conditioning is based on vapor compression. This is a mature technology, however, that has likely seen the vast majority of improvements already made. In addition, with emerging mandatory requirements for new refrigerants, which may provide additional challenges to traditional system performance, alternative technologies such as thermoelastic cooling being explored in this project are both timely and relevant.
- The project has identified these critical market barriers, assessed them quantitatively, and has oriented the product research and development to make significant improvement in the existing state-of-the-art such

that, if developed successfully, the potential exists to develop a product that would be competitive with current technologies, while offering a notable improvement in device efficiency.

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) **2.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The extensive pre-work has been done under ARPA-E support (2010-2015). A provisional patent has been filed. The project team is now working under Generation V prototype. Both simulation and testing have been performed. The major comment is in measurement accuracy. Brush thermocouples may not provide the accurate and consistent reading. The more attention should be paid to the testing methodology and protocols.

- *None*

- The project is within the first 12 months of performance. Based on this timeline, the project has progressed towards achieve the performance goals through analysis and fabrication of a bench top prototype unit. If successful, the project will significantly contribute to achieving the programs goals of reducing the technical risk of this very new technology.

- Project progress to date has been good. The team appears to have a solid understanding of the physical mechanisms and principles associated with the membrane-based thermal and mass transport. The team has identified several near-term target goals, and are making progress both on the analytical and experimental fronts.
- Being essentially a brand-new technology, it is understood that there will be many fundamental challenges. In particular, since deformation of the material is intimately tied to its temperature change, the challenge of avoiding heat flow into the material as the load is removed and the material cools is an extremely challenging task. The use of compressive rollers is innovative, and seems to work and does appear to be working, however there may be other approaches that provide improved thermal capture.
- The team is well aware of these challenges, and has a realistic assessment of the complexities involved in developing this technology maturity.

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) **2.25** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- It looks like the project team mostly relies on the UMD partnership however, still actively communicated with outer world. The main impression on project collaboration and integration - it is still seeking the best partner for the very promising cooling technology for the engineering and commercialization support.

- *None*

- Project collaboration between UMD and MEST is good and well established. Role of industry partners is not clear (consulting, market research, etc.). Teaming with a materials supplier would be valuable, as cost and availability of material is a stated critical risk.

- The teaming with the University of Maryland is noted. Given that the TRL of this technology at a significantly earlier stage, teaming with a well-respected research university is a good choice. Moving

forward is additional developments are made, and the technology continues to be proved out, it is suggested that a commercial partner be brought on board to provide guidance in terms of economics in system design that are cost-favorable.

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 team perfectly understands and clearly outlined the future scope in both short-term and long-term prospective. The key challenges to be overcome are parametrical optimization for the scale-up and high-efficiency heat exchange system design.

- *None*

- The project as presented appears to show that PIs have down selected to a roller based design and the project will consist of optimizing this design. Additional risk mitigation strategies would help improve confidence that project can be successful. Material cost is a clear hurdle to achieving cost targets. The cost of material at scale (i.e., not medical grade, etc.) should be explored to assess if economic targets are realistic.

- Moving forward with laboratory demonstrations and a working prototype would be a substantial milestone. The team is aware of this and has arranged its tasks and objectives to meet these milestones.
- In particular, some quantitative demonstration of COP or energy in/energy out would be helpful, particularly in helping to convince those not familiar with this new technology that it is a viable path forward.

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

***High*: 2** reviewers
- *None*

- Air conditioning is an essential resource for the entire country.

***Average:* 2** reviewers
- The effort is over 5 years in term and over $3M in funding. It would be expected more outcome to date. More intensive collaboration with the advanced engineering groups and OEMs is essential to accelerate the development.

- The presentation of the model was not sufficiently discussed in order to understand what the main assumptions of the model were and what would be the limitations. For example, heat losses seems to be not accounted for.
- The presentation of the cost analysis of missing and discussion was minimal. Miss to discuss the risk mitigation strategies, if performance and/or reliability and/or cost target are not achieved by the next milestone.

***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

- Key research and development areas such as loading mechanism redesign and identified materials characterization are receiving the sufficient attention. However, as mentioned above - due to other extensive duties and obligations of the key stakeholders of the project team (beyond the MEST activities) more emphasis should be done towards to collaboration with the engineering groups, OEMs and potential commercialization partners.

- *None*

- The task distribution and emphasis is well-balanced for the program targets.

***No*: 1** reviewer

- Performance, cost, reliability, scalability challenges were not discussed in the presentation.
- 1 kW cooling power is still too small to be relevant. Scaling up 10x is another big step for this technology and the project should indicate the feasibility of this technology for achieving larger capacity at reasonable weight/volume of the unit. The PI could also highlight the limitations of the state-of-the-art technology currently available and research areas that need to be further investigated in order to overcome technological and/or market barriers.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Very promising cooling technology based on the material's property. If successful in material selection (both technical performance and economic aspects) the presented technology may be a great alternative to the traditional compression systems.

- Novel concept for a non-vapor compression cooling. Some results from previous prototypes are available and this is helpful for this project, which can take advantage of those results.

- Strengths:
  - Very novel, non-vapor compression technology.
  - Demonstrated increase in TRL from previous DOE (arpa-e) projects. Ambitious targets.
  - Important to BTO goals.

- This is an innovative, interesting and potentially game changing technology for air conditioning. It is understood that thermal elastic cooling for A/C is a new and relatively unexplored area.
- Also, although not directly related to the PTO project, advances in this technology may find significant use in a variety of other related temperature, thermal, heat transfer, and cooling applications.

2) **Project Weaknesses**

- More attention should be paid to the measurement methodology and accuracy. The reliability of the collected data will help in follow-on comparison with the state-of-the-art technologies performance to prove the superior benefits.

- Performance of preliminary lab systems seemed to be fairly lower than the level expected for the target performance. Need to focus on testing and provide some technical evidence that would generate confidence with the achievement of the target performance and target reliability levels.

- Weakness:
  - Does not adequately address material cost/availability, which is a critical risk.

  - No risk mitigation if roller design is not successful was presented.
  - Role of industry partners is not clear.

- As mentioned above, the challenge of mechanically compressing material while also taking advantage of the temperature change in the presence of the compression is an intrinsically challenging task.
- Another issue, which the team is also aware of, is long-term performance of the TiNi material when considering a service life of years.
- Finally, titanium is a core ingredient in the thermal elastic material, may present an economic challenge if the technology (a) requires a large amount for a given system, and (b) begins to see an adaptation had very high volumes.

3) **Recommendations**

- There is no strategic vision of the commercial concept design yet - how the final system should be looking as commercial product. That's why the prospective commercialization partner and OEM should be involved in the project from the beginning.

- Could benefit from closer involvement of OEMs and HVAC manufacturers in the project. There are several factors to be considered for the overall system design focused around the thermoelastic cooling module. Examples might be capacity modulation and control, startups, variance of temperatures after cycling due to hysteresis, and operating envelope conditions of the overall system.

- *None*

- *None*

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

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 is perfectly aligned with the BTO's goals and it presents one of the key technologies of the BTO portfolio. The presented ECC technology may very well serve as a viable cost-effective and cross-cutting one for targeted reduction in buildings energy use

- *None*

- Clear project objectives of reducing energy consumption by HVAC systems using ECC technology. Target of 5000 BTU/hr, COP of 4.5 and price premium of $7 kBTU/hr. Project also would reduce reliance on high GWP fluids in HVAC systems. Represents an alternative to mechanical vapor compression.

- This project is aimed at developing an electrochemical compressor- based system for air-conditioning applications. This is highly relevant for the DOE BTO program mission, both in terms of the advancing of innovative enabling technologies as well as the potential energy savings.

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.

- ECC is a transformational technology for the cooling applications. Current effort is focused to integrate ECC and ILD into residential AC unit (target - 5000 BTU) to meet the BTO's metrics and satisfy the market targets. Close cooperation with the market leaders to enable the project team to identify the critical barriers for the technology. Key outstanding issues are cost of the components, integration solutions and operation security.

- *None*

- Key market barriers identified include cost (allowed premium), size, and performance/reliability of compressor components including membranes, etc. Project (as presented) appears to focus primarily on developing ECC compressor. Balance of HVAC plant may require less innovation or work to overcome barriers. Barriers/risks that were not explicitly addressed are sensitivity to noncondensables and sensitivity to changes in condenser/evaporator pressure.

- Air conditioning remains an essential and core need for many residential and commercial entities. The state-of-the-art in air-conditioning is based on vapor compression. This is a mature technology, however, that has likely seen the vast majority of improvements already made. In addition, with emerging mandatory requirements for new refrigerants, which may provide additional challenges to traditional performance, alternative technologies such as electrochemical compression being explored in this project are both timely and relevant.
- The project has identified these critical market barriers, assessed them quantitatively, and has oriented the product research and development to make significant improvement in the existing state-of-the-art such that, if developed successfully, the potential exists to develop a product that would be competitive with current technologies, while offering a notable improvement in device efficiency.

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 team took a good start and made a strong progress since the project inception. ORNL synthesized and evaluated a performance of the ILD candidates (selection is due by Q3-2016). Xergy has prepared for endurance testing and initiated a cooling cartridge design along with the Gen II MHHX development including the material selection and absorption-desorption rate optimization. Most of the progress is transferring from the other programs' findings and accomplishments.

- *None*

- Project is in early stages. Accomplishments to date (including prototype design/construction/test) seem satisfactory to achieve desired project objectives.

- Project progress to date has been good. The team appears to have a solid understanding of the physical mechanisms and principles associated with the electrochemical compression process and liquid ionic desiccants. They have identified several near-term target goals, and are making progress both on the analytical and experimental fronts.
- Based on the progress to date, the indications are good that future work by the team will continue to progress towards the program goals. A COP greater than 4 is a noteworthy challenge; however, if achieved, this would represent a significant advance in this technology.

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.

- As indicated in slides 15-16 the project team is integrating and collaborating with the global market leaders (not quite clear the relationships with Samsung, Panasonic, BMW, Coca Cola, etc.), ORNL and University of Delaware... The Chinese OEM Haier is listed on the title page but for some reason the details of such a collaboration, if any, are excluded from the slide 15 and were not clearly presented.

- *None*

- Strong collaboration and teaming with key stakeholders including Haier (primary partner) and other industrial, academic and federally funded (ORNL) partners. Potential for the developed compressor technology to enable other energy efficient technologies is attractive.

- The teaming with the University of Delaware, Oak Ridge National Laboratory and Haier represents an excellent partnership. Delaware provides fundamental research capability, Oak Ridge spans the gap between transitioning this fundamental technology to a commercializable system, and Haier represents a path to eventual commercialization.

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.

- Most of the stated future plans are related to other relevant programs... The next steps for the reported project should be elaborated in more details and focus on approved SOW.
- *None*
- Proposed work plan seems sufficient to achieve project goals.
- Moving forward with laboratory demonstrations and a working "ECC cartridge", would be a substantial milestone. The team is aware of this and has arranged its tasks and objectives to meet these milestones. Concepts are also underway for next-generation design.

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

***High*: 3** reviewers
- The presentation could benefit for some insights about end cost and major barrier(s) for cost reduction. Miss to discuss the risk mitigation strategies, if performance and/or reliability and/or cost target are not achieved by the next milestone.
- *None*
- Air conditioning is a critical resources required across much of the U.S.

***Average:* 1** reviewer
- Most of the reported deliverables were developed under other relevant projects, so they should be adequately adjusted for this effort. Project team is highly qualified, so the produced deliverables under the reported effort will satisfy the target markets.

***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 key areas of the ILD identification/characterization along with MHHX design development are in the immediate focus of the project team.
- The continuation of endurance testing is a very good idea. However, it would be beneficial to provide interim evaluation steps of the experimental results during the testing campaign. The interim test results could be used to modify and optimize the next ECC based system as well as for model validation and model incremental stages of refinements.
- *None*
- The task distribution and emphasis are well-balanced for the program targets.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project is built mostly on the results of prior BTO-funded work that may help enabling the overall performance success.

- Good resources and strong background to complete the project.

- Strengths:
    - Innovative technology that is in line with BTO goals
    - Excellent teaming partners with clear knowledge of challenges of developing a new HVAC technology
    - Versatility of technology to enable other energy efficient building technologies
    - Technology has realistic chance of overtaking mechanical vapor compression systems in the intermediate term

- This is an innovative approach to air-conditioning that avoids traditional vapor compression.
- The low DC voltage available that is required for the cell operation couples naturally to solar panels, and the team is suggested to pursue this possibility, if time and resources permit.

2) **Project Weaknesses**

- The major weakness of this effort is design integration and packaging of the system to create "the harmony" at the competitive cost.

- Need to focus on testing and provide some system level results (either experimental data and/or simulation results) that would generate confidence with the projected target performance and target reliability levels.

- Weaknesses:
    - Some technical risks are not addressed including durability, noncondensables and operating envelope range for a fixed system
    - From the presentation, it wasn't clear what innovations/risks exist in the balance of plant, or which project team member would be addressing those.

- The presence of non-condensable gas may present a problem for long-term performance. Proper sealing will help in this regard, and Haier likely has substantial expertise in this area, which may be used for the project.
- In reviewing the graph for COP verse membrane voltage, there is a very narrow peak at which the COP is maximum, and this falls off rapidly when the voltage is too high or too low. Also it appears that this peak voltage is only about 0.03 V. At the same time the membrane will presumably be experiencing current flows measured in amps. One concern is that is the current flows across the positive or negative electrode grid on either side of the membrane, there will be small but significant voltage drops as one moves away from the power supply lead. This might result in a substantial drop in membrane performance, even if the voltage drop is only a few millivolts. The team is encouraged to explore this further, as the potential to improve performance may be significant if the grid design can be optimized to minimize even very small voltage drops.

3) **Recommendations**

- Integrated system operation safety has to be included into consideration at the design stage as well as estimating of the system losses that would be helpful for the future cost-benefits analysis. Safety aspects of the ECC and ILD should be given more emphasis as to many other systems for commercial and residential applications

- Recommend to present some modeling efforts that could be used to indicate the potentials and limitations of the technology at various operating conditions and for different environment applications.

- PIs should consider sensitivity of system to “condensing” and “evaporating” conditions. If metal hydride performance has a steep gradient in performance the typical range of operation this could be troublesome. PIs should also at least more quantitatively address issue of noncondensables. Achieving a true hermetic seal at sub-ambient conditions in consumer grade equipment is difficult.

- *None*

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

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 provides support to BTO's goals that are clearly stated in MYPP. The concept of electro calorimetry is quite challenging in aspect of material selection, however, directly aligns with the BTO strategic interests to reduce EUI. The reported effort is in its early stage but has a strong potential for further development.

- *None*

- Project is clearly aligned with DOE BTO goals of reducing energy consumption of HVAC systems. The project is a high technical risk effort to move away from vapor compression systems and is in line with identified research opportunities DOE report on non-vapor compression HVAC technologies.

- The project is developed an alternative to traditional vapor-compression refrigeration systems. The approach is innovative, and has the potential for future developments and advances. It is relevant for BTO 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.

- B.1. The Phase 1 of the project is targeted to develop and demonstrate the 8+ degree material-level calorimetric performance that enables the module with COP >6. The major market barrier is the overall cost of the system and operating efficiency to ensure the lowering the utility bills for the customer. Carrier Corp as an integral part of UT is involved in this challenging development and provides the metrics and market requirements to the UTRC team during the project performance to avoid (or mitigate) any risks and barriers on the later stages of the technology and product development, demonstration and commercialization.
- B.2. The specific design of the heat pump module is a subject of Phase 2. Assuming the design phase of this development will be performed jointly with the OEM team the associated market barriers to be addressed during the detailed engineering and manufacturing of the pre-commercial prototype. The participation of the appropriate certification agency (such as UL) would be essential at the early design phase in order to prevent the possible adjustments during the market certification process.

- *None*

- The primary market barrier is the low TRL of the technology. Due to the low TRL significant effort to address market barriers have not yet been identified. The project team has identified a work plan to elevate the TRL of the technology and begin to overcome the barrier of low TRL. In particular the project team is focused more on module/system development rather than fundamental material development. I believe this is a strength to “de-risk” the balance of plant. PIs do not explicitly address experimental delta T or capacity targets in presentation that will be achieved by end of project. PIs do identify that seasonal COP target of 6.0 (modeled) is goal for full commercialization.

- Air conditioning remains an essential and core need for many residential and commercial entities. The state-of-the-art in air-conditioning is based on vapor compression. This is a mature technology, however, that has likely seen the vast majority of improvements already made. In addition, with emerging mandatory requirements for new refrigerants, which may provide additional challenges to traditional system

performance, alternative technologies such as electrocaloric cooling being explored in this project are both timely and relevant.
- The project has identified these critical market barriers, assessed them quantitatively, and has oriented the product research and development to make significant improvement in the existing state-of-the-art such that, if developed successfully, the potential exists to develop a product that would be competitive with current technologies, while offering a notable improvement in device efficiency.

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 is in early stage so it is not enough results and accomplishments to make the solid and justified conclusions, however, the project team has a good start by demonstrating the 8+ degree temperature lift at the in-house micro-calorimetry rig using sub-scale material.

- *None*

- The project is at a very early stage. The project team has apparently successfully completed their first milestones in the development of a micro-electrocalorimeter that will be essential for verifying future performance claims. No significant technical issues were reported and it appears that the team will continue to achieve project milestones.

- It was somewhat unclear during the presentation and in the slides what exactly the recent project progress has been on it appears that the majority of the work has focused on developing a high precision calorimeter in order to measure the temperature change for electro-caloric materials.
- There was some discussion that the current electro-caloric module size is on the order of 1 cm, and this was to be scaled up to 10 cm in the future, but again specifics appeared to be lacking. The project team is encouraged to provide some context or background when presenting research results for those not immediately familiar with the project, so as to better grasp the particulars of the advances being made.

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) **3.75** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Regardless of the presentation states that there is NO key partners - it is well known that Carrier Corporation, one of the world largest and reputable HVAC&R OEM, is in-house partner and potential commercialization party for UTRC development.

- *None*

- Project team (UTRC) has strong connection with OEM Carrier Corp. Carrier will supply dynamic modeling software developed for commercial HVAC components and consult on techno-economic analysis of system. As an OEM, Carrier has a clear expertise in the risks in moving a new HVAC technology to market.

- The team has demonstrated and is knowledgeable in terms of what it takes to advance and early-stage technology to commercialization. Although there are no external partners identified, the team has the

benefit of Carrier available to provide commercialization assistance, economic analysis, and feedback in the terms of field experience and recommendations for system design.

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 presenter clearly illustrated the next steps and future plans for the remainder of Phase I and Phase II. The potential risks are assumed to be mitigated upon project progressing according to the approved SOW.
- *None*
- Future work plan as presented seems reasonable. More clearly defined performance targets would strengthen presentation. In particular under what operating conditions will be the 6.0 COP be demonstrated? This is an ambitious target, but no discussion of modelling approach is provided.
- Moving forward, the project will be addressing issues such as scalability, demonstrating a COP target of 6, and a complete heat pump module. Although this is an aggressive timeframe, the team has the experience and technical expertise to accomplish this.

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

***High*: 3** reviewers
- At this stage of the project the presented deliverables encourage the project team to move forward according to the approved SOW.
- If successful, this project could provide some much needed inertia to non-vapor compression technologies. It is likely that even after completion of the project, additional DOE/federal funding may be necessary to continue to move the project to market. However, the high risk of the project is balanced by the potential high reward of significant energy savings and reduction in GHG production.
- Project is still in very early phase. Everything seems to be working well at this point.

***Average:* 1** reviewer
- The presenter could put more emphasis on the project outcomes at the completion of the tasks and any plan for dissemination of the results.

***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
- At this stage the project team has been emphasizing to the demonstration of the key component's performance to create the electro caloric module with COP>6
- Perhaps conduct some techno-economic analysis earlier than at the end of Phase II. It is recommended to be earlier than Phase 2, and should be included for the Go/No-Go review decision of July 2016.
- *None*
- No concerns.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The way a new technology reaches the market place is a long way with many challenges and risks. The trend in electro calorimetric material development (early 1900s - 1C, early 2000s - 10C) indicates a strong potential for presented technology to replace (fully or partially) the state-of-the-art.

- Good team. Novel approach. Sound approach and fairly comprehensive methodology.

- Strengths include:
  - High risk/high reward technology for reducing energy consumption and GHG
  - Experienced OEM partner in Carrier Corp.
  - Use of established dynamic system model from Carrier Corp.
  - Focus on module/system development rather than only electrocaloric material innovation.

- The use of electrocaloric refrigeration is novel and is most definitely worthy of further exploration. It is understood that there will be many challenges, and, in some respects, it is unfair to compare the current metrics and performance of the technology at this point in time with that of a competing major technology.

2) **Project Weaknesses**

- It is premature to discuss the project weaknesses due to its early stage, however, the presented technology development is associated with the serious engineering challenges to minimize all kind of losses (energy, pressure, electrical, etc.) and resolve the scale-up issues.

- Early stage project. Need some system model validations to support estimated target performance in the environment application.
- Need to discuss how the issue of scalability will be addressed as well as the challenges related to the module construction and integration.

- Weaknesses include:
  - I recognize the sensitivity regarding IP generated during the project. However, it makes it difficult to more accurately assess the project when so much of the work cannot be divulged.
  - More details on the planned system modelling task would be useful. In particular, what empirical parameters from the electrocaloric experiments will be required for closure to the model and under what operating conditions will be the 6.0 COP be demonstrated? These are ambitious goals it is not clear how this will be realistically achieved during the projects periods of performance.

- It was stated that each module will provide about 1W of cooling. This would require about 1500 modules for a small (5000 BTU/hr) window air conditioner. This might make the system cost-prohibitive.
- Scaling up the technology to a full -sized system may also present some technical challenges, given the large electric fields required (1000 V), and the need to evenly distribute this field across a large number of modules. Also, if the modules must be thermally arranged in series, there may be temperature -dependent effects between, e.g., those modules on the coldest side of the stack versus those on the warmest side.
- Another concern is long-term performance of the electro-caloric material. Fatigue and long-term degradation may result in system performance being compromised after the device has been in service for several years. It is understood that this is a question that naturally will be addressed at a later stage, after the initial technology has been proven.

3) **Recommendations**

- Project team should provide more consideration on the influence of the external electrical fields on the stable and safe performance of the system.

- Plots of the technology performance are incomplete or not clearly illustrated. For example, in the COP and equivalent DT plot, the effective capacity delivered is somewhat missing; is the delivered capacity constant for each point?

- *None*

- Since most people in the audience will not be familiar with electrocaloric cooling, a slide or two on the basic operating principle at the beginning of the presentation would be helpful.

Project # 312112: Magnetocaloric Air Conditioner

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Presented for review project is critical to BTO and develop a very promising concept of solid-state cooling for air conditioning application. It is truly revolutionary idea to use MCM moving rods to replace the heat transfer fluid and to achieve 8-fold increase in heat transfer with a strong potential of cost reduction

- *None*

- Project is important to BTO goals of reducing energy consumption and use of high GWP fluids in building energy systems. Project objectives are relevant to BTO as it is focused on novel system development and integration rather than purely on magnetocaloric material R&D.

- This project is aimed at developing a heating and cooling technology based on the magneto-caloric effect as an alternative to traditional vapor compression. This is highly relevant for the DOE BTO program mission, both in terms of the advancing of innovative enabling technologies as well as the potential energy savings.

B. Approach

This project was rated:

1) **3.50** 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.

- At this early stage of the reported effort the project team has identified as many as possible of the critical market barriers and initially targeted to window AC application. There are key issues were presented as well such as magnet design and accuracy of machining along with the need to mitigate the effect of increased frequency on the system balance (vibration, structural strength, performance efficiency, etc.).

- *None*

- At the low TRL of magnetocaloric systems, the key market barriers identified are system cost, complexity and achieving theoretical efficiency. The project has been designed to overcome these barriers by exploring a new magnetocaloric architecture using solids to transfer heat. The project design will lead to a prototype unit demonstrating the viability of the new concept.

- Air conditioning remains an essential and core need for many residential and commercial entities. The state-of-the-art in air-conditioning is based on vapor compression. This is a mature technology, however, that has likely seen the vast majority of improvements already made. In addition, with emerging mandatory requirements for new refrigerants, which may provide additional challenges to traditional system performance, alternative technologies such as magnetocaloric cooling being explored in this project are both timely and relevant.
- The project has identified these critical market barriers, assessed them quantitatively, and has oriented the product research and development to make significant improvement in the existing state-of-the-art such that, if developed successfully, the potential exists to develop a product that would be competitive with current technologies, while offering a notable improvement in device efficiency.

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.

- For the first 6 months since project inception the project team has demonstrated the fair progress by formulating the concept design and developing 1-D discrete model. However, the heat generated by friction (even in presence of thermal grease) should be taken into account for the next level of modeling to estimate the losses and energy consumption to oscillate the MCM rods. Effects associated with the frequency induced vibration should be considered as well at the modeling and design stages to avoid any discrepancies in the follow-on cost-performance analysis.

- *None*

- The project is very early in the performance period. The initial steps (establishing partnership with materials manufacturer and modelling) are in support of the project objectives. As presented, there appears to be potential for the project to achieve the desired goals.

- The team has demonstrated a solid understanding of the basic physical principles involved in magnetocaloric cooling. Project efforts to date have been understandably focused on modeling to prove out the basic operating principles and expected performance. It would be useful to provide some experimental data, even if only in laboratory setting, to validate the modeling and/or provide suggested improvements to its fidelity.

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.

- Involvement of the key stakeholders at the early development stage will ensure the overall effort success. Collaboration with Vacuumschmelze and initiated communications with GE Appliances indicate the right direction for project integration towards to the successful performance.

- *None*

- The project team appears to have engaged the right stakeholders. At this low TRL, it is probably premature to engage OEMs. However, engaging with a material supplier is extremely important, as magnet cost, availability and form factor are identified as critical technical risks.

- The team has demonstrated and is knowledgeable in terms of what it takes to advance and early-stage technology to commercialization. The ORNL team has also partnered with Vacuumschmelze, a leading manufacturer of magnetic materials, which should prove to be beneficial in the modeling, experimental and scale-up phases. It is understood that this is in the early stages of proof of concept, and thus may be premature to require a commercialization partner at the stage.

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 team clearly understand the future steps of this challenging effort such as further development of the numerical simulation model and engage the OEMs into the project as early as possible to ensure the manufacturer's oversight of the system design evolution.

- *None*

- There are many technical risks that could prevent the project from achieving BTO goals. Insufficient detail was provided on risk mitigation plan or detailed path forward.

- This is a very innovative project that was a pleasure to see. The authors are encouraged to move forward to advance this potentially very useful technology.

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

***High*: 3** reviewers
- Need to show how the projected impact of the project at the end of the work will be achieved and what will be the areas, if any, that will require additional research.

- Successful demonstration of the project as proposed would be a significant advance in the technology. This may spur additional system level (rather than material) development and lead to actual commercialization.

- Air conditioning is an essential resource for most of the U.S.

***Average:* 1** reviewer
- During the first 6 month there was no significant value of the deliverable has been reported (produced).

***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
- Just preliminary schematics and estimates were performed up to date. Too early to draw any conclusions.

- In the 1D solid state model, in the coupled equations, is there a way to include the heat losses in and out from the control volume? And could you assess the assumption(s) made on the edge effects.
- Discuss the issue/challenges with scale up and staging of the AMR module. One AMR module generate about 2-W for 8K temperature span in slide 15. Could you discuss the system core feasibility and barriers on the number of modules needed in parallel and in series to achieve 1-kW of cooling power with same T span?

- *None*

- The task distribution and emphasis is well-balanced for the program targets.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- The reported project is a challenging and revolutionary development that could make a big difference on the AC market place, if successfully developed and demonstrated.

- Novel concept and unique compressor technology approach. Good resources and strong research team and partnership to complete the project.

- Strengths
    - Novel, non-vapor compression technology.
    - Focus on system development versus pure materials research.
    - Strong industrial partner (material supplier).

- This is an innovative, interesting and potentially game changing technology for air conditioning. It is understood that magnetocaloric cooling for A/C is a new and relatively unexplored area.
- Also, although not directly related to the PTO project, advances in this technology may find significant use in a variety of other related temperature, thermal, heat transfer, and cooling applications.

2) **Project Weaknesses**

- MCM materials and magnet design and fabrication may not be so cost-effective as tentatively anticipated.

- Project is in early stage. A basic thermodynamic and heat transfer model was developed but it needs further refinements and validation.
- Need to generate confidence with the projected target performance and target reliability levels. For example, did not show system simulation results that indicate 25% target energy savings with respect to AC window with minimum efficiency units.

- Weaknesses
    - Significant technical risk in increasing frequency of system, managing friction, manufacture etc. Risk mitigation was not adequately presented.
    - Magnet material/cost/availability are high technical risk. Insufficient detail on the cost and availability of these materials at volume was provided.

- All of the reviewers brought up the concern about friction between the rods. This is an issue that needs to be addressed in further detail. If the friction is close to zero, then the thermal contact between the rods and the surrounding material will be poor, thus hindering heat transfer. On the other hand, excessive friction will require mechanical work to move the rods in and out, and this will actually cause two problems: the first is the work required, e.g., from a motor, and the second is that that work will be dissipated as heat within the rod and surrounding material. It was mentioned in the presentation that lubrication or thermal grease will be added between the rods, however this will eventually work itself out through the natural oscillation process of the rods.
- A magnetic field of two Tesla is also very high, and there are some concerns that the losses associated with producing such a field may offset the potential COP benefits obtained from the device itself.

3) **Recommendations**

- The lack of negative effect of the magnetic field on the human health should be emphasized and strongly justified. It would be also recommended to invite the certification agency (such as UL) to overview the draft design prior to pre-commercial development (it may save substantial time during the commercialization phase).

- Effectiveness of the heat exchangers to this environment application should be accounted in the overall system performance.

- None

- *None*

Project # 32210a: High-Efficiency, Low-Emission Refrigeration

A. Relevance

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

- *None*
- This presentation does not make a compelling case for CO2 systems since it compares against a run of the mill HFC system. And it only outperforms those at lower ambients. In the Southern U.S., we may see very little annual savings. CO_2 is more popular in Europe due to refrigerant regulations. It's not clear this technology will become successful here. It is doubtful it will become cost competitive with traditional refrigerants.
- Potentially high value, given the number of grocery refrigeration systems in service. Limiting factor will be the number of system configurations in the field within the sub-type developed.
- The technology would likely apply to new construction, but not to retrofits.
- Supermarkets use a significant amount of energy so any effort to develop technology to reduce this energy is relevant to BTO program goals.
- The goal of this project is to develop a supermarket refrigeration system that reduces greenhouse gas emissions by 75% and has 25% lower energy consumption than existing systems. As such the project is critical to the BTO and fully supports BTO's goals.
- The target savings for supermarkets will help meet BTO goals.

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 work with an OEM on highly relevant work.
- Cost barrier was not realistically addressed. The fact that the system performs poorly at higher ambients makes the system unsuitable for large areas of the U.S.
- Field testing will lead to discovery of practical limitations.
- The approach of taking a system-wide approach to improving efficiency and technology is reasonable.
- The approach involves analyzing refrigeration system strategies, selecting and fabricating a laboratory-scale prototype refrigeration system, and conducting field characterization of the prototype. Most of the critical barriers have been identified. The investigators are making a good effort to overcoming critical barriers.
- The project, with CRADA partners, is bringing the technology all the way to market.

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) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Not sure on adoption rate to meet interim market goal.
- The steps are good, but the results are not positive. Savings compared to a run of the mill existing system become negative at higher ambients. Maintenance issues are likely to lead to higher than expected head pressures so it is likely that over time, any performance benefits will diminish rapidly.
- Transformative within the limits of the market's use of the particular system configuration.
- Much has been accomplished in terms of increasing component and system performance efficiencies.
- The investigators have presented strong qualitative and quantitative work so far. It is very likely that the project will achieve the program's interim market goal. They built a prototype CO_2 transcritical booster among other things.
- The transcritical CO_2 supermarket refrigeration system has exceeded the energy and emission savings targets. It is a proven technology in Europe. The main question at this point is how large market penetration will actually be.

D. Project Integration and Collaborations

This project was rated:

1) **3.83** 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) **3.67** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Having an OEM involved and some field experience shows great collaboration.
- Coordination and participation are well covered. And CO_2 has had some buzz due largely to the GWP and acceptance in Europe, but this project shows that it is likely not a good answer for U.S.
- Excellent partners chosen.
- The project has assembled an impressive number of interested industrial partners.
- Dr. Brian Fricke who presented the work demonstrated an excellent level of understanding of the key stakeholders. He is collaborating with Hill Phoenix (CRADA partner) among others. CRADA is tasked with deploying a low emission high efficiency system in 2014.
- Collaborations and partnerships on this project are outstanding.

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.

- *None*
- A demonstration project is a good step but likely to further highlight shortcoming of the technology.

- Exploration of system limitations and efficiencies across the full range of operating ambient temperatures is imperative and will be supported through field testing.
- The project's focus is now to complete system evaluations and to get a third.
- Future work is focused on evaluating the performance of the prototype refrigeration system in the laboratory and in a third-party installation, and tasking CRADA partner to begin deploying systems and then eventually developing a 2nd generation prototype system. The presentation states that this was scheduled for end of 2014, but it is not clear whether or not this actually was done.
- Future plans are appropriate.

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

***High*: 5** reviewers
- *None*
- Within the system's applicability and other limitations it should have high market penetration.
- *None*
- The project is highly relevant to the BTO program goals. Work done so far is very good.
- Again, system exceeds performance targets and is on its way to market.

***Average:* 1** reviewer
- Steps and results are reasonable.

***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
- *None*
- Probably.
- *None*
- The key research areas are receiving sufficient emphasis.
- *None*

***No*: 1** reviewer
- I believe it should be made clear that this technology falls short of the DOE efficiency objectives.

H. Additional Comments and Recommendations

1) **Project Strengths**

- *None*
- Quite well laid out program to test the technology.

- Basic operation has been demonstrated.
- Commercial success of similar systems in Europe indicates probable success here.

- The project's strength is that it is focusing on an application that is overall inefficient and in need.

- The strength of the project is in its investigators and partners who are highly qualified for the job in hand.

- System has excellent performance and is being brought to market.

2) **Project Weaknesses**

- *None*

- Technology shows itself to be weak in this application compared to alternatives. For example high efficiency condensers with low GWP heat transfer fluid.

- Modeling should take into account the full range of outdoor operating temperatures, especially on rooftops, and in hot climates. Reported COP is worse than existing systems above 90 F, which may occur in southern & western climates.

- None.

- There are no weaknesses. I would like to know if CRADA partner deployed the prototype by end of 2014 as stated or not.

- *None*

3) **Recommendations**

- *None*

- Recommend the project be completed and ended.

- Field testing (as planned) will be valuable in identifying specific applications, installation configurations, and climates where the technology is most appropriate.
- Training installer infrastructure will be critical, as most have never dealt with CO_2 refrigerant.
- Emphasis was placed on the high refrigerant-leakage rate of existing systems. The present system does nothing to reduce leaks, and given the same "balance of system" leakage locations, the leakage rate could be higher due to the higher pressure of the CO_2 system.

- None.

- Very good project.

- *None*

Project # 32210b: Magnetocaloric Refrigerator

A. Relevance

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

- *None*
- This project is not yet sufficiently developed to determine if the technology can be overall successful.
- Current energy star refrigerator energy use is so low that this system must have minimal incremental cost vs. traditional compressor systems to achieve market penetration.
- The development of magnetocaloric refrigeration is relevant to BTOs program goals.
- The project report focused on manufacturing of magnetocaloric heat exchangers; little evidence was presented that an energy efficiency improvement can be reached. Perhaps that was covered in the original proposal or an earlier progress report. But this report covered a lot of interesting material on the manufacturing challenges.

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.

- *None*
- We are not to the point of a complete solution, but at this point only working to get the cooling output targeted. So there are a whole lineup of potentially new barriers that may need to be addressed. It appears certain that some new barriers will be identified that have to date not been identified.
- Biggest market barriers will be system cost and reliability. While a compressor has been eliminated, there will be a power supply, valves, and pumps that may have greater reliability issues. Parts-count may be higher than in current compressor based systems.
- This technology is one of the most promising and innovative of all the ones being investigated.
- Again, we didn't see any performance data for the whole cycle, only manufacturing work, so any market barriers related to efficiency were not addressed.

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) **2.20** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Still some work to show that interim market goals can be achieved in such a different approach,
- There has been some important microchannel progress but there are a number of other issues that have to be resolved. There are many obstacles to meeting the program's goal - some of which have not even been identified.

- The magnetocaloric science has been well demonstrated and has been advanced. It is too early to know whether the science and technology can be implemented in a marketable and reliable product.

- Major components have been researched, developed and are presently being evaluated.

- Again, considering what was presented, it is hard to see how well this project will support achievement of performance goals or market 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) **3.40** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Good collaboration showing interest from a manufacturer.

- Not clear that there is really an effective dialog with the industry that would have to adopt this technology. I appreciate this is new and not yet well developed, but a more holistic approach could perhaps limit going down dead ends with a more robust integration and collaboration environment.

- Collaboration with GE is wise.

- The partnership and involvement of GE is significant.

- Collaboration with others at ORNL and with GE is highly appropriate.

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.

- *None*

- One of the problems of a siloed approach as appears to be the case here is that a substantial amount of time, energy, and money can be committed before issues that could make the concept impractical are found. Then it can be hard to give up because so much has already been done. I'd like to see a more in depth analysis of the practicality of the overall technology package included and reported so that a preliminary analysis can be made to see if it is likely to meet performance and cost effectiveness program's goals.

- Project was designed to develop magnetocaloric materials. This goal appears to have been accomplished well. Future work would require up-scaling the BTU capacity of the MCM system and then implementation into a product. This is not part of the current project.

- Major steps and milestones must still be undertaken.

- Future work on manufacturing is appropriate.

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

***High*: 2** reviewers
- *None*

- If magnetocaloric refrigeration is to progress, the type of research leading to an understanding of how magnetocaloric heat exchangers can be designed is important.

Average: **3** reviewers
- *None*

- I question if there will be enough information to determine if this technology can and will be successful.

- The deliverables are simply a first step.

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
- *None*

- Yes, but there are many more that require some attention even at this stage of R&D.

- MCM material has been shown to be operable.

- *None*

- Current research emphases are appropriate for technology development level.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- *None*

- This team has shown that it can find and resolve difficult problems.

- MCM material manufacturing at the low volume research level has been demonstrated.

- Transformative technology.

- The project is working in a highly unknown area (fabrication/manufacturing of magnetocaloric materials) and I think the work is appropriate. The magnetic orientation of the particles seems very promising.
- The score is perhaps lower than the project deserves because of the way this questionnaire is formulated.

2) **Project Weaknesses**

- *None*

- This is a new technology and there are many diverse components that need to be addressed for it to become successful. It would be much more effective if some effort were made at this early stage to address a greater range of hurdles than to focus, as appears to be the case, rather narrowly before addressing others.

- There is simply a long path from this successful work to a practical application.

- None.

- The main weakness from the perspective of a reviewer just seeing this report is that it is hard to see what the final performance is likely to be.

3) **Recommendations**

- *None*

- Recommend broadening the scope to identify a broader range of issues so that a more complete evaluation of the viability of the technology can be made by the end of this project.

- Future work should focus on efficient pumping and efficient heat/cool extraction from the MCM material.
- I didn't have a chance to ask: can the additive printing process automatically switch from one curie-point material to the next (like changing ink colors), so individual disks can be produced as a single item, and do not have to be stacked manually?
- It wasn't clear: has the additive printing process been abandoned in favor of the magnetically stabilized microchannel process? Is the printing process still used in making the latter disks?

- None.

- *None*

Project # 32212: High-Performance Cold-Climate Multi-Stage Heat Pump

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project is in active performance since 2010 and it is critical to BTO portfolio by demonstrating over 40% energy savings while satisfying the program goals. The approach is known since 1927 (Vorhis cycle) but was not practical until 80s due to lack of reliable automatic controls

- *None*

- A more efficient cold climate heat pump that displaces electric resistance strip heating would yield significant energy savings, in line with BTO goals. However, project does not address more recent goals of moving to low-GWP working fluids. It would also have been interesting to see how significantly the performance would need to be improved to be competitive with natural gas fired furnaces on a primary energy basis.

- This project is aimed at enhancing a traditional vapor compression cycle using two fixed-speed compressors and an adjustable charge for cold-climate heat-pump applications. This is relevant for the DOE BTO program mission, both in terms of the advancing of innovative enabling technologies as well as the potential energy savings.

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.

- Project focuses on critical market barriers such as cold climate operations and heating capacity to match building load. Testing methodology (both laboratory and field) should be elaborated in more details in order to justify the presented (measured) benefits

- *None*

- The primary barrier identified was first cost and operating cost (consumer bill). One barrier that was not addressed was delivered air temperature/thermal comfort. It would have been helpful if actual $ amounts were included. Furthermore, it would have been helpful if a cost of competition (variable speed systems, etc.) were included as a reference.
- The project was designed in a manner to address both of the critical barriers. In particular, I thought the approach of a “base model” and “premium” version was a good idea.

- Heat pumps have the promise to improve energy use, but have seen limited application in the U.S. due to cost and performance issues. If successful, the proposed technology would provide improved heat pump performance, thus allowing greater penetration into the commercial markets for heating equipment.
- The project has identified these critical market barriers, assessed them quantitatively, and has oriented the product research and development to make improvements in the existing state-of-the-art such heat pumps.

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.

- Upon multiple testing of the lab and field prototypes throughout the project term the 40% reduction in daily energy use was established at coldest conditions. COP >2 has been achieved. All test prototypes demonstrated compliance with the set project goals. There is still some cost-effectiveness challenge for the commercial unit.

- *None*

- The PIs present good quantitative data demonstrating project success. In particular, the field testing showing a drop in utility bill was an important outcome. The PIs should try to further isolate the contribution of the equipment to the drop in utility bill (i.e., compare on degree day basis, control for other equipment, etc.).
- The future additional data in Alaska will help further verify the team's progress towards their goal.

- Project progress to date has been good. The team appears to have a solid understanding of the requirements needed to improve the performance of a traditional vapor compression system. Although the technology advances largely incremental, the results are still significant, and may provide the much-needed bump in efficiency to make heat pump systems more attractive to the U.S. market.

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.

- The project team that is led by ORNL is quite impressive and include all necessary expertise and experiences.

- *None*

- The project team has identified and is working with a key stakeholder (Emerson Climate Technologies). The role of Emerson should be clearly defined to better understand project coordination. Other stakeholders that would have been interesting to engage include system integrators (e.g., Carrier, heat pump manufacturers) and electric utilities.

- The teaming with Copeland Scroll and Emerson climate technologies is noted. Since the compressor design is an integral aspect of advancing this technology, Copeland scroll provides a valuable asset. Emerson can provide market studies, feedback, and economic and technical input in terms of finalizing the designs for eventual commercialization, as well as providing potential customer sources, pilot studies, and marketing.

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.

- Future field testing of the latest configuration in the most appropriate climate conditions. It is critical to prove an anticipated COP increase for this approach in the cold climate conditions. Follow-on commercialization activities upon successful completion of the testing in Alaska in 2016-2017, as planned.

- Could clarify more (in the report) about the criteria used during the comparison of the proposed system(s) against CCHP units available in the market today. Especially when the COP is equal or low than competitive units, the report can highlight that the initial costs of the proposed tandem system might be

lower, or something else was more beneficial. And look into what made the cost lower and how much lower (in percentage for example).

- The project is nearly complete. However, the final field testing data should provide a satisfactory conclusion and assessment of the projects ability to achieve their stated goals.

- Moving forward with additional field test demonstrations to confirm the COP and performance targets are important and recommended.

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

***High*: 3** reviewers
- Stable system operation in the cold climate conditions is of great value for both the target audience and the market.

- *None*

- Cost-effective heat pumps that are attractive to the U.S. market would be extremely beneficial.

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
- All key research areas are covered and sufficiently studied by the highly qualified project team.

- The presentation (and final report) could benefit from some additional information about cost and market penetration strategies, if the proposed technology will be likely adopted by the cold climate heat pump industry.

- *None*

- The task distribution and emphasis are well-balanced for the program targets.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Relatively stable operation in a wide temperature range (including low numbers) and a strong potential for the energy savings at the cold climate conditions.

- Good resources, strong background, and excellent experimental results that indicate that the project objectives are likely to be met and target performance achieved.

- Strengths:

- + Comparison of low first cost “base” and “premium” model rather than jumping to more technologically advanced solution
- + Good collaboration with Emerson
- + Demonstrated utility bill savings is ultimate success metric which will drive consumer adoption

- The technology builds on the proven history of vapor compression systems hence the technical risk is minimized. At the same time, the target performance increase may provide a significant multiplier in leveraging this technology to become more competitive with more traditional heating systems.

2) **Project Weaknesses**

- Testing methodology and measurement accuracy should be re-evaluated to better justify the reported benefits.

- In future work of the present project, some additional field testing or simulated field testing for long periods in a laboratory environment at various cold climate zone conditions should be conducted, with different humidity levels and for various building loads profiles. These data will generate a broader acceptance of the proposed tandem systems among the industry.

- Weaknesses:
- Insufficient discussion of competitors already in market on basis of cost and energy consumption. What is the advantage of the proposed system(s)?

- The system cost and complexity are increased significantly with the proposed design. Fortunately, the added components are industry-standard devices, and use standard joining, interface, and powering requirements. Still, a careful assessment of the capital and ongoing maintenance costs will be an important part in determining the overall net economic benefit of this technology.
- It is also noted that there are competing concepts using single, variable speed compressors and other innovations to achieve the same goal. The team is encouraged to keep abreast of competing developments that they might be able to (a) incorporate into their own designs, and (b) ensure that they are not duplicating similar effort elsewhere.

3) **Recommendations**

- It would be helpful to engage the certification company into the testing process to avoid possible re-designs.

- What were the limitations and which technological or market barriers were identified from the results of the project?

- It would be valuable to investigate if the lessons learned here could be applied to systems with low GWP refrigerants.

- *None*

Project # 32218a: CO_2 Heat Pump Water Heater

A. Relevance

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

- The presented 6+ year effort is critical to the BTO's portfolio because it strongly supports the key targets and goals such as development and market deployment of high-efficient and cost-effective low-GWP water heating technology.

- *None*

- CO2 heat pump water heaters contributed to BTO goals of reducing energy consumption and reducing use of high GWP fluids in HVAC/water heating systems. Driving the cost down of this products may spur market adoption.

- This project is aimed at developing a carbon dioxide heat pump-based hot water heater for residential applications, while utilizing a low GWP refrigerant.
- This is relevant for the DOE BTO program mission, both in terms of the advancing of innovative enabling technologies as well as the potential energy savings.

B. Approach

This project was rated:

1) **3.00** 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 team has selected a viable approach - to utilize the low-cost components and optimized designs while maintaining Energy Star rating. Working with the market leaders ORNL team identified and focused on the key critical market barriers to successfully overcome them in the course of project performance.

- *None*

- The stated project objective/impact was to develop CO2 heat pump at price point viable for U.S. residential market while also increasing EF of water heater. While cost is certainly an important market barrier, the project did not discuss any other relevant barriers to CO2 heat pump water heaters. The presentation focused almost entirely on CFD modelling and optimization of a wrapped tank gas cooler. While GC performance is important to overall system efficiency, no information was provided regarding experimental or analytical work on balance of plant. It seems that significant cost reductions and energy improvements could also be realized in suction line heat exchanger, compressor, valves, controls, etc.

- Heat pump-based hot water systems have the promise to improve energy use, but have seen limited application in the U.S. due to cost and performance issues. If successful, the proposed technology would provide improved hot-water heat -pump performance, thus allowing greater penetration into the commercial markets for hot water equipment.
- The project has identified these critical market barriers, assessed them quantitatively, and has oriented the product research and development to make improvements in the existing state-of-the-art of hot water heaters.

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) **2.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- There are four main accomplishments made to date (based on the presentation materials - there is no photo of the tested prototype has been presented):
  - CFD model has been developed and appropriately validated.
  - Numerical simulation of the various designs has been performed at different temperature approach values.
  - Optimal prototype design has been selected, fabricated and evaluated (EF - 2.1 has been achieved).
  - Projected installed price premium of less than $750 has been achieved.

- *None*

- Project appears to have met many of targets in terms of cost and performance, however presentation as nearly identical to presentation from 2014. It was not clear what accomplishments or progress has been made over the past two years.

- Project progress to date has been good. The teams done a systematic review of the key he transfer phenomena occurring in the system, including stratification, heat loss, and the optimal arranging and configuration of the "condenser" tubes that surrounds the water tank.
- It is noted in passing that the current visitation appears to be nearly identical in every respect to the presentation given one year prior. It is thus unclear what the contributions have been over the past year. In the future the team may wish to make this distinction clear.

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) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Highly reputable and qualified team provided the extensive integration activities including publications, presentations, and technical/business communications.

- *None*

- GE is identified as a CRADA partner. Role of GE is unclear. Partnership with HVAC OEMS manufacturing heat exchangers, compressors, etc., would be valuable to the goals of the project.

- The teaming with GE Appliances is particularly attractive for eventual commercialization of the technology. GE has a long history of developing innovative appliances, and can provide valuable feedback in terms of economic, marketing, customer, and usage constraints as the technology is further developed for commercialization.

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 team set clear path for the future work that includes the final UEF evaluation, as required, followed by the Final Reporting to conclude the entire effort.

- *None*

- Majority of work is complete. Future work is focused on preparation of report.

- It appears that the project is coming to a close. The authors are encouraged to consider preparing journal papers based on the results so that others in the community can learn from the research efforts.

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

***High*: 2** reviewers
- The affordable and energy-efficient water heater with the low environmental impact is of a great value for both the target audience and the market.

- Cost-effective heat-pump hot water heaters would be attractive to the U.S. market and have the potential to save significant amounts of energy, if adopted for widespread scale.

***Average:* 2** reviewers
- The target for efficiency seems to be more or less in line with BTO performance metric but the path of cost reduction and market penetration of CO2 heat pump technology are only in the first stages and might need further work with manufacturers.

- A cost competitive and efficient CO2 heat pump water heater could have both market and economic saving potential.

***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 highly qualified and experienced team of this project carefully considered all possible research areas and business/market aspects of the reported development.

- *None*

- The task distribution and emphasis are well-balanced for the program targets. See comment about similarity between adjacent year presentations, however.

***No*: 1** reviewer
- Again, the project (as presented) seemed to focus most effort/funds on gas cooler design and optimization. Compelling evidence that this is indeed the critical barrier was not provided.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Low price premium achievement that improve the market potential for the commercial product developed under this effort.

- Good demonstration project for a CO2 based heat pump technology.

- Strengths:
    - Relevant problem, project goals are well aligned with BTO goals.

- The use of a heat pump for water heating applications has clear and distinct advantages. Also the use of a low GWP refrigerant is attractive, particularly in the current climate of reassessing the impact of refrigerants on global warming.

2) **Project Weaknesses**

- The project team did not pay enough attention to the advanced heat transfer enhancement techniques that may improve the system performance and resulted in further reduction of the components' cost.

- The project outcomes were not clearly presented nor quantified in the presentation. It would be helpful to discuss how the performance were achieved and how the cost reduction was realized. Also, no information was given on the CO2 components efficiency and cost estimate. For example, the impact of an internal heat exchanger or a suction line heat exchanger.

- Weakness:
  - Project (as presented) seemed unbalanced in focus on gas cooler design/optimization
    - No information provided on experimental studies.
    - Role of GE as partner is unclear.
    - No apparent progress since 2014 peer review.

- As a side note, it was mentioned in the presentation that the value of the thermal conductivity of the thermal pace was used to get the model results to agree with the experimental data. This is really not an acceptable approach, and will likely give grief to the team if they eventually attempt to publish this work doing the same.
- Better is to accept the inevitable variability's between the simulation in the experiment and do one's best to explain the differences and/or consider additional simple tests that might be done to determine where the discrepancy arises.

3) **Recommendations**

- There an elevated operating pressure is assumed, so the relevant components should be compliant and meeting the structural strength requirements and regulations, if any. Engage the certification party into the final UEF testing to avoid possible re-designs during the future certification process.

- With regard to slide 7 of the project presentation, discuss the criteria driving the selection of a non-contact heat exchanger design over a contact (mixing) heat exchanger design. It is true that water pumps and some water fouling issues are minimized if not eliminated, and cost might be also lowered, but there is a significant thermodynamic decrease on the efficiency associated with a non-direct contact heat exchanger based pump systems.
- The PI could perhaps clarify some of the criteria selected for the final system design in the final report and what were the main drivers for the final system realization (efficiency, cost, low GWP, reliability, safety, etc.).

- *None*

- *None*

Project # 32218b: Commercial Absorption Heat Pump Water Heater

A. Relevance

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

- Good agreement with BTO's goals.

- Not clear that this will be cost effective. Sample project would save just a few therms a day and as diagrammed, the concept only supplement a standard water heater so most of the cost would be additive.

- Good to focus some projects on natural gas water heating efficiency.
- Efficiency measurement and rating needs further examination.
- My primary concern with the efficiency measurement is how the customer will see the system's efficiency. Slides 7 and 13 show the HPWH feeding into a booster tank, which is intended to further raise the delivered water's temperature. The customer will see this as a package, and will be interested in the efficiency of the package. If the HPWH is delivering water at less than "full" temperature and the booster WH is doing part of the work, the SYSTEM COP will be less than the COP of the HPWH.
- If the booster tank is really functioning as a buffer tank, to stabilize the temperature of the delivered hot water, then this is not an issue.
- The bottom line is that the HPWH should be able to deliver hot water at the facility's desired temperature without the booster tank. The booster might be needed only when there is an unusually high HW demand.

- Absorption technology with its potential for reducing energy is relevant to BTO goals.

- The output of the project is a 140,000 BTU/hr GAHP achieving a cycle COP of 1.63 at the rated condition of 47 F ambient.
- The target market includes hospitals, hotels and full service restaurants gas hot water heating market. As such, the project aligns very well with the BTO's program goals.

- WH makes up a significant part of the energy consumption for some commercial building types.

B. Approach

This project was rated:
1) **3.17** 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.

- Service is likely one of the biggest market barriers and it does not seem deeply addressed

- There are really no new developments here. It is not reasonable that this effort will encourage entries into the market due to cost versus relatively modest reduction in energy costs.

- System size (BTU rating) appears to be chosen well as a first effort in addressing the hotel/restaurant market.
- Shortcomings (below-target efficiency, rectifier performance) are known and being addressed.

- The development of the single-effect cycle through modeling and bread boarding is a very worthwhile approach.

- The approach involves thorough single-effect cycle modeling to predict target performance, system and component analysis of the prototypes to identify areas of improvement, and assembling a dedicated

fabrication team at SMTI. Key Issues involves dealing with the high pressure drop on the hydronic side and dealing with the under-performing rectifier component.

- Market barriers weren't presented in the report but presumably first cost is a key one; a second one might be space outside the building.

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.

- Good demonstration of technology.

- This envisioned product will not save substantial energy and is unlikely to achieve any meaningful market penetration.

- The biggest barrier to achieving market goals is that the market is so fragmented in terms of equipment sizes required for different applications (small vs. large hotels, hospitals, restaurants, etc.). This is not a fault of the technology design. Some sites may need multiple, staged, copies of the HPWH feeding into a much larger storage tank.
- The team is to be commended for testing to outdoor temperature as low as 8°F.

- The alpha prototype is complete and has shown significant results.

- Accomplishments so far include developing an optimized single-effect cycle model to predict target performance. In this regards; (1) the breadboard testing has been completed; (2) 87% of performance target at design condition has been achieved; (3) a 3:1 modulation has been achieved; (4) an Alpha packaged prototype has been fabricated and tested; (5) 92% of performance target at design condition has been achieved; and (6) a 3:1 modulation has been achieved.

- Alpha test unit has shown good performance, approaching target levels, but defrosting and electrical input were not included if I understood correctly.

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.

- Good demonstration of collaboration between 3 entities.

- There is collaboration, but it's hard to see how this will result in a successful product. Absorption technology is not at all maintenance free and it is not well understood by the maintenance and repair community. It is not at all clear how these products will be maintained even if they were cost effective.

- AO Smith and ORNL are good choices of collaborators.

- The collaboration of A.O. Smith is important to the project's success.

- Project collaboration is very good. Partners include ORNL with expertise in building equipment performance evaluation and modeling, AO Smith (OEM) who provides component design, fabrication,

testing support, market research, and cost share to the project, and SMTI who provides component and system design, fabrication, testing, testing support, and market research.

- Good team and reasonable collaboration with WH mfr.

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.

- *None*
- Good idea to develop and analyze initial test installations. However, the one in operation is not showing itself to be cost effective.
- Future work should include several monitored, field tested units in various applications, to help discover operating conditions that were not anticipated.
- Attention should be paid to how the unit defrosts its outdoor coil during cold weather operation. Defrost controls can get complicated.
- The beta prototype is being assembled and then it will be evaluated.
- Future plans include the following: (1) Continued testing & verification of Alpha unit by ORNL, (2) Steady-state testing, (3) Fabrication & testing of Beta prototype at SMTI, (4) Target incremental performance improvements, (5) Controls optimization, (6) Test under commercial water heating conditions, (7) Testing of Beta unit by ORNL, and (8) steady-state testing.
- Appropriate future plans.

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

***High*: 4** reviewers
- The technology appears to be well developed, and needs only to have practical-implementation bugs worked out (like any new technology).
- *None*
- Valuable deliverables.
- Significant potential for energy savings over conventional gas water heaters.

***Average:* 2** reviewers
- *None*
- The project has done a reasonable job but this is not an application that is likely to succeed.

***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
- *None*

- Yes, there is sufficient emphasis but there really is no emerging technology to emphasize.

- Development areas have been addresses. Shortcomings are mostly known.
- Deployment has not yet been addressed.

- *None*

- Research areas and deployment activities receiving sufficient emphasis.

- Research and deployment plans are correctly aligned with what's needed.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good demonstration of technological capabilities.

- *None*

- The 3:1 modulation capability should be very effective at reducing system-cycling losses. Cycling loss is a major cause of working efficiency being lower than rated efficiency. There will still be cycling losses due to some types of water heating loads.

- A promising technology is the project's focus.

- Great team and good promise of success.

- Could be a good alternative to conventional gas water heating.

2) **Project Weaknesses**

- Still some gaps in adoption challenges, specifically around service and integration into existing technology stock.

- If this product had market appeal it would have likely found its way onto the market by now. First cost, and maintenance compared to alternatives are the likely reasons it has not be marketed to date and is unlikely to find success.

- I question the PI's method of stating efficiency. The AHPWH system should include the "booster water heater" in its measurement of total system efficiency. This is a problem, because commercial water heaters do not have a standard draw pattern. See previous comments about the booster. It should be confirmed that the HPWH can deliver the required HW temperature.

- None.

- None that I know of.

- Burning gas in the summer to make hot water is one downside.
- Hard to say if payback will be satisfactory.

3) **Recommendations**

- *None*

- Recommend this project be completed ASAP and the results made to the gas appliance community for any further action on its part.

- The customer may not realize the anticipated savings that a laboratory measurement would indicate if the HPWH is only carrying part of the total water heating load. Field testing in a variety of applications would give a realistic range of customers' gas savings for their water heating systems.
- As a generic comment, implementing absorption technology will be slow because there is essentially no retail installation and service infrastructure that understands this technology. The manufacturer will need to include a budget for installer training.

- None.

- Promising project.

- *None*

EMERGING TECHNOLOGIES
WINDOWS & BUILDING ENVELOPE

Project # 30001: Certification and Rating of Attachments for Fenestration Technologies (CRAFT)

A. Relevance

This project was rated **3.86** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- An important and logical addition to rating and labeling of window products.
- This project will provide certification label and ratings that enable consumers to compare the energy performance of different attachment products.
- Project's outcomes include providing certification label and ratings that enable consumers to compare the energy performance of different attachment products and publicly available and searchable database and website of Attachments Energy Rating Council, AERC-certified products. This project would provide the technical backbone for the DOE supported and funded, AERC, organization.
- The objective of this project is to develop an energy performance rating, certification, labeling, and verification program and maintain a web-based database of certified window attachment product performance. By collaboration with researchers from LBNL, who are responsible for the development of rating procedure, this project is important for manufacturers, policy makers, and consumers. The objectives of this project strongly support BTO's goals to improve buildings energy efficiency.
- The rating system that will result from this project will be very useful in getting efficient fenestration attachments into market and is directly supportive of BTO's goals.
- The project focuses on window attachments which are part of window technology and may contribute substantially to both residential and commercial building energy use.
- Window attachment is critical to building energy performance. Initiating such an organization/program is important to regulate and promote high quality and proper use of such devices.

B. Approach

This project was rated:

1) **3.14** for the degree to which it focuses on critical market barriers, and
2) **2.86** for the degree to which the approach addresses the market barriers identified.

- The slipping of project scheduled goals indicates the difficulty of achieving consensus within fragmented industry, but also underlines the importance of consistent technical ratings.
- The project will provide standardized energy-performance ratings.
- The project is focusing on raising awareness of window attachments technology and energy savings potential to the public, and on communicating energy performance to consumers. Another approach is to offer consistent, accurate, and comparable data that is publicly available through an electronic database and website. Yet, the present approach does not include the details of the technical part. How you will develop energy performance ratings for residential and commercial window attachment products? Are you using simulation models or/and experimental testing? This is the most important part in the project. Did not include a method to ascertain and compare product performance.
- It seems that this project is more administrative in nature, which involves engaging various stakeholders for consultation and program development. The project focuses on marketing and outreach to raise public awareness and consultation for developing the certification program.

- This project depends on another project for its technical aspects. This project will package and communicate to the industry and public about the benefits of fenestration technologies.

- The critical barrier is that there is no standard method to evaluate and rate window attachments. This project is focusing on this assessment and rating process using a series of typical attachment products. However, except for this overall project objective, based on this presented content, technical barriers and solutions are unclear.

- As understood, this project will focus on the business/marketing model for promoting the rating, labeling and certification of window attachments. The program has identified most barriers within this context. However, the program has little knowledge or vague understanding of the rating/labeling systems to be promoted. Without a solid "product" to be pronounced, a well-rounded plan for business or marketing model development is almost impossible. This is reflected by marginal progresses that have been achieved by far (mostly just partnership identification). It is highly suggested to have technical foundations built (or at least well framed) before this program's next steps are planned and implemented.

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.86** 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 is the program, so it is well aligned. Adjustment of schedule seems a realistic assessment of the challenges of national agreement and roll out.

- The project is in good progress.

- Qualitative and Qualitative:
  - Qualitative: The accomplishments are related to forming organizations, offering a presentation to raise awareness of window attachments as an energy savings measure. No mention of the accomplishments made in the technical part such as approaches to ascertain and compare product performance.
  - Quantitative: No quantitative accomplishments have been reported regarding technical part.

- Progress to date mainly focuses on the formation of the organization and outreach to the key stakeholders, which seems reasonable. Limited market impact since the certification program has not been launched yet.

- *None*

- The project will contribute to the BTO programs and market, but the current progress has more to do with the organization activities without detailed technical description and methodology.

- The project made several progresses in administrative and partnership developments, which are on track. A product database and web are ready to launch on 9/30/2016. However, due to the debate on the real "product" form (as stated), the expected progress of this project is hindered by the other associated technical project (and the communications between the two projects). The anticipated contribution to the program market goal could take a long-way to reveal.

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) **3.57** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- *None*
- Good public-private collaborative efforts. Formed board of directors and committees.
- The project team has diverse membership that unites manufacturers, public interest groups, and energy efficiency organizations. Also, the project team has engagement with energy efficiency stakeholders. This will help to accelerate movement of proposed technologies into market.
- Good collaboration and engagement of various stakeholders.
- Very strong collaboration: WCMA, Kellen Company, D+R International, Intertek-ATI, LBNL. Plan to conduct outreach to other organizations.
- The project team has very strong collaboration with industry and academia.
- The project staff has a good general understanding (and experience) on similar activities. Most important stakeholders are identified and contacted. Substantial work would be expected beyond attending conferences, likely after a solid system is built (or at least clearly framed and demonstrated).

E. Proposed Future Work

This project was rated **2.86** 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.

- Realistic appraisal of barriers and adjustments to lessons learned have been incorporated in plans for future work.
- User-friendly tools can be developed, which can be easily used by the public.
- Many changes have been made in milestone schedule. Presentation did not include specific steps for the technical part (i.e., methods to ascertain and compare product performance).
- The proposed future work seems appropriate.
- The planned publicly available web site and database will be of great value.
- This project will take the characteristic window attachment products as the specimen to explore the assessment process and rating methods. The proposal future work and plan are reasonable.
- The project will need a more specific plan for attacking the marketing barriers and/or including critical stakeholders. At some points, some kind of testbeds or small pilot tryouts may help verify and improve the system and model to be developed.

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

***High*: 5** reviewers

- Standardized information is essential for a well-functioning market.
- The standard will be widely used.

- The target audiences include manufacturers, professionals, and consumers. The deliverables will enable the consumers (i.e., building owners, managers, utilities, and designers) to compare the products' energy performance and make informed decision.

- The target market is the window sector for a wide range of buildings.

- The project is anticipated to have an important impact on long-term building energy use by regulating window attachment devices.

***Average*: 2** reviewers

- The project team has built strong communications with key stakeholders to accelerate movement of technologies or practices into market. However, the technical part is missing.

- *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*: 5** reviewers

- *None*

- Sufficient emphasis has been received.

- The project mainly focuses on the development and launch of the certification program. Therefore, it mainly focuses on the deployment activities.

- *None*

- The deployment approach seems OK but conventional. To accelerate the progress, new methods/models may be explored, considering the unique (or complex) nature of the systems to be promoted.

***No*: 2** reviewers

- One vital goal is to have the technical tools that allow measuring of the products' technical performance. The details of these tools were not provided.

- Based on the presented content, the research activities part is weak.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project is aimed at the most challenging and among the most important aspects of energy saving technology, which are the actual market and implementation. The standardization of energy ratings for window attachments is a valuable and key step in market transformation, informing designers and consumers about products.

- Great effort to create a standard and raise the awareness of window attachment as an energy saving measure.

- Excellent collaboration with industry and key stakeholders. Excellent outreach (to both the professional and public sectors).

- The objectives of the project strongly support BTO's goals. The approach taken is appropriate.
- Concur with the plan to produce a certification label and ratings.
- The goal of this project – namely, focusing on window attachments that are not part of current standard and rating system – is one of the project strengths. On the other hand, the project team has strong connections and cooperation with industrial and academic areas.
- Two strengths: (1) Important topic with anticipated long-term impacts. (2) Good team with general knowledge on the proposed activities

2) **Project Weaknesses**

- Challenges of developing a nationally effective organization have delayed initial targets, but these have been addressed in modified plans.
- It is more advantageous if easy-to-use program can be developed from this project.
- The present approach does not include the details for the technical part.
- *None*
- *None*
- Based upon the presented contents, there are no clear technical methodology and detailed work plans. The project so far emphasizes only the organization and related activities.
- Two weaknesses: (1) Lack of a deep understanding of the technical foundations. (2) More barrier-targeted marketing and solution analysis. Is there anything beyond regular marketing approaches for fast promotion of the "developed" system?

3) **Recommendations**

- *None*
- No.
- Conducting simulation models and experimental testing to ascertain and compare product performance.
- *None*
- *None*
- *None*
- Enhance the conversation with the technical team and include the technical team more actively into this project.

Project # 30004: Building Integrated Heat and Moisture Exchange

A. Relevance

This project was rated **2.83** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Hard to see a direct tie to equipment instead of envelope.
- This is an interesting and relevant development concept. But it may not be realistic to believe this will be anything but a long term project. There are enormous architectural and mechanical issues that need to be understood and addressed before the technology, as currently envisioned to be applied, is likely to be effective and to be accepted.
- This energy recovery ventilator technology (ERV) technology is aimed only at new construction (I assume). A fundamental issue that has not been addressed (at least at this meeting) is why the heat exchange technology needs to be implemented as wall components instead of within a central HVAC system. It would seem more expensive to have to manufacture a wide variety of ERV panels to accommodate various architectural constraints.
- There is relevancy to BTO's goals of developing an ERV that is integrated into a building's envelope.
- The project aims at manufacturing of a unit at a target installed cost 48% lower than the current benchmark with equivalent performance. With accelerating market adoption, the installed cost premium of the technology will be further reduced through economies of manufacturing at scale. This impact is aligned with BTO MYPP Sections 2.2 (HVAC/Water Heating/Appliances) and 2.3 (Windows and Building Envelope) which promote the development and deployment of Next Generation Technology tracking both energy performance improvement and installed cost.
- This system has the potential to reduce fan energy required for introduction of outdoor air to indoor air quality. It is possible that it could do this while providing part of an energy-efficient building facade.

B. Approach

This project was rated:

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

- Good work on identifying manufacturing barriers.
- It appears many of the right issues are being addressed. And progress to date appears good. However, I was somewhat surprised to find the relatively high pressure drop through the unit and I question what the noise component will be with these relatively high friction losses. This may have a large impact on acceptance. It is also not clear whether there will be deterioration in performance due to particulate deposition from the air streams, and how such a unit would be cleaned. In short, there are many issues that may appear and will have to be resolved.
- Project emphasis seems to have been primarily on efficiency and assembly methods; not on market research.
- The approach of having an ERV with a large footprint is innovative and certainly has good potential for reducing building energy.

- The approach seems to be sound and seems to lead to the desired results. There are several issues to consider including adhesive selection, complying with applicable codes and standards (such as NFPA 285, UL 1812; AHRI 1060; and ASHRAE 62.1/62.2), and satisfying space constraints in a given building.

- The project team has identified the barriers in market penetration that are directly associated with it being a cross-cutting technology.

C. Accomplishments/Progress/Impact

This project was rated:

3) **2.83** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
4) **2.33** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Hard to see how the interim market goal will be realized.

- While not specifically stated, it appears this product is really going to be most effective in warm, humid climates. It is far less likely to be as successful in cold climates for a number of reasons. This limits its potential overall impact to some degree.

- PI has been working on efficiency improvements. The presentation did not address why or when this technology would be better than centralized ERV integrated with the building's HVAC.

- The project results support the stated program performance goals. A number of technical challenges have been addressed and overcome.

- The project seems to be moving in a positive direction and if successful could be transformative.

- It is hard to say now if the technology will achieve both sufficiently high performance and market penetration to significantly assist in meeting BTO goals.

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.

- *None*

- Seems like the project team has a good range of collaborations.

- The project needs to do market research to determine whether architects would be willing to incorporate the product in their designs. Hunter Douglas collaboration is good, but doesn't address the "market pull".

- The project understands stakeholders and has interacted with industry on a significant level, which is important since using a new ERV approach that is radical in concept will be a challenge.

- The investigators are working with several key partners such as Oregon State University, DuPont Technologies (as a material supplier), Boost Consulting LLC (for commercialization), BasX Solutions (for production), and Hunter Douglas Facades (for sales).

- Good project team; collaboration with a major building curtain wall manufacturer.

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.

- *None*
- I agree that getting these units in realistic testing situations is the correct next step.
- PI should work directly with a hands-on building designer and a construction crew to explore actual implementation details. (Maybe this has been addressed previously, but was not discussed today.)
- The future work is focusing on building additional demonstration units to promote the concept and to engage future partners.
- Future work involves demonstrating of manufacturing at target cost, creating of exchanger production line (capital required, used equipment available), completing required product certifications, completing three additional demonstration installations by 2018, building sales pipeline, and engaging partners in global sales & distribution.
- Planned attention to lower manufacturing cost while seeking first-adopter-type customers seems appropriate.

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

***High*: 3** reviewers

- The product itself appears to be able to work well and achieve its expected energy recovery efficiency, given that the design (i.e., flow direction) is still being evaluated.
- The target audience should utilize the technology developed here.
- Deliverables could result in significant energy savings.

***Average*: 3** reviewers

- *None*
- Project team appears to be keeping DOE up to date with developments.
- The deliverables are promising but still need further refinement.

***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

- None
- Identified hurdles and issues are realistic and approach appears to be sound.
- Yes and no. Research areas are being addressed well. Deployment issues should be addressed next.
- Yes, relevancy has been established.

- Approach taken and goals identified are relevant to achieving the project goals.
- Emphases are appropriate.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good technical accomplishments, specifically around manufacturing challenges
- This project may result in a substantial reduction in ventilation air conditioning energy in some instances
- Product design and assembly have been carefully researched. Investigators seem to be very knowledgeable about membrane science and technology.
- The strength of the project and resulting product is that it could significantly influence and promote the use of energy recovery devices, such as ERV's.
- Project could be transformative.
- Cross-cutting technology that could make a significant difference in reducing fan energy costs while providing an energy-efficient building facade.

2) **Project Weaknesses**

- Difficult to see adoption path.
- There are a number of potential issues remaining that will only be known as a result of longer term testing.
- Savings have not been measured in the field, so impacts on HVAC seem speculative. Architects may not want to deal with ventilation specifications. I overheard other audience members commenting on possible fan noise issues due to high 200 CFM flow. Would like this issue measured and addressed in a future presentation.
- The project is due to conclude in a few months and some technical issues still need addressing, such as noise.
- Project is dealing with a tough issue, but the investigators seem to be on the right track.
- The main weakness seems to be the difficulty in making this at a cost that is acceptable in the market.

3) **Recommendations**

- *None*
- Real life testing applications will be critical to determine if the way this is intended to be deployed will be successful.
- Compare the installed cost of this product to a central ERV. Perhaps work on developing a central ERV with similar efficiency specifications. (Product would be large, in order to replace lots of building-facade panels.)

- None
- Very good project.
- *None*

Project # 31397: Bio-based, Noncorrosive, Nonflammable Phenolic Foam Insulation

A. Relevance

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

- It has addressed a key issue of using phenolic foam, which has a potential to achieve a great energy saving.
- The project outcome is to develop new bio-based phenolic foam thermal insulation materials to be used in buildings to minimize heat losses. This addresses the BTO's mission to develop advanced insulation materials for building envelopes.
- The objective of this project is to develop a non-corrosive bio-based phenolic foam with stronger mechanical properties at competitive cost. Should the product be marketed successfully, it would provide alternative insulation materials with better thermal insulation values and less environmental impact to the building industry to improve building envelope performance. Therefore, the project is well in line with BTO's goal to improve buildings' energy efficiency.
- The insulation product that would result from this project would be very useful and is directly supportive of the goals of the Window Envelope Program.
- Cost competitive phenol foam for building insulation is critical to the BTO's mission and aligns with the roadmap. The success of this project would significantly contribute to insulation technology and energy efficiency.
- This project aims to develop high performance low cost insulation materials, which is highly requested by the field and the DOE roadmap.

B. Approach

This project was rated:

1) **3.33** 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 approaches seem reasonable.
- Throughout the presentation, the level of thermal conductivity of the proposed foam was not defined or even predicted. The thermal conductivity of the insulation material is one of the key parameters to be addressed. Other thermal properties should be addressed as well; thermal diffusivity.
- In general, the effective thermal properties of foam materials depend on ligaments orientation and the voids/solid ratio. The project did not address both of them.
- Did not define the Dollar amount/ft^2 for the proposed foam materials.
- The critical barriers have been identified. The project employs a comprehensive approach to addresses these challenges by developing new foaming process, testing lab-scale foam products, development of scaled up production assembly, and long-term field testing of full scale products.
- *None*
- The project developed a new foaming process using bio-base precursors and focused on the reduction of phenol foam acidity and corrosion potential, which shows distinctive features.

- The team has great experience on the subject with solid understanding of the technical barriers and thus clear goals.

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.

- Six patent applications demonstrate the accomplishment of the project.

- Qualitative:
  - Adding nano/micro reinforced fibers will damp the bubbles' growth during foaming process.
  - The project did not include whether the properties of the used foam are isotropic or anisotropic properties.
  - Did not include validation for the findings.
  - No error analysis was introduced.
- Quantitative:
  - Did not measure the thermal properties for the proposed foam material.
  - Did not define the Dollar amount/ft^2 for the proposed foam materials.

- It seems that the project is progressing well. Bio-based phenolic foam at higher PH has been successfully produced and a series of lab testing has shown promising results in terms of mechanical properties, durability, and thermal performance. The potential market impact of this project is evident.

- Accomplished all key milestones.

- The presenter demonstrated the performance of the resultant insulation and its performance by testing the samples. The achievements and meaningful contributions are clearly presented.

- The team has developed the prototype with most targeted performance achieved (except the cost – which was not mentioned) and the durability study (arranged at the remaining project period).

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.

- Well balanced team.

- The collaboration includes, University of Tennessee Knoxville, Atlas Roofing Corp., and Plenco, plastic engineering company. The project team has built strong communications with key stakeholders to accelerate movement of proposed technology.

- The project has demonstrated good collaboration with the key stakeholders of the industry including manufacturers, research organizations, and consumer groups.

- Strong partnering with Atlas Roofing and the University of Tennessee.

- The presenter demonstrated a strong connection to the industrial partners which enable the transfers the technology from the lab to the market.

- A good team with close collaborations.

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 foam has a higher fire resistance (40 seconds subjected to fire) but still need to be careful when and where to use these foams. The durability of the foam is another issue that worthy of consideration.
- A plan for measuring the thermal properties for the produced foam materials should be introduced and verified.
- The proposed future work is well planned, built on past progress and focus on making the product marketable as quickly as possible.
- Project ending soon. Already achieved key milestones.
- The project is approaching the end of this proposed work. The future works are more to do with scale-up, tests, and activities for market transfer. The plan for the future work is meaningful.
- Future work relates to scale-up tryouts and accelerated performance test. All are relevant and appropriate.

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

***High*: 4** reviewers

- The deliverables have great values.
- The target audience is building sector. The availability of a bio-based phenolic foam with R8 insulation value will provide the building industry with alternative solutions to build high performance building envelopes to improve buildings' energy efficiency.
- *None*
- An important and promising product.

***Average:* 2** reviewers

- The level of cost is not define which will not allow comparing its feasibility in the market.
- The insulation product that would result from this project would be very useful and is directly supportive of the goals of the Window Envelope 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*: 6** reviewers

- Sufficient emphasis has been received.
- The project main outcome is to develop new bio-based phenolic foam thermal insulation materials to be used in buildings to minimize heat losses.

- Both research areas and deployment activities are receiving sufficient emphasis.

- *None*

- *None*

- Most of the important areas are included in the project tasks.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Promising technology, which can increase the use of phenolic foam.

- The project addresses the BTO's mission to develop advanced insulation materials for building envelopes.
- Introducing new insulation foam materials with less acidic, non-corrosive, and mechanically stronger properties.
- Outstanding collaboration.

- This project is very practical and has a good team of experts. The achievements of the project strongly support BTO's goals.

- Already achieved key milestones, including ASTM tests.

- *None*

- Good feasibility study and challenge/need analysis.
- Solid team.
- Sound technical plans.

2) **Project Weaknesses**

- Fire is a concern, especially for high rise building.

- Did not include the effect of adding nano/micro fibers on foaming process.
- Did not define the Dollar amount/ft^2 for the proposed foam materials.
- More qualitative and quantitative details are required to address the properties of the produced foam materials

- *None*

- *None*

- *None*

- Cost tech barrier analysis (especially with the proposed bio-based materials).

3) **Recommendations**

- No.

- Consider measuring the thermal properties of the produced foam material in the three dimensions.
- *None*
- The presenter frequently mentioned patent applications and IP. Therefore, some details of the work was not presented. I assume DOE BTO staff has access to the full results and therefore is able to verify that the project has been as successful as the presenter has stated.
- *None*
- It will be nice to include techno-economic analysis to address “the low cost” target.

Project # 31395: R25 Polyisocyanurate Composite Insulation Material

A. Relevance

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

- It addresses BTO's Roadmap to add R24 window to existing walls.
- The project main outcome is to develop a 2-inch thick composite foam insulation board with R25 (hr-ft^2-F/Btu), with a cost premium of \$0.30/ft^2. This addresses the BTO's mission to develop low-cost, high-performance advanced insulation materials for building envelopes.
- The objective of this project is to develop a low-cost R12 advanced insulation for high performance building envelope, which is well in line with BTO's goals to improve buildings' energy efficiency.
- The advanced insulation product that would result from this project would be very useful and is directly supportive of the goals of the Window Envelope Program.
- The research project aims to develop low-cost high-performance insulation materials for envelopes, which complies with the BTO's roadmap on the insulating levels. The target market is residential walls and commercial roofs for both retrofit and new construction. To this review, the new construction will be the entry point of this proposed material. The good point is that the investigators will place attentions to identify installation challenges of retrofit applications.
- This project aims to develop high performance low cost insulation materials, which is highly requested by the field and the DOE roadmap.

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 approach is reasonable using a combination of MAI and polyiso.
- One of the key parameters of the encapsulated foam is the voids to solid ratio. This ratio has a great impact on the final properties of the encapsulated foam. This ratio was not considered in the proposed project.
- The target level of cost is \$0.30/ft^2, yet for this project it exceeds the \$2/ft^2 (in the lab).
- The critical barriers have been identified and the approach adopted seems appropriate. It involves lab-scale testing in terms of mechanical properties and durability, guarded hot box testing and modeling of thermal performance for the assembly sized panels, and planned long-term field monitoring, which is comprehensive.
- By focusing on manufacturing process, the project is directly addressing the "cost" market barrier.
- Research approach presented at this stage is about the prototype fabrication and testing, which is clear and convincible. The project also addresses the questions arose from the experiment.
- R value and cost are two identified barriers, and efforts are put to increase the R value but less discussion on major cost barriers (to the targeted cost goal).

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.

- More samples are suggested to be tested to have more conclusive results.

- Qualitative:
  - Although the simulation models consider a 3-D model, yet it considers the heat flow in 1-D, which is not the case for a real application. This will lead to inaccurate analysis for the real application.
  - The project did not include whether the properties of the used foams are isotropic or anisotropic properties.
  - The simulation model was not validated
- Quantitative:
  - Did not mention how many samples were tested.
  - Did not mention how they measured the foams' properties.
  - The target level of cost is \$0.30/ft^2, yet for this project it exceeds the \$2/ft^2 (in the lab).

- It seems that the project is progressing well. The lab-scale testing and thermal testing and modeling of the first phase assembly line product have been carried out. Lessons learnt from the initial tests have been integrated to the second phase design of the product.

- Slide 15 showed that out of 12 panels produced during July 2015, two of them failed. This is a large percentage and is problematic. On the positive side, the fact that the presenter included this fact under "lessons learned" indicates an appreciation for the seriousness of the problem and the need to address it.

- The research achievements are showed through substantial evidence focusing the insulation performance and producing process.

- The project is making good progress in prototyping and testing the thermal performance. Favorable performance was achieved, while quality control may still be an issue.

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.

- Good integration with DOE labs and companies.

- The project is collaboration between ORNL, Firestone Building Products Company and NanoPore, Inc. The project team has strong understanding of the key stakeholders to accelerate movement of the proposed new composite insulation into market.

- It seems that a good collaboration exists with two main manufacturers, which is very important for the development of this composite insulation.

- Strong collaboration with ORNL, Firestone, NanoPore and Tegnos Research.

- This project has good collaborations between national lab and industrial partners.

- The project is too early to speak for marketing potential. More engineering efforts will be required before it can be massively produced. The project has started to look at code compliance, which is good. An integration among ORNL and several private companies was reported.

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.

- Future work seems reasonable. No timeline is provided for additional tasks. Will it be covered by this project or other funding?

- Will develop accelerated aging test protocol for MAI panels.
- Will verify improved composite boards to be R12/inch.
- Field-testing of thermal performance of composite boards.
- Detailed techno-economic analysis and cost optimization.

- The proposed future work seems appropriate to address issues identified based on the progress to date. There are still quite a lot work to do to make the composite R12 insulation a commercially available product with satisfactory long-term durability and being cost effective.

- Accelerated aging test will add great value.

- The project will continue the lab-scale experiments and testing, and will conduct field-scale testing. The presentation doesn't show the potential risks and mitigation strategies.

- The proposed next steps are necessary and suitable for reaching the set goals.

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

***High*: 4** reviewers

- It will help BTO to achieve its goals.

- Should the proposed product be developed successfully and adopted by the industry, it will make significant contributions to advance the insulation technology, provide solutions to build high performance building envelopes, and therefore significantly reduce energy consumption of buildings.

- The research project matches the BTO missions and roadmap.

- The product, if made successful, will have a large impact on low-cost high performance insulation material market.

***Average:* 2** reviewers

- The project team has built strong communications with key stakeholders to accelerate movement of proposed technology. Yet, the main issue is that the level of cost which exceeds $\$2/ft^2$, while the target is $\$0.30/ft^2$.

- By focusing on manufacturing process, the project is directly addressing the "cost" market barrier.

***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

- The project has identified these areas.
- The project main outcome is to develop a 2-inch thick composite foam insulation board with R25 (hr-ft^2-F/Btu). The project introduces a simulation model for the insulation system and will examine the insulation system in the lab.
- The key research areas related to testing and improving the product's performance is receiving sufficient emphasis. The deployment of the product in terms of its cost effectiveness seems at planning stage, there is not enough information about the cost optimization and production at this stage yet.
- *None*
- Yes, the research activities from lab to field-scale in this project received sufficient emphasis.
- Although the current focus is mostly on technical properties, techno-economic analysis is planned next step. How to compromise performance and cost will be an interesting topic.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project addresses BTO's roadmap. It is in good progress.
- The project addresses very well the BTO's mission to develop low-cost, high-performance advanced insulation materials for building envelopes.
- Introducing new composite insulation.
- Very strong collaboration.
- The strengthen of the project is that it is practical and serves the needs of the industry and well supports the BTO's goals for developing advanced insulations for high performance building envelopes. It has good market potential should the product becomes available at low-cost and with reliable long-term performance. It will provide solutions to the problem of highly insulated walls using standard insulation materials being very thick and eliminating associated billability issues.
- *None*
- The project aims to address the EERE BTO's mission to develop low-cost, high-performance advanced insulation materials for building envelopes, which complies with the BTO roadmap and missions. The technical approach and current achievements are clear and convincible.
- Clear targets and approaches.
- Promising intermediate results.

2) **Project Weaknesses**

- More tests are suggested in order to have more conclusive results.
- The target level of cost is \$0.30/ft^2, yet for this project it exceeds the \$2/ft^2 (in the lab).

- More qualitative and quantitative details are required to address the properties of the used foam.
- Although the simulation models consider a 3-D model, yet it considers the heat flow in 1-D, which is not the case for a real application. This will lead to inaccurate analysis for the real application.

- The feasibility, durability and its cost effectiveness of this composite insulation have yet to be demonstrated through accelerated aging tests and long-term field monitoring.

- *None*

- *None*

- Cost barrier analysis to the target ($0.3/ft^2).
- Quality control and waste management approach (in manufacturing).

3) **Recommendations**

- No.

- Measure the foam properties in the three dimensions and compare them to figure out if the foam has isotropic or anisotropic properties.

- *None*

- Long term testing in actual buildings is not part of this work, as stated on slide 17. However, that would be of great value.

- *None*

- It will be nice to include alternative solutions if targets can be met (for both R and cost values).

Project # 31396: Low-Cost Haziness-Free Transparent Insulation Based on Hierarchical Porous Silica Particles

A. Relevance

This project was rated **3.17** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- It has a potential to achieve a saving of 0.52 quads energy.
- The project main outcome is to develop a new thermal insulation material to be used in windows to minimize heat loss through windows. This addresses the BTO's mission to develop advanced insulation materials for building.
- The objective of this project is to develop an insulation material with visible transmittance >0.8, R-value >5 at premium cost <$6/ft^2. The product is intended to be integrated into windows to enhance their thermal performance. The objectives support BTO's goal to improve buildings' energy efficiency.
- The transparent insulation product that would result from this project would be very useful and is directly supportive of the goals of the Window Envelope Program.
- Transparent insulation for fenestration is a critical area for building energy and BTO, so that this project very aligns with BTO's mission and roadmap.
- The project has a nice but ambient goal to develop a low cost high performance glazing material (one goal of BTO), which however was not solidly established in physics but hoped to scale up in near term.

B. Approach

This project was rated:
1) **2.83** for the degree to which it focuses on critical market barriers, and
2) **2.83** for the degree to which the approach addresses the market barriers identified.

- It has addressed the market barriers.
- One of the key parameters of the insulation material is its thermal conductivity. The project is paying more attention to other properties; visible transmittance, and haze. Another main issue is that, the thermal conductivity for the proposed material is 0.038 W/m K, which is higher than that of the air; 0.027 W/m K. This means that an air gap will be more effective (as an insulation material) than the proposed material.
- The target level of cost is ≤ $6/ft^2 which is very high compared to the existing products in the market.
- The technical challenges identified are cost, durability and visible transmittance issues. The project so far focused on overcoming the technical challenges to achieve required visible transmittance at lower cost by investigating different processing methods.
- The project is addressing the "cost" market barrier.
- The methods shown in the presentation is now separated into thermal and optical aspects (thermal testing on solid fabricated materials and optical testing on transparent solution), which is acceptable at this stage. However, so far, the key challenge combining high insulating abilities and transparent features is still not addressed.
- The project understands the need of the market and somehow properties of the materials. Although haze and optical properties were mentioned, these were not considered currently except the R value. In fact, it is

unclear how the raw material property (e.g., transmissivity) vary with wavelengths and what are the implications of this to solar, thermal heat and daylight (very critical for building application).

C. Accomplishments/Progress/Impact

This project was rated:

1) **2.17** 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 is shown better mechanical strength in the expected advantages. This statement needs to be supported by some test results.

- Qualitative:
  - Did not consider the effect of solar reflectivity and wave length.
  - The scope of the project was changed.
  - The project did not include whether the properties of the used material are isotropic or anisotropic properties.
  - Did not include validation for the findings.
  - No error analysis was introduced.
  - Used equations are not represented properly in the presentation.
- Quantitative:
  - Did not measure the thermal diffusivity for the proposed material. The thermal diffusivity includes three properties, thermal conductivity, heat capacity and density. It has the ability to quantify the ability of the material to conduct heat to its ability to store heat.

- The required visible transmittance has been achieved at lower cost, however, there are issues to be solved to achieve the near-term goal of the program. In terms of the medium and long-term goals, there are still a long way to go. The product has not been integrated to window product application and their performance has not been tested.
- It is still early to demonstrate the market impact of this project given that the product development is still at the initial stage and there are still challenges to overcome to make it a reliable insulation product, which hasn't been integrated into window application yet.

- Project changed focus during execution.

- The current research results presented are related to two parts: thermal properties and optical properties. However, the results are coming from two separated experiments. The research team has found out the challenge for their future study, which needs to either modify the technical method or scope.

- The first round of test seems unsuccessful that leads to the hybrid silica gel as a new focus, which however did not present sufficient scientific ground.
- With the understanding of this being a R&D project, the project presents some scientific evidence of one possibility for developing targeted glazing, however, high-risk exists due to unclear technical solutions. It is a far away from what might impact the market.

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) **2.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Good partnership with industry. Good publication record.

- One partner, VELUX. The project team has limited communications with the key stakeholder.
- So far, there is one industry partner on the project, though the researcher indicated that more industrial partnerships are being initiated to help bring the technology to the market.
- Strong collaborations. One formal partner, VELUX, and ongoing discussions with others, including universities. One industry partner interested in funding.
- The presenter doesn't demonstrate the strong connections and how they were cooperated in this project.
- Some contacts were initialized. No substantial collaboration was mentioned, maybe due to the very beginning stage of the research.

E. Proposed Future Work

This project was rated **2.83** 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 is reasonable. Potential funding from industry partner for the next stage of work is promising.
- Will select and optimize methods to remove the solvent from inside the pores of the newly developed material.
- Will measure the optical and thermal properties of the developed material.
- Proposed future work seems to address issues and challenges identified from the past work.
- May have an industry partner to help fund future work. Concur with pursuit of industrial manufacturing as described on slides 14 and 15.
- The team has identified the challenge of their project and proposed a few research plans on the technical aspect to overcome the barrier.
- The planned next steps are highly exploratory. With the project end date of 9/30/2016, the project may likely come up with little success.

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

***High*: 2** reviewers

- It will achieve a great energy saving and has a potential big market.
- *None*.

***Average:* 3** reviewers

- The introduced material should have less thermal conductivity than that of the air gap.
- The level of cost is very high compared to existing products in the market.
- The targeted audience is the window manufacturers and consumers. However, the product has not been integrated into windows and there is still a long way to go to make it a reliable product.
- *None*

***Low*: 1** reviewer

- It is highly unlikely a promised deliverable can be presented by the original end date.

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

***Yes*: 4** reviewers

- They have received enough emphasis.
- The project main outcome is to develop a new insulation material to be used in windows to minimize heat loss through windows.
- *None*
- *None*

***No*: 2** reviewers

- Research areas receiving sufficient emphasis, perhaps because it is still at the early stage of development, the deployment activities such as engaging with manufacturer is not receiving sufficient emphasis.
- The project has been focusing on addressing the very basic challenges such as developing the prototype and improving R value. Without these, other areas of interest (e.g., cost, transmissivity, haze) have less meanings at the moment.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project is in good progress and has good integration with industry partners.
- The project addresses the BTO's mission to develop advanced insulation materials for building envelopes.
- Introducing new insulation material.
- The overall objectives of the project support BTO's goals to improve buildings' energy efficiency. Should the product proposed be developed and adopted successfully by the industry, it will make significant contribution to improving window's thermal performance at lower cost.
- The change of focus of the project is indicative of a good grasp of the technology and the lack of a potential for future success of the original plan. I see this as a positive factor in the performance of the presenter.
- The project focusing on transparent insulation for fenestration very aligns with the BTO's mission and roadmap.
- Nice initial concept and vision.

2) **Project Weaknesses**

- Some points need to be substantiated.
- The target level of cost is $\leq \$6/ft^2$ which is very high compared to the existing products in the market.
- More qualitative and quantitative details are required to address the properties of the proposed material.
- Not enough collaboration.

- Some progress has been made in terms of the technology development, however, there are still many challenges to overcome to make it a reliable product. Issues such as cost and durability still need to be addressed.

- *None*

- The major concern is the current research findings are not significant to the existing literature and technology.

- No substantial feasibility study and alternative solutions planned.

3) **Recommendations**

- The budget shows on project summary slide seems not reasonable. The expenses to date are the same as total project. It is different from what is shown in the project budget slide. Is it a typo or the budget has been exhausted?

- Measure the material properties in the three dimensions and compare them to figure out if the material has isotropic or anisotropic properties.

- *None*

- *None*

- *None*

- A thorough feasibility study would be nice for all solutions proposed.

Project # 33390: Novel Thermal Break with Simplified Manufacturing for R7 Commercial Windows

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 can improve window performance and reduce manufacturing cost.
- The project outcome is to develop advanced thermal performance (R7) commercial windows and the manufacturing process based on novel thermal break technology, at no additional cost compared to the incumbent Kawneer R5 OptiQ windows. This addresses the BTO's mission to develop advanced thermal efficient windows for buildings.
- The objective of this project is to develop a R7 commercial windows using a novel thermal break technology integrated into the aluminum frame at no additional cost to current R5 windows. Windows are the weak components in building envelopes in terms of energy efficiency. The thermal performance of metal frame significantly reduces the overall thermal resistance of windows. With the improvement of metal framing by integrating novel thermal break, the overall thermal resistance of windows will be significantly reduced, which will contribute to improving the building envelope performance, therefore, support the BTO's goal to improve buildings' energy efficiency.
- The goal of improving a window from R5 toR7 is directly supportive of BTO's goals.
- Windows substantially contribute to both residential and commercial building energy use, and the thermal break system can significantly improve overall window u-factor. This project focuses on the new thermal-break system design and manufacturing process, which aligns the BTO's goals, especially on the window section.
- The product, if made successful, will have a large impact on high performance window frame - one critical field on BTO agenda.

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.

- The project addresses an important market barrier.
- While the simulation model is a 3-D model, yet the heat flow is assumed to be in 1-D, which is not the case in the real application. This assumption would lead to inaccurate predictions for the heat flow and temperature patterns in the system.
- Integrating foam materials in a system is crucial. The properties for some foam materials are anisotropic, which requires measuring these properties in the three directions. The proposed approach introduces the foam properties without defining the direction.
- Did not define the initial prediction for the Dollar amount for the proposed system.
- The project employs a comprehensive approach to addresses technical and market challenges including developing test specifications and protocols and carrying out a series of performance tests at levels ranging from material properties, small composite, to lineal and full window scale.
- An R7 commercial window will be a great contribution.

- The project technical approach is focusing on the evaluation and testing on material properties. The presenter clearly showed its research process and tasks completed.

- The project is focused on developing innovative thermal break in order to reach R7 window. Although it claims it developed the first R7 window design, the change was mainly on thermal bridge side (and associated frame structure modification – all FEA based). Other barriers to R7 window (such as glazing, spacer) were underestimated.

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.

- The project is in good progress.

- Validation for the simulation model was not introduced.
- Did not measure the thermal properties for the proposed foam material in the three directions.

- Good progress has been made. Materials for the thermal break have been selected and tested. Test results showed promises. R7 windows have been designed and test specification and protocols for the new thermal bridge systems have been developed. Should the product be developed and marketed successfully, the potential market impact of this project is evident.

- Slides 7 through 14 show the many tests performed. Indicates a well-run project.

- The team has completed preliminary product and conducted validation of the proposed thermal-break system. The progress in on the track to achieve the original research objectives.

- The project is making reasonable progress by developing the prototypes and testing mechanical properties. Several critical properties were not tested yet such as thermal property and structure concerns at a larger scale (beyond the sample size).

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) **3.17** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Good collaboration with partners on this team.

- Active engagement between Alcoa, Kawneer, key material partners, and line integrators. The project team has built strong communications with key stakeholders to accelerate movement of proposed technology.

- The project has partnerships with extrusion manufacturers, material suppliers, and curtain wall manufacturers. The researcher indicated that further partnership with manufacturing line integrator is being initiated. The partnership and collaboration seems reasonable.

- Strong collaboration with Alcoa, Kawneer and others.

- Upon the presentation, no clear demonstration on the activities and plans of collaboration is showed.

- The collaboration is mainly between two private companies. It expects to reach out to major manufacturing partners next.

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.

- Thermal cycling effect is encouraged to consider and also the interface between the foam and window frame.
- A comprehensive future plan has been introduced.
- The proposed future work is well-planned and built on past progress with a focus on market development and assessment, which will help advance commercialization and deployment of the product.
- Concur with future work described on slide 17.
- The future works include manufacturing task, product development, and market transfer and commercialization. The proposed future work and plan is meaningful.
- The project plans to scale up to manufacturing pilot line. But seems more and thorough tests will be needed even at the individual window size for various structure, thermal conditions.

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

***High*: 5** reviewers

- The project will benefit both retrofit and new construction by providing a window with higher thermal performance.
- The project introduces new design based on simulation and experimental testing.
- The target audience is building sector. The availability of a R7 commercial window will help build high performing building envelopes for commercial buildings, therefore, contributing to improving buildings' energy efficiency.
- An R7 architectural window will be of great value to the target market of the Window Envelope Program.
- *None*

***Average:* 1** reviewer

- The project targets to develop novel thermal bridge that is important for high performance window. The project is focused on some sort of new frame design to incorporate a "selected" rigid form, which is practical but not fully original. It is important to highlight how this design fundamentally overbeats other designs.

***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

- Sufficient emphasis has been received.

- The project outcome is to develop advanced thermal performance (R7) commercial windows and the manufacturing process based on novel thermal break technology. A simulation model for the proposed system was performed and experimental tests were performed as well.

- Both research areas and deployment activities receiving sufficient emphasis.

- *None*

- *None*

***No*: 1** reviewer
- The project by far has been focused on addressing various challenges in prototyping. More property tests will be necessary to fully claim the advantages of the proposed system.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good technology to improve the thermal performance of the window without incurring additional cost.

- The project addresses the BTO's mission to develop advanced thermal efficient windows for buildings.
- Developing of advanced thermal performance (R7) commercial windows and the manufacturing process based on novel thermal break technology at no additional cost compared to the incumbent Kawneer R5 OptiQ windows.

- This project is very practical and strongly supports BTO's goals. Based on the achievements so far, the project shows a high potential for the successful commercialization of the product.

- Testing protocol and execution are impressive.

- The proposed adhesive bonded thermal-break system has simplified manufacturing process with high insulating abilities, which enables the architectural window's overall thermal properties to be improved. The project aligns the BTO's missions of window performance and energy efficiency.

- Simple design and concept (lead to simple manufacturing and low cost).
- Simulation-assisted design and improvement.

2) **Project Weaknesses**

- Some loading effect, such as thermal cyclic needs to be considered.

- Considering the heat flow in 1-D.
- Did not include the foam properties in the three directions.

- *None*

- *None*

- *None*

- Novelty of the improvement need be better clarified (with using existing material, slightly tuned frame structure).
- Cost analysis (so as to reach the goal of "no extra cost to current R5 window").

3) **Recommendations**

- No.

- Consider measuring the thermal properties of the used foam in the three dimensions.
- Consider 3-D heat flow in the simulation model.

- *None*

- *None*

- *None*

- May add an overall description, analysis and justification of so called first R7 commercial window and how this “novel” thermal bridge plays a critical role in this.

Project # 33391: Fabricate-On-Demand Vacuum Insulating Glazings

A. Relevance

This project was rated **3.17** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project can overcome the cost and supply chain issue of traditional VIG manufacturing.
- The project outcome is to design a fabricate-on-demand manufacturing process to overcome the cost and supply chain issues preventing widespread adoption of Vacuum Insulated Glazing, VIG. This will lead to manufacture the High-performance windows (HPW) with less cost. This would address the BTO's mission to develop advanced energy saving windows for buildings with acceptable cost that meets cost goals of DOE roadmap.
- This objective of this project is to design a fabricate-on-demand manufacturing process to enable widespread adoption of VIGs by overcoming the cost and supply chain issues. VIGs offer higher thermal resistance than standard IGUs and the cost is the main barrier for its widespread market adoption. Should a manufacturing process as proposed be developed successfully, the widespread adoption of VIGs would become possible, therefore, significant energy savings could be achieved. The success of the project provides good support to BTO's goals to improve buildings' energy efficiency.
- The goal of the project was to make high-performance windows more affordable, which directly supports BTO's goals.
- This project focused on high-performance windows using vacuum insulated units, which may substantially improve the thermal performance of overall window systems. This project aligns the BTO goal and roadmap.
- The project presents a process to customize VIG, an approach enabling the adoption of VIG whenever appropriate.

B. Approach

This project was rated:

1) **2.67** 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 and reduce the cost and eliminates the barriers that prevent smaller manufacturers from entering the market.
- While the simulation model and experimental tests worked well, yet the main goal of the project was NOT achieved, which is developing manufacturing process that reduces cost and eliminates the barriers that prevent smaller manufacturers from entering into the market.
- The project outcomes offer very high Capital cost: $2.2MM, and Installed cost: >$13/ft^2 which they do not meet cost goals of DOE roadmap.
- The key issues identified mainly focus on technical aspects including edge sealing, pillar design and placement, and vacuum evacuation. The project aims to identify more cost effective solutions for these production processes to reduce the initial equipment investment and increase the product outputs. Therefore, the approach taken is testing and modeling of edge sealing and pillar design and material selection. A few materials were tested and evaluated, however, it seems insufficient to find the optimal cost-effective solutions associated with these processes. There is no detailed information about work done on the vacuum evaluation and the presenter indicated that the vacuum evaluation process prohibits the project from meeting its cost target.

- The market barrier addressed by this project was cost.

- The presenters illustrated their approaches how to reduce cost of manufacturing and increase mechanical stresses of the samples, which is clear and meaningful.

- The project is mostly focused on addressing the cost issue of developing VIGs, which is most important for promoting VIGs. The current cost ($6/ft^2) seems 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) **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 in good progress.

- Materials and design for low-cost evacuation process do not meet cost goals of DOE roadmap.
- The capital and fabrication costs exceeded both the window manufacturer's expectations and the market acceptance threshold.

- Some progress has been made. Sealing edge and pillar design/process have been tested and a small prototype was fabricated. However, the evacuation process failed to meet the cost goal, which prevents the project from proceeding with its original plan and objectives.

- Project has shown that Vacuum Insulating Glazing will not result in a cost-effective product.

- The results of this project at this time include material selection, fabricated prototypes, and tests. The method of design and fabrication of the proposed technology was identified and verified to meet the performance and cost targets.

- The project proposed and developed a manufacturing process to fabricate on-demand VIGs. It is unclear how this process is different from other processes (including those for massive production), and why this process is most cost-effective.

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.

- Good collaboration among DOE lab and industrial companies.

- While the project team includes many technology partners and manufacturing equipment providers, it seems that this collaboration did not work out to achieve the main goal of the project. On the other hand this collaboration succeeded to predict the capital and installed costs for proposed fabrication process and final product.

- The partnership and collaboration includes glass, coating and window manufacturers and one national research lab, which seems appropriate.

- Strong collaboration with Gyrotron Technologies, GED Integrated Solutions and ORNL. Large cost share.

- The project team includes technology partners and manufacturing equipment providers, which strengthens the project and presents strong potentials.

- The project lists the partners but did not mention specific collaboration efforts among them (besides supply materials and fabrication).

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.

- More loading effect, such as wind load, can be considered. The spacing of the pillars can be optimized.

- No future plan to pursue an alternate high-performance window IGU design that meets both the performance and cost goals.

- The proposed future work is vague. Up to date progress suggested the redirection of the project, it seems that the original objectives may not be achieved.

- Project results suggest no further effort for BP 1. However the redirection suggested on slide 15 seems worthwhile.

- Upon the presentation, the future work plan is unclear to this reviewer. There are no clear objectives and tasks for the future work.

- Redirection to other solutions.

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

***High*: 2** reviewers
- It has a great potential to enter the market.

- *None*

***Average:* 2** reviewers
- The value of this work is that it has shown that the VIG process that was tested will not result in a cost-effective product.

- It may provide an alternative approach for producing VIGs.

***Low*: 2** reviewers
- The capital and fabrication costs exceeded both the window manufacturer's expectations and the market acceptance threshold.

- There is risk that the original deliverables may not be achieved by this project.

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

***Yes*: 4** reviewers
- Sufficient emphasis has been received.

- *None*

- *None*
- The project aims to develop a fabrication-on-demand process for VIGs, which was achieved.

***No*: 2** reviewers

- The project failed to overcome the cost and supply chain issues preventing widespread adoption of VIGs.
- Up to date progress suggested to redirect the project, it is not clear whether the initial objectives would be achieved and the future plan did not provide details regarding overcoming these barriers.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Innovative way to manufacture VIG. ABC pillars can be 3D printed.
- The simulation model and experimental tests worked well.
- The objectives of the project support BTO's goals.
- Project has shown that Vacuum Insulated Glazing is not cost-effective.
- *None*
- Specific target and goal.

2) **Project Weaknesses**

- The configuration of the VIG can be further optimized.
- Materials and design for low-cost evacuation process do not meet cost goals of DOE roadmap
- The capital and fabrication costs exceeded both the window manufacturer's expectations and the market acceptance threshold.
- The objectives of this project seem quite ambitious and present high risks.
- *None*
- *None*
- Reasoning and justification of the process.

3) **Recommendations**

- No.
- I recommend terminating the project and to save the rest of the project budget because the main goal of the project was not achieved and there is no future plan to fix that issue.
- *None*
- *None*

- *None*
- Need better reasoning and justification of the developed process.

Project # 35312: Fenestration Software Tools

A. Relevance

This project was rated **3.83** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The project will develop validated simulation models and procedures, and test methods to characterize properties and energy impact of a wide range of window attachment.

- Project's outcomes include, developing of validated simulation models and procedures for characterizing properties and energy impacts of a wide range of window attachments, developing of test methods for measurements of material properties and whole product performance, and implementing validated simulation models in software tools for use in rating and product development. This, in turn, will provide performance rating mechanisms for assessing energy performance of fenestration attachments that will enable consumers to identify fenestration attachments that maximize energy savings. At the meantime manufacturers will have guidance to optimize technology innovation for new product development. This project will provide the technical backbone for the DOE supported and funded Attachments Energy Rating Council (AERC) organization.

- This project covers three aspects including development and validation of simulation models, development of test methods and procedures, and development of web-based tools for rating the energy performance of window attachments. The outcome of the project will provide validated tools and procedures to quantify and rate the energy saving potentials of different window attachment products and also assist new product development. It is important for manufacturers, policy makers and consumers. The objectives of this project strongly support BTO's goals to improve buildings energy efficiency.

- The rating system that will use the technical results of this project will be very useful in getting efficient fenestration attachments into market.

- Window attachments account for a big part of the overall window energy flow and affect the energy use of the building. So, this project fits into the BTO's goals and roadmap by focusing on window attachments rating methods and systems. This project is correlated with another DOE funded project and provides the technical part support to the overall project.

- Window attachment is critical to building energy performance. Quantifying the performance of various attachments are important for achieving high performance buildings.

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 project can enable rapid and cost-effective rating and certification of window attachment.

- While the project introduces comprehensive validated simulation models combined with experimental testing, yet the figures for the comparison of measurements and simulation methods have bad quality and do not show clearly the ranges for heat flux at the vertical axis, page-8. Also, the units for the heat flux in these figures are not correct and contradict the units for heat flux (W/m2) at the table at the same page, page-8. One possibility is that this vertical axis is describing a different variable; in this case the vertical axis must include this variable instead of the heat flux. Furthermore, at page-8, the figure that describes the relation between the height and temperature has unrealistic values; cold side has (-95^{o}C) and hot side has (+80^{o}C). Perhaps the ranges for the x and y axes are incorrect or unclear, in both cases providing good qualities for the figures will eliminate the confusion.

- Key issues have been identified. A comprehensive and effective approach is employed to address these challenges including model development and validation, which will provide reliable, rapid and, cost effective evaluation tools, development of test standards for product standardization, lab and field testing to validate energy saving claims, and development of rating procedure for certification.

- Emphasis on testing, measurements, and eventual incorporation into simulation models is well thought out and is being well executed.

- The approach includes both computational simulation and experimental measurements. The approaches shown in the report and presentation are clear and meaningful.

- The project focused on developing/improving tools, testing facilities/methods, and creating databases. These are all critical for the proposed subject.

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 in good progress and expected to achieve its goals.

- Qualitative:
  - Some results for the simulation model and experimental testing have been put in graphs. There are discrepancies in some of these graphs that would lead to inaccurate conclusions.
- Quantitative:
  - Both the simulation model and experimental testing measure the key parameters that describe the proposed systems.
  - Collaboration with industry is arranged to quantify the scope of attachment product variances including: fabrics, installations, and gaps.

- Good progress has been made. Models have been developed and validated by laboratory testing. Test procedures have been developed both for material properties and components. The tools and procedure developed is being adopted by AERC in rating and certification of window attachments. Market impact is evident.

- Significant accomplishments on simulation model, thermal model, new standards and sensitivity analysis.

- The project completed the simulation models for thermal and optical analysis, and it also developed new standards for thermal and optical measurements on window attachments.

- The project is making good processes in all proposed aspects. The team may need consider thoroughly in terms of the labeling and certification program, due to the type diversity of window attachments and different properties and indicators.

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) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Balanced team among DOE lab and industrial partners.

- The project team is collaborating with many rating and certification organizations, which is vital to this project. The team project has many other partners/subcontractors; AERC, NFRC, Shading Manufacturers, and window manufacturers. Collaboration with industry is arranged to quantify the scope of attachment product variances including: fabrics, installations, and gaps.

- Excellent collaboration with stakeholders exists. The partnership and collaboration includes window manufactures, shading manufacturers, professionals, consumers, and rating and certification agencies, utilities.

- Strong collaboration: AERC, Hunter-Douglas, Levelor, Rollease, ES-SO, PAMA, ESSA, NEEA.

- The project team is closely collaborative with NFRC and AERC, and also has strong connections with industry and manufacturers.

- Close technical work relationships were found. However, the relation between this project and the AERC was found loose.

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.

- It will be helpful if a web-based simple program can be developed, so that the public can use this program to evaluate their window attachment.

- Comprehensive future plans have been introduced for both technical and organizational divisions.

- The proposed future work is well-planned and built on past progress and focus not only on the technical aspects but also the collaboration and engagement with certification agencies, consumer groups, and manufacturers to promote the awareness and adoption of the high performance window attachments, which will definitely help achieve the project goals.

- Agree with proposed future work as described on slide 17.

- The proposed future work includes two aspects on technical and organizational parts, which shows clear plan and meaningful activities.

- Both technical and organizational work proposed are reasonable and important.

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

***High*: 5** reviewers

- There is a potential big market for this modeling and testing method developed from this project.

- The project team has built strong communications with key stakeholders to accelerate movement of technologies or practices into market.

- The target audiences include manufacturers, certification agencies, professionals, code officials, policy makers, and consumers. The deliverables will enable the quantitative evaluation and certification of energy saving potentials of window attachment products and assist new product developments. This will help various stakeholders make informed decision on product specification, policy making, new product development, etc., therefore, this project will produce valuable outcomes to its main audience.

- *None*

- All developed tools/methods/databases will be useful for the field.

Average: **1** reviewer
- The rating system that will use the technical results of this project will be very useful in getting efficient fenestration attachments into 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
- Sufficient emphasis has been received.

- Validated simulation methods have been introduced to model thermal, optical and energy performance of fenestration attachments. These validated simulation methods will be incorporated into associated software tools for rating and certification as a cost-effective alternative to physical testing.

- Both research areas and deployment activities are receiving sufficient emphasis.

- *None*

- *None*

No**: 1** reviewer
- Most tech emphases were covered but the links to the targeted labelling program remains unclear or undetermined (as stated).

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project can provide a useful tool for rating and certification of different window attachment.

- The project introduces comprehensive validated simulation models combined with experimental testing
- Excellent collaboration with industry and key stakeholders.

- The objectives of the project strongly support BTO's goals. The approach taken is comprehensive and effective. Excellent accomplishments and good collaborations with key stakeholders. Potentials for high impact on energy efficiency.

- Significant accomplishments on simulation model, thermal model, new standards and sensitivity analysis.

- *None*

- Clear identification of major tech challenges and needs.
- Sound research approaches.

2) **Project Weaknesses**

- It will be more useful if a simple program can be developed to promote wider adoption of this method.

- There are discrepancies in some graphs that would lead to inaccurate conclusions.
- *None*
- *None*
- *None*
- Unclearness on labelling and certification progress and practice and thus associated technical needs.

3) **Recommendations**

- No.
- Providing sound graphs that describe accurately the simulation and experimental findings.
- *None*
- *None*
- *None*
- It will be nice to learn from the marketing needs to enhance the technical needs.

Project # 94151be: CBERD: R&D Building Envelopes

A. Relevance

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

- Create cool roof and phase change walls and test them in India.
- Main goals of the project include the evaluation of: the use of: phase-change materials in building walls, and cool roof materials in roofs. Also, the project examines the light redirection and solar reduction. This addresses the BTO's mission to develop new techniques and advanced materials for building envelops.
- This objective of this project is to help the adoption of cool roof, PCM and shading devices into building designs in India by help them setup research infrastructure and develop simulation tools tailored to Indian climates. On the global stage, these activities will help improve energy efficiency of buildings in India, however, it is not clear how that related to BTO's goals. Although it is stated that the adoption of these technologies in India will facilitate U.S. manufacturer's penetration to that market, which seems quite vague.
- The technologies being tested will mainly be applicable to the Indian climate and infrastructure. Therefore, the results of this project will be of limited usefulness to the goals of the Window Envelope Program.
- The project is focusing on the India building energy efficiency and connecting U.S. manufacturers to it. Some project aspects about the solar shading evaluation, phase-change materials align with BTO's goals.
- This program has a very specific goal: allows U.S. manufacturers to sell their products in India. This project's activities all act in aligning with this goal.

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.

- Can leverage Indian investment for U.S. market benefit.
- Use of phase change materials (PCMs) in building walls is very critical. The following characteristic for the used PCM must be examined before integrating it in building walls: toxicity, melting point, auto ignition temperature, flammability, and volume change during phase change. The proposed project did not mention/define any of these characteristics and the presenter did not do as well.
- The issues identified mainly focus on technical aspects; however, the critical barrier seems to be the cost. The project did not address cost issue. The approach employed includes lab and field testing and modeling. Identical test houses were set up at different locations in India and the data collected were used to validate models and evaluate energy saving potentials offered by cool roof and PCM. However, it is not clear what typical applications the research is focusing on to find cost-effective solutions for that particular climate and market.
- Agree with implication on slide 6 that natural exposure trials of 3 years are necessary.
- The technical approaches shown in the presentation includes both computational simulation and experiments which are clear and convincible to reviewers.

- The project targets at some selected topics that are important for India. Corresponding approaches (either modeling or experimentation) were developed to promote the U.S. techs.

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) **2.83** 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 good progress.

- Measuring the PCM characteristics is vague. A lab measuring instruments is mentioned in the report without mentioning what it measures. Thermo-physical properties of the proposed PCM must be examined before integrating it in building walls.
- No validation for the findings.
- Did not define the dollar amount/ft^2 for the proposed materials.

- Some lab testing on PCM has been carried out and field monitoring of test houses with cool roof and PCM is ongoing. Some progress has been made on the modeling program for shading device design. It is too early to indicate any market impact.

- The technologies being tested will mainly be applicable to the Indian climate and infrastructure. Therefore, the results of this project will be of limited usefulness to the goals of the Window Envelope Program.

- The impact on the building energy savings in India is expected with high level, but the implementations in the U.S. and potential connections to the U.S. manufacturers are unclear upon the presentation.

- Some systems are still oversimplified, which may question the accuracy and meaning of the obtained results. Close communication with India partners will be suggested to better understand the challenges and critical barriers (and even state-of-the-art) in India and thus come up with more realistic and advanced solutions.

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.

- Well balanced team from India and the U.S.

- U.S. India Joint project that comprises ORNL; Pluss Polymers; International Institute of Information Technology, Hyderabad; Centre for Environmental Planning and Technology University (CEPT), Ahmedabad; Saint-Gobain Research India; and Saint-Gobain/CertainTeed (USA). The project team has built strong communication nationally and internationally with key stakeholders to accelerate movement of proposed technology.

- The collaboration is mainly with research institutes in India and some manufacturers.

- Strong collaboration with Indian partners.

- The project integration and collaboration is through conference calls, meetings and connections with industrial partners. No detailed events and programs were described in the report but the onsite experiments and measurements showed that the potential supports from the industrial partners and academia.

- Some contacts were established, mostly reflected by jointed papers.

E. Proposed Future Work

This project was rated **2.83** 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 will be more helpful is simulation models can be developed and verified with the test data from this project. The models can then be used to cover more parameters.

- A detailed plan for measuring the thermo-physical properties for all proposed materials (including the PCM) should be introduced.

- The proposed future work is to complete the research component of the project. It is not clear how the final deliverables help achieve the project objectives.

- The lab aging tests mentioned on slide 17 are essential to proving that the project results are worthwhile.

- The future work is on field-test data collection and analysis and some database update as well, which fits into the project scope and meaningful.

- Continuous work on started researches. It will be helpful to establish some sort of anticipated quantitative and quantitative targets to judge or evaluate the success of the project (such as the accuracy and deployment of the model, usage of the test facilities).

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

***High*: 2** reviewers

- The project will be of interest to both India and the U.S.

- *None*

***Average:* 3** reviewers

- The level of cost is not defined which will not allow comparing its feasibility in the market.

- The targeted audiences are building officials, architects, building owners and developers. The deliverables of the project would be design tools for shading devices, energy saving potentials offered by cool roof and PCM, and research facilities. These tools and facilities will provide the targeted audiences with tools and information on the energy saving potentials of these technologies, therefore, help them make informed decisions.

- In the long-term, it may help promote U.S. products on India markets.

***Low*: 1** reviewer

- The technologies being tested will mainly be applicable to the Indian climate and infrastructure. Therefore, the results of this project will be of limited usefulness to the goals of the Window Envelope Program.

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

***Yes*: 6** reviewers

- Sufficient emphasis has been received.
- The project main outcome is to develop new materials to be integrated in buildings wall, windows, and roofs to overcome heat waves in India.
- The key research areas relevant to the project objectives is receiving sufficient emphasis. More emphasis may need to be placed on promoting the tools and technologies to increase the awareness of the targeted audience to facilitate the adoption of these technologies.
- *None*
- *None*
- All selected focuses were equally covered.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good effort between India and U.S.
- The project addresses the BTO's mission to develop advanced insulation materials for building envelopes.
- U.S. India joint project.
- Introducing of new advanced materials to be integrated in building walls, windows and, roofs. It will create infrastructure for cool-roofs and phase change materials in India that allows U.S. manufacturers to sell their products in India.
- *None*
- Solar shading seems to be a potentially very useful, low-tech, application for Indian applications.
- *None*
- Clear goals.
- Specific tasks.
- Start from U.S. existing mature techniques.

2) **Project Weaknesses**

- Some extra effort, such as modeling, can allow the project to have a more significant impact.
- Did not examine/define the main characteristics for proposed PCM, toxicity, melting point, auto ignition temperature, flammability, and volume change during phase change.
- It is not clear how the objective of this project supports BTO's goals.
- The phase change material part of the work is weak. Not sure what the results are.

- *None*

- Justification of the implications of developed tools/facilities to promoting U.S. products (e.g., who will use these, how to promote the use of these, how the accuracy of the models/facilities will affect the outcomes, etc.).

3) **Recommendations**

- No.

- Consider measuring the thermos-physical of all proposed materials.

- *None*

- *None*

- *None*

- It will be interesting to highlight the technical differences/challenges between U.S. and India (such as in model, algorithm apparatus). Are there any findings that can help improve the products/models or enhance our understandings of India building conditions?

EMERGING TECHNOLOGIES
SENSORS & CONTROLS

Project # 31490: Equipment Health Monitoring with Virtual Intelligent Sensing

A. Relevance

This project was rated **2.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- *None*
- When applied to small or medium sized buildings with no adequately trained maintenance staff, this program should provide an improvement to system efficiency and reliability.
- The overall goals of the project does project DOE interests in terms of monitoring building plug loads for energy monitoring/control, especially without adding expensive sensing equipment but monitoring the power signature using existing equipment. The fault detection objective is directly in line with BTO's goals.
- Low cost building faults but not sure how the cost element was addressed.

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.

- *None*
- Approach will work well on smaller buildings with limited loads. Larger buildings with multiple units will not be a good candidate for this project.
- Power signature detection is not a technology that can do it alone as far as HVAC fault detection goes. The PI seems to want to sell it more than what it is. It would be a powerful addition along with other sensed data, some already present in the control systems along (without adding more sensors), in order to paint more complete picture of the system status. Using power signature identification for loads is difficult as many devices and combination of the device could produce similar signature, and high frequency monitoring is often required to decipher these combinations. The PI's academic partner seems to produce the logic to decipher basic constructs of these signals, hence using a "clean" building for test is a plus here. For real buildings, the electrical noises might render these logic unusable or misidentification.
- As the other panelists and audience questioned, aging effect and variance in equipment can change these power signatures from building to building as well, how to establish a good baseline for a specific building is a difficult challenge to solve.
- Disaggregation approach very useful and novel.
- Mention estimate of health but then did not address this in an organized way.

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.

- *None*
- The data that was presented seems to indicate they have a relatively accurate way to show what is running and what is not. Fault detection data was not yet available and provide more confidence in the program.

- The basic software capability has been validated using the ORNL test buildings, and that is very important. But translating that to work on real buildings without the needs to calibrate the signals for long period of time will be crucial success. Quantification of induced fault detection is also problematic because one cannot guarantee all the possible combination of faults have been included and tested, so a process to continuously capturing new fault and learn its tendency is needed. This process needs to be self-learning and adapt to its building in a long term basis. A static program is unlikely to be successful.
- Still, this approach has a lot of promises, especially when combining with other fault detection techniques, and if it can be used reliably, it can be deployed to buildings immediately since there is little cost in terms of new investments.

- The biggest contribution is the disaggregation element.

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) **2.25** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Heavy on academia and consultants. The team may consider adding some manufacturers and businesses.

- Limited partnerships, but scope, at this point may not need to have many collaborators.

- Collaboration with U Tennessee mostly, using UT's algorithm and tests it on ORNL's facility... what Does Richman Surrey do here? Perhaps for future tests on real buildings? If so, there is little or no industry collaboration up to this point. Can the UT algorithms be validated independently by Richman Surrey in anyway?

- This project seemed to have only light collaboration.

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.

- *None*

- Limitations were presented and progress was shown with timeliness for next milestone.

- It seems like the software package with limited equipment design will be ready for real building tests soon, and the outcome should determine the readiness of the proposed solution. The only drawback is what if the planned solution does not work well compare to the tests in the "Clean" buildings, what is the fallback solution salvaging the technique developed?

- This project lacked a strong vision going forward.

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

***High*: 1** reviewer

- Deliverables shown at this point seemed positive and would be an improvement to no controls system or qualified maintenance staff.

Average: **3** reviewers
- *None*

- Not a lot of test results to tell whether this proposed solution can work or not, although the potential is pretty high.

- This would have been below average but the load disaggregation work is novel and noteworthy.

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
- *None*

- Data shows they can accurately identify load profile.

- The spirit of the work is in the right direction, just requires more engagement from the inventors to do the hard work.

No**: 1** reviewer
- I think the weakness of the power signature technique is not well discussed. A list of what exactly being tested, and more comprehensive scope would go a long way.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good approach and logics behind the project plan.

- Some proven success up to this point.
- Tapping a market with very little penetration and a significant portion of energy waste.
- Appears to be a strong team performing project.

- There is a lot of merit in terms of using power signature to determine equipment health. The idea and approach seemed very sound.

- Load Disaggregation.

2) **Project Weaknesses**

- Project team may consider [collaboration with] industry and business.

- Scope will be limited to building complexity. HVAC, multiple loads, etc.

- However, the details of how these will all come together seems a little lacking, especially scope wise. What will be the metric to determine the fault detection failure and success? How about the inclusiveness of the faults to be detected? Those are not well expressed in the review.

- The project needs a major contribution from the principal organization.

3) **Recommendations**

- *None*
- Work within the sweet spot of this technology and maximize the potential for that market.
- If PI can consider a perfect fault detection system, then decide how power signature detection can fit inside that system, instead of trying to oversell the capability of the developed technique.
- Tackle the difficult problems with sound engineering practices, math, problems solving, and programming.

Project # 31491: Transforming Ordinary Buildings into Smart Buildings via Low-Cost, Self-Powering Wireless Sensors and Sensor Networks

A. Relevance

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

- *None*
- The ability to have a self-powered sensor removes the need to change batteries on a frequent basis.
- Self-power sensors would be an excellent addition in building systems in terms of monitoring and controlling energy use.
- Vibration harvesting is relevant but limited in that the sensors have to be co-located with the vibration source.

B. Approach

This project was rated:
1) **3.25** 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.

- *None*
- Initial prototype was good, but plans to miniaturize the unit increases the desirability of product.
- People want cheaper and low/non maintenance sensors, so by harvesting PZE the sensors could be low in cost and required no maintenance. However, this has only been addressed using off the shelf products and evaluation of the actual product design. There is no innovation in terms of using established PZE harvester and integrated with existing sensors and communication packages. There is only so much you can do by cutting power consumption and shrinking the total size.
- Novel energy harvesting idea.
- The approach would benefit by including the control system that the sensor is connected to so that sample frequency can be considered. A Model Predictive Control strategy would enhance your sensor lifetime.

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.

- *None*
- Successful prototype built. Exceeded the original impact goals.
- The accomplishments are primarily of student activities (mostly in business competitions)... very little on technology development. This is usually a sign of very little tangible work has been completed that student activities are used as fillers for progress. In fact, it is shown only a couple of prototypes have been constructed and tested, and very data is shown to support the work of sensors other than power used per time. There was no indication of sensor reliability, detection failures, communication failures, etc. PIs claim x amount of time can be achieved from PZE alone, but provided no metrics on how that is evaluated.

- Several awards from outside agencies noted. Slides were inserted after the reviewers had the material.

D. Project Integration and Collaborations

This project was rated:
1) **2.25** 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) **2.25** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Good collaboration team.

- No real collaboration here. University and a spin off company from the university.

- The collaborator is a startup company spin off from the university research group and still use the campus offices. I do not think that's proper collaboration with industry. Additionally, the PI's answer regarding sensor locations demonstrated that he is not familiar with the requirement of building control / HVAC industry, so some REAL industry partners would be nice.

- This project appears to have very little outside collaborations and industry involvement.
- All of the elements were tied to Case Western in some way and put in place to satisfy the collaborations element.

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.

- Device as well as Wireless functions needs to be completed (tested and implemented) before start building a prototype that does not means "Commercialization" is just the start of product development.

- Testing is complete and ready to connect to an active system. Some minor tweaking left.

- While further miniaturization and VC makes sense, what is the value of the project if all is being done is to package existing technology together without improving them. Some progress should be made to see whether PZE harvesting can be improved by making the harvester more in line with the movement/vibration of the surface? Or change of the form factor to help PZE harvesting? These are possible ideas that could improve the technology.

- Fundamental Apparatus work very positive.
- Investigation beyond co-location should be done to see if other aspects can allow sensors in other locations.

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

***High*: 2** reviewers
- *None*

- Appears product is a reality and ready for distribution.

***Average:* 2** reviewers
- Great idea but not too great execution. PI should imagine how such idea would work flawlessly first then come up with the components/improvement to achieve the vision, instead of just slap some off the shelf parts together. This is more like a maker's fair project instead of BTO project.

- This project is more of an emerging technology and will require some appeal for wide 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*: 3** reviewers
- The development of this sensor has been realized and the project was a success.
- It seems like PI understand they must demonstrate the PZE use is possible and they certainly have done that in some sense, but the approach can use a lot of effort in terms of improve existing technology instead of trying to build the products which is borderline working.
- Yes, energy harvesting is a key element of exploration.

***No*: 1** reviewer
- Commercialization needs to have a stronger focus in order to meet schedule.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Good relevant project with a great technical team.
- Successful prototype constructed.
- Ability to self-power with no need for batteries.
- Great idea to use PZE.
- The project was willing to try a novel approach towards powering sensors.

2) **Project Weaknesses**

- Devices need to be ready (including a built and tested prototype); wireless functions need to be designed and proven before start commercialization.
- Sensor placement (for electro mechanical input) may not be where you want the temperature reading.
- Packaging and miniaturization is not really the key to make this all work.
- Co-location does limit the location and applicability of the methodology.

3) **Recommendations**

- Commercialization will not be on schedule, it may be in 2017-2018 time frame.
- As mentioned in the presentation. Potential return duct placement may provide vibration with a suitable thermal reading.
- Try improve the PZE harvest somehow. Cutting the power consumption of the wireless chip can only get you so far.

- Consider locating vibration units on the vibration source and then beaming the power to the sensors.

Project # 32611: Low-Cost Wireless Sensors for Building Monitoring Applications

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- *None*
- Lower cost sensors help make energy control systems more affordable, therefore more attractive to install.
- Development of printable low cost sensors definitely align with BTO's goal in terms of monitoring building energy consumption.
- Solving wireless integration is relevant and needed.

B. Approach

This project was rated:
1) **3.25** 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.

- *None*
- Approach seems to be effective in reaching the goal.
- The difficulty of printing sensors were well documented and all barriers were identified. The design will address most of the issue it seems, but with some of the sensor might require geometry beyond 2-D, better integration of foreign parts (outside of the print medium) or the use of 3D printing might be helpful. Key issues on sensors accuracy and drift overtime was not addressed, but might be irrelevant due to sensors price and short service life.
- The approach is more fundamental in that it is attempting novel antenna design for the HVAC solution space.
- The approach is solid towards achieving the goal.

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.

- *None*
- Good range of 1000 meters.
- Cut the price down to $10 per node.
- Open platform communication.
- Print your own sensors in the near future?
- Almost to market prototype quality is impressive. Although with only 1 sensor and radio antenna included, it is still very good in term of progress. Perhaps a lot of work has been completed before the start of the BTO contract. The functionality and cost of integrated parts are detailed. If there is additional performance data on the sensor side it would have been even better (the presentation is heavy on the antenna side of things).

- This project has the look and feel of a real new low cost sensor coming to market within the next couple years. So the achievement is very real.

- There is good results thus far.
- The nature of the work and accomplishments was more of a “solve the fundamental problem” and the authors are on a good path.
- Slides with incorrect data. Not 6-8 quads but 0.3 to 0.4 quads.

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.

- *None*

- Working with Molex very closely on the development of this product.

- The fact the partner Molex was able to produce prototype at such quality indicate good collaborations. The only comment is that is a manufacturing collaboration. Some more end -user collaborator who can deploy these sensors would have been much better. Perhaps the contract is more about producing the thing not to test it is the primary cause.

- The project does have an industry partner in the fundamental work.
- There does not seem to be significant collaborations beyond the industry partner..

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.

- *None*

- Potential low cost sensors made available to the open market.

- It is likely the inclusion of RH and temperature sensors will successful while tricky, as the PI indicates, but all signs seem to point to the challenges can be solved. The issue here is again, there is no plan to actually test them in real building, nor was any lifetime assessment planed either, so we do not know how long these will last.

- The plans to wrap this up and complete seem to be well within reach.

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

***High*: 3** reviewers

- Low cost sensor to replace the costly sensors available today.

- Very good due to the clarity on method used and the well-constructed prototypes.

- Once this is completely demonstrated it is useful to the industry.

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
- *None*

- Low cost, reliable parts with open communication.

- The key objective is low cost sensing, and the project seems to deliver it.

- Impacting the wireless space is essential to HVAC going forward.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Overall good project plan and it appears to be on schedule.

- Affordable cost.
- Good range of transmission.
- Open platform communications.

- Very strong project with a lot to show in terms of real low cost sensor development. The inclusion of high quality in-step prototypes are impressive, showing strong connection with the manufactory industry and mastery in the technology used in making this product.

- Fundamental research with a wireless antenna design to solve the problem.

2) **Project Weaknesses**

- Recommend more than one manufacture involvement.

- Potential security risk when they introduce two-way communications.

- Lack of "user" side of input. The real performance of these sensors is unknown. We are very sure they would work and they will be cheap, but the life span and accuracy is not going to be determined, not whether these sensor package will really benefit the end users.

- Review of the state of the art in other domains and if any of that work can be leveraged.

3) **Recommendations**

- More inclusion of manufacturers and business in the project as a collaborative efforts.

- None.

- If the PI can add some inputs from users of these sensors I think the project would be very, very strong. Additionally, if some estimation of sensor performance can be obtained, the low cost and easy to deploy nature of these sensors will be even more attractive.

- Drive to completion and then compare with the state of the art to see how feasible your solution is.

Project # 32612: Building Energy Management Open-Source Software Development (BEMOSS)

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Great project that will help energy reductions goal for commercial as well as residential buildings.
- Ability for a low cost solution for small and medium sized commercial buildings is important.
- A platform that can make building devices communicate with each other, specific for smaller commercial buildings which does not have support for high dollar BAS systems, the project is attractive to BTO's goals in terms of providing additional capability for building energy saving.
- Goal alignment is good.

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.

- This project has Industry, Academia, Scientific Community, etc., that makes a great combination in order to focus on market conditions vs. product development.
- System appears to be moving forward. Barriers were identified: ASI language translation and ability for a third party market to pick up the program to mass produce and support it.
- The PI seems to place the critical market barrier at "inability to communicate" between devices, which is only partially true. The actual barrier is more about "too many languages for one to communicate to all" or "refusal by some to communicate". This distinction might be lost among other distant observers, but it is an important one for people who will be integrating the systems.
- The PI have built a platform that will allow different things to talk to each other with techniques and technology that have been used for last 20 years. We already know how to do all that 20 years ago, only thing changed is added new protocols. PI also pushed that the "innovation" here is the openness of the platform, yet the "driver" portion, the most important part of the whole thing, was not well discussed until panelists and audience asked. The only interesting portion of the platform is the "open source" which I am not sure the PI actually understand the implication. Such issues will be discussed in the later comments.
- Software platform with good attention to interoperability.
- The need for a hardware platform to support the software is questionable. This software platform should be portable to exist on premise or in the cloud.

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 project accomplishments are overall good, I recommend a stronger focus in finalizing the software as soon as possible. It seems like the BEMOSS software 3.0 deployment should have been done well before

field testing with 3 buildings. The fact the BEMOSS 3.0 is not ready for deployment (tested) it may impact the field testing performance and therefore the project may have to be extended another year.

- Presenter did a poor job in delineating this from other open protocol systems currently on the market.

- The demonstration of what can be done with the system is very rudimentary, showcasing that it is possible to make one system communicate and control with another systems or base control using reading from other systems, etc. This demo itself shows very little since there are literally hundreds of YouTube videos demonstrate these integration paths. What is not demonstrated, is how well this platform can go forward? The key is whether any integrator can easily get something going when they approach the project. Currently, the answer would be no. Without Signiant polishing at the software level, the current solution is not better than a science project. Furthermore, with the authorship and validity of "driver" software not very clear, as an integrator, one would have very little trust or faith in this platform.
- What is the actual differentiator here for the integrators? Not needing to pay for the control software? That would be the least worry as the integrator, as the good margin does not coming from the software cost, but speed to deploy and fewest callbacks after deployment. The demonstrated system did not show any of these.

- This project has good project management and is has good leadership.
- The project is well integrated.
- The BEMOSS UI was not in the slide deck and authors should be cautioned to not insert material after the slides have been sent to reviewers.
- Excellent project execution.

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.

- Great Collaboration team from Academia, Builders of the technology, labs, etc. Well done!!

- Compatible with VOLTTRON and DOE support.

- While the collaboration effort seems solid, the fact the PI mentioned the need to spin off a company to upkeep the platform is an indicator the effort is very similar than any other startup in the home automation or building control system industry in the past two decades, just this has the backing of BTO. Without the key differentiator mentioned previously, it would only be natural for the platform to fail like others before it.

- Good to see results in open source.
- The integration to commercial companies needs attention.
- It was hard to distinguish this work from a startup trying to get into the Building Automation space.

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.

- I am apprehensive about the future work. I believe the software tool should be done before field test can start.

- What is the cost compared to other systems already in production?
- Need third party to make and support program.
- Require other third parties to make apps for use.

- The PI seems to think by completing the integration platform the job is done. Perhaps it is done for the duration and scope of the contract with BTO, but by just doing that, the solution will just be another failure. A spin-off company to keep the software going to ok, but one should realize the actual software development required here. Can any low cost integrator take this and make money? It is unlikely because it requires a lot of building blocks that do not exist, such as energy management logic, control logic as well as customizable front end. And adding and changing devices along will be a huge undertaking, especially with literally tens of thousands different protocols out there changing all the time.

- Adding Demand Response viewed as a positive.

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

***High*: 2** reviewers
- *None*

- If they can solve the commercial adoption element, then this work can be leveraged by industry.

***Average:* 1** reviewer
- With better information, this may have some better deliverables to the target audience. Too many questions as of now.

***Low*: 1** reviewer
- Target audiences are the lower cost integrators, who are unlikely to develop many of the functionality that is lacking currently in the platform. So what is the value here? There is a word "turn-key" in the title of the project, and there is nothing really turn-key about the solution from what we reviewed.

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

***Yes*: 3** reviewers
- *None*

- If the objectives were to create an open protocol to sit on VOLTTRON, then yes.

- *None*

***No*: 1** reviewer
- As mentioned, the emphasis of the project is in a completely wrong area.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Application in buildings booth commercial and residential.

- Open protocol.
- VOLTTRON platform.
- DOE support.

- Attempt to increase openness of communication between devices in buildings.

- Overall project was well run.
- Utilization of state of the art software design tools and hardware platforms.

2) **Project Weaknesses**

- The logic behind leaving software completion to the end.

- Cost compared to other open protocol platforms.
- Why should people move to this platform vs. what is currently available?
- Seems very cumbersome when lumped in with VOLTTRON.

- Failure to understand the true beast behand the problem. The current solution is like building a universal translator, and [having] it currently speak English and Chinese and just ignoring other languages and [then] say we will add them later. The challenge here is not how to build the translator, it is how to manage the language over time and adding new language. So the emphasis is completely misplaced and the result is the same old failed product like many before it.

- Compare and contrast how this differs from VOLTTRON.
- A plan for commercial adoption that is not in conflict with company solutions.

3) **Recommendations**

- Finish the software 3.0 before doing field test.

- Need to quantify cost comparisons.
- Need to show value compared to other open protocols.
- Costs of systems discussed in the presentation seemed very high compared to actual install costs for existing systems.

- The powerfulness of open source is the fact any one can use it, change it, manage it and update it, therefore the responsibility of maintaining the source is delegating between numerous, sometimes hundreds and thousands of individuals. It’s not just "I can use it for free", which seems like the understanding of the PI. I doubt the PI will acknowledge these comments, but the true value here, is to promote a community that will continue to develop and maintain the communication drivers for the platform, instead of forming a company to "safe guard" it. If you are just making the basic building blocks, then make sure others can take it and build anything they want. In theory that is what the PI wants to pledge, but in reality it seems like none of the actual building blocks has been built for people to use it truly the open source way.

- *None*

Project # 94151sc: CBERD: R&D Integrated Sensors and Controls

A. Relevance

This project was rated **2.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- *None*

- Most of this technology or research is probably important for the India market and power grid. I do not see much value for this country as our grid is fairly stable and rates do not fluctuate near as much. Without a better interface to control price or demand of power, not sure this will be accepted.

- The overall goals of the project does reflect DOE interests in terms of monitoring building plug loads for energy monitoring/control. However, it is unclear how the project can turn an India-U.S. collaboration in terms of cheap technology into tangible results. Perhaps there is a market for much cheaper load sensors and control which can make it much more available, but is that what BTO wants?

- Transactive Energy interesting terminology for price based energy and demand response.
- Demand pricing should also be considered in operations when summed together.

B. Approach

This project was rated:
1) **2.50** 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.

- *None*

- Approach for India market is fairly good.

- I think the fact the Indian market driven goals impacted the project a lot. For example, the personal control in a single cubicle is tangible when considering how Indian office works with fans. That types of control (personal ventilation, etc.) has interests from scientists and researchers in U.S. and Europe for some time, but never mature to break into market at all. It's primarily due to the practice in U.S. HVAC industry. Unless the norm is changed somehow, such solution is just a nice demo that will never be widely implemented.
- Also, the PI said the economic indicator for saving energy is the driving force, but showed no such data collection but only demonstrated a web interface. Such integration is not novel but pretty much the norm in the building control industry, it is difficult to see what the buzz is about here.

- India Joint effort program management complexities appreciated.
- VOLTTRON platform utilized positive.
- The approach is very simple currently. There needs to be a brain to the decision making to move the approach into new territory which will add benefit to the DOE.

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) **1.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Progress has been slow. It is fair to recognize that this is an International Project (U.S. and India) and there are time differences, language barriers, etc., that may naturally delay a project. There is a lot to be done in

two years and based on the plan scope of work, I believe this project may need to be extended until 2018 or early 2019.
- Perhaps one of the things that needs to be evaluated is the project schedule to have a more realistic time line.

- For our market I give this project low scores.
- For the India market, the scores would improve some.

- The product development in India is the highlight of the project it seems, so there are tangible results from the project. However, as mentioned previously, there is no indicator what is being worked on here can quickly penetrate the U.S. market and provide any impact in the U.S. market at all.

- Demonstration was good but very simple. The demo served the purpose of making it real. Lack of big theme to the work. Bounced all over from radiant heat ideas to many other items. Seemed to want to say any good idea that may pique interest. More of an integration project than making a fundamental difference with a new technology.

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.

- I recommend to reach out to more U.S. Industries for this project. They can bring different perspective regarding market development

- Collaboration was good and stakeholders were identified as the India market.

- Due to the India-U.S. joint effort, it is obvious the industry related partners are all from India. While it is demonstrated that a good working relationship has been established, it is difficult to see what kind of tie the project has in U.S. industry. It might be due to the nature of the funding, but some sort of connection to U.S. market would have been much more beneficial.

- A high degree of collaboration with others and funding of collaborators.
- This is the shining part of this effort. If we can realize contributions from other areas of the world the future benefit of projects like this can be significant impact.

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.

- *None*

- Being able to cut individual loads on and off or dimming fixtures will take a tremendous amount of education for the inhabitants of the spaces. Plugging a non-dimmable load into the wrong outlet will burn out the load. Need a behavioral change component to be included with this technology for it to have a chance of being successful here.

- Further product development and software testing is good, but what is the real impact here? It is unclear how much, if any impact will this project have in the U.S. market.

- Did not clearly communicate future deliverables.
- The level of funding at US$200,000 per year is not much to run a cross functional multi-location project.

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

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

***Average:* 4** reviewers
- *None*

- Better fit for market in India or other non-reliable grid markets.

- In the Indian market, the value is pretty high, but there is little value to the U.S. market.

- Satisfactory given the funding.

***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
- *None*

- Product appears to do what is advertised.

- The overall purpose of the development of energy saving technology is there, but the specific goals seem not aim at solving any immediate or emerging problem, which could make this project more focused.

- *None*

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- Vision and the Collaboration between USA and India.

- Ability to control loads off cost of power.

- The strength of the project relies on the working between U.S. and India in developing less expensive technology in terms of building energy monitoring and control. This capability can be industry changing if the underlying technology can be produced and distributed at a much lower cost than right now.

- An integrator of fundamental work done by others. Pulling together the project management of resources in India is the greatest achievement of the work.

2) **Project Weaknesses**

- Unrealistic timeline and project plan.
- Unrealistic budget.

- Needs more U.S. Industry Collaborations not just National Labs.

- No behavior change component.
- Need education for users.
- Outlet strip was bulky and probably costly to reproduce on building wide scale.

- However, the key weakness of the project is the lack of the connection with the U.S. market and its underlying industry. The goal of the products seems to be serving the Indian market as well as the software and control schemes. This detached objective is likely due to the specific funding nature of this project. But it is still not an excuse for such lack of context in terms of U.S. industry and market.

- Not having a solid big theme to the work and clearly articulating the value added to the DOE.

3) **Recommendations**

- Prepare a realistic project schedule with time lines.
- Prepare a realistic budget.
- Recruit more collaborations with U.S. Industries.

- Not sure this is beneficial for this country.

- It is already near the end of the project, but if there is some technology transfer from Indian product to U.S. company this could be a lot better.

- Review decision-making theory and optimization and apply it here.

EMERGING TECHNOLOGIES
BUILDING ENERGY MODELING

Project # 31590: A New Hybrid Approach to Energy Modeling

A. Relevance

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

- As an experimental method, the ground work and research performed by this project represents a very innovative attempt of merging measured data with modeled data along with cleverly manipulating the core algorithms within EnergyPlus to solve a difficult engineering analysis problem.

- It is a small but important enhancement to the Energy+ modeling procedure for existing buildings. It provides a more accurate calibration by overcoming a common guestimate method for infiltration and thermal mass in existing buildings. Savings estimates are not backed up by evidence from comparison of "with and without" this procedure.

- The improvement of energy modeling tools like Energy+ is in direct support of BTO's goals, as proper energy modeling helps practitioners to estimate and implement energy conservation measures more accurately and effectively.

- This project does not play a central role in the effectiveness of Energy+, but I believe that it does constitute important progress to continually make Energy+ more accurate and easy-to-use for performing complex calculations (and have addressed the problem that it solves numerous times).

- The project support to BTO’s goals is fair with potentials of improving the current computational methods of developing calibrated whole-building energy models for existing buildings to be used for evaluating the relative effectiveness of energy conservation measures (ECMs). More robust evaluations and comparisons of ECMs for existing buildings could reduce energy use intensity (EUI) levels. However, the ultimate goal of BTO for Emerging Technologies (ET) program is to provide substantial reduction of energy consumption in comparison to high-efficiency technologies but not relative typical commercial buildings. From this perspective, the project does not reveal potentials for substantial energy savings due to the assumption that detailed EnergyPlus models are existing for the proposed hybrid model to be executed. This may not be the case for a great majority of existing buildings. The second fundamental assumption that the proposed hybrid model is working on the actual/field data sensed and stored by the smart thermostats also includes problems of wide-scale availability, particularly for existing buildings that are exhibiting inferior energy performance and most likely missing advanced technology installments such as smart thermostat systems.
- Very relevant due to the uncertainty of operation configurations of existing buildings.

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.

- The project represents the first of its kind - a project whose fundamental hypothesis will be tested not only using under strict laboratory conditions utilizing the LBNL FlexLab facilities. Others have, in the past, attempted to solve the problem of dynamically estimating building infiltration rates using a variety of correlation based techniques. In this case, validation The presentation

- Clear understanding of the need. Well established method and process.

- "Critical market barriers" are not as applicable to this project, but the project does address several key issues that practitioners, particularly for existing buildings, have with using Energy+. I consider this project as important and relevant in supporting the continual improvement of the software tool.

- The project has identified the market barrier of energy modeling practices needing accuracy in the descriptions of buildings' physical characteristics and operations. This project offers a detailed method to deduct two difficult-to-obtain building data which are infiltration rates and internal thermal mass. The project approach could help reducing the differences between model estimates and measured values. The project does not provide ways or techniques about how to integrate the proposed hybrid modeling with existing design tools and/or control design-implementation tools. All of these together with automation of energy modeling tasks are critical market barriers and not identified/addressed by this project. The project's approach for addressing the identified barriers is good and effective with empirical validation of the proposed physically based modeling techniques. But this could be improved by extending the testing of the entire hybrid modeling approach (not just algorithms but data flows and usability) to a real world/as-constructed building case subjected to actual operational conditions and possible challenges that comes with them.

- Uncertainty in infiltration and impact of internal mass are critical features in existing building energy modeling and can provide significant values for errors. Therefore, the combination of air temperature physical model, combined with measure data and physical model and simulation data validation, validation using FLEXLAB is a significant improvement forward. All the strategies presented make sense to the reviewer and are valid.

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) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is demonstrating a useful scenario for the FlexLab facility, in order to filed verify the fundamental assumptions underpinning the research. The 2 step validation approach used by the researcher to first virtually validating the proposed algorithms by using prototype models and EnergyPlus prior to field validation via FlexLab testing represents an approach that should be used by future researchers investigating improvements to EnergyPlus as well.

- Once tested and implemented in E+ it will enable existing building retrofit analysis. If claims of savings are accurate these will be significant in the future.

- I believe that Energy+ as a whole has significantly contributed to the program's impact goals. The question is irrelevant for this specific feature, as it has not yet been implemented (this is different from the average project).
- I believe that this project will contribute significantly to achieving the program's interim market goal once implemented. Proper estimation of infiltration is a key issue for existing building retrofit projects, and the market will benefit greatly from a tool that accurately gets to the root of this issue. This will be a significant boost for energy plus.
- I'm not sure that I totally agree with the project's estimation of 1 quad of energy savings potential, but I also recognize the difficulty in making accurate estimations for tools such as this.

- The project reveals a modest qualitative support. It is not clear which percentage of the existing building stock size is ready for the deployment of the proposed approach. The project doesn't identify potentials of reduction of building's energy use per square foot relative to 2010 high-efficiency technologies as stated in the ET program performance goals. Contributions to ET interim market goals will likely be marginal. Due to added complexity of current workflow of energy model development and calibration. The project needs to identify what type of standardized and BTO-advised building data collection, storage and model integration techniques could be utilized to facilitate the proposed process. The projected contributions could also be diminished due to the requirements of installing smart thermostat sensing and data acquisition systems to existing buildings. Furthermore, in the hybrid modeling workflow, there may be inherent

uncertainties in the model inputs other than air infiltration rate and thermal mass. These uncertainties can be due to degraded building materials and/or equipment efficiencies, and schedules of occupancy and plug loads. The project fails to identify how to isolate specific uncertainties of infiltration and thermal mass from the others, attributing all sorts of the variance of model response to these two factors could result in biased recommendations in prioritizing the ECMs to be applicable to a building case.

- Developing the Hybrid in the middle between Heat balance equation, and Thermal mass and infiltration makes sense to the reviewer. This reviewer would question the use of a fan to create infiltration rate. Can infiltration rate not be validated with a blower door test? As infiltration is the obvious wild card in all energy modeling, it would be very beneficial to compare multiple methodologies.

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.

- While the project has demonstrated integration with the EnergyPlus team, little discussion was provided around discussing how the target audience (modelers of commercial and/or residential buildings) will expect to integrate with the software. Collaborative discussions with ESCOs, large portfolio owners, utilities and/or energy consultants to better understand restrictions and workflow expectations were not described.

- Limited user input. May be sufficient for this procedure.
- Not clear if users will readily accept the approach. No evidence of user survey.

- The first question is more relevant to the Energy+ software itself, which continues to do an excellent job of coordinating with key market stakeholders.
- For both questions, I want to highlight the value of the collaboration that the project team had with FLEXLAB. I think that this was an exceptional idea for making a model that's focused both on the relevant building science and measured data from a real-world simulation.
- Under the structure of this project, I believe that the project team did an exceptional job of working with the proper collaborators.

- By collaborating with California Energy Commission (CEC) Pier (Public Interest Energy Research) through cost sharing, the project demonstrated a basic understanding of the key stakeholders. However, some other stakeholders such as governmental institutions (municipalities) who can provide case studies for testing of existing buildings are omitted in addition to some ESCOs to implement the proposed method in their workflows and some other public and private stakeholders than can help penetrate to the residential building market for extended applications. The collaboration with other relevant stakeholders exist but should be significantly improved and specific information should be given about some possible industry members from AEC designers and energy efficiency consultants, utility companies, manufacturers (of smart thermostats technologies) and implementers during the formation of the proposed hybrid modeling workflow. Possible inter-lab collaboration is currently missing in this application. Collaboration opportunities (related to the integration of EnergyPlus with Open Studio) with NREL has to be clearly identified with specific contacts to related personnel.

- The project should collaborate with stakeholders outside of California to develop impact.

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 future work involving both field verifying the proposed research via FlexLab experiments and, if successful, deploying the algorithms to both EnergyPlus and OpenStudio are, in this reviewer's opinion, excellent next steps.

- Needs additional task of proving user acceptance. Needs language to add to E+ / Open Studio guidance documentation (not mentioned in presentation). Testimonials of leading users would help in outreach webinar.

- The project's next steps are simple, relevant, and going to bring the team's work into useful implementation (as the feature is rolled into Energy+). I wouldn't say that the proposed future work is particularly creative or innovative, but I also don't believe that the nature of the project allows for much more than effective implementation with Energy+ and dissemination of the team's findings.

- Proposed future works mostly focus on hybrid model fine tuning and implementation with EnergyPlus program. Strategically located decision points are not provided. The application failed to address the identification of key technical risks and quality management and possible risk mitigation strategies. The application should develop a main framework to get possible industry partners to deploy the workflow. Future work should be extended with the inclusion of how the hybrid model could be incorporated into Open-Studio ecosystem of EnergyPlus-based tools to tackle with the ET building energy modeling (BEM) barriers of "missing or brittle automation of common energy modeling tasks and insufficient integration of energy modeling tools with existing design tools". No alternative pathways to mitigate possible risks preventing the project's objectives are given in this application.

- Quantify calibration improvements and Energy Plus as well as OpenStudio integration are very valid next steps
- There should be a very thorough user application guide.
- And educational module would be valuable.

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

***High*: 3** reviewers

- The project is attempting to generate, through proxy measurement, what is known to be a very difficult energy modeling input to measure. When achieved, this will contribute to a growing movement of trust in the results of EnergyPlus predictions, as more EnergyPlus input data will be based on measure (proxied), and less on pure conjecture.

- As explained above, this update to the software is very important for Energy+ and will signify a valuable update to the tool.

- This project will just be integrated into Energy Plus and do its job well.

***Average:* 2** reviewers

- Not essential but useful.

- The deliverables of this project can generate an average value to the key target audiences and markets of the ET program due to the following reasons:
    - The hybrid modeling approach assumes an EnergyPlus-based initial model input but does not address the required level of detail of this model and challenges to come up with such a model input.

- The approach doesn't include data sensing, storage and model integration framework and doesn't address possible burdens on the users that can hinder the wide-scale applications.
- The approach assume smart thermostat technology which may not be readily available in existing buildings that will undergo a deep energy retrofit activity.

***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 a bit week in the deployment or dissemination side once finalized. Just one webinar proposed.

- As explained above, the improvement of DOE's modeling software is critical to supporting private sector energy efficiency retrofits and new construction projects. Changes that make the tool more effective, accurate, and easy to use support this end and should encourage practitioners to use these tools and receive useful results.

- Project activities are in line with the ET program objectives of advancing current technologies in building energy modeling to a higher level through dealing with one of the fundamental market barrier of the lack of accuracy in description of building physical characteristics and operations. The project can be further developed for the integration with operational use cases (such as low-energy control algorithms, control of common building mechanical systems, model-predictive building controls)

- The project will act as an improvement to the larger project EnergyPlus.

***No*: 1** reviewer

- As mentioned before, the specific deployment of the modeling feature, and how it is to be integrated into the EnergyPlus engine, were not well defined nor discussed in any detail during the project presentation. This reviewer believes that details relating to the feature deployment are as important as the technical details, and will have an impact on feature usage and adoption.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project represents an innovative approach to manipulating first principle heat and mass transfer equations along with measured data to produce a simulation input of high value to the user community. Current methods of estimating building infiltration rates are ill-defined the community has labeled them as inaccurate with little trust in simulation results. This project, if successful, will change that.

- Appropriate problem to solve. Goal is good.
- Focus on existing buildings is needed now.

- Provides much-needed tool for Energy+ that makes modeling existing buildings more accurate, effective, and simple. Included extensive analysis. Incorporated a real-life building model and detailed measurement and verification of the modeling feature.

- Offers technically well-grounded and empirically validated methods to couple data-driven (inverse) models with powerful simulation engine of EnergyPlus for improved model calibration and HVAC modeling.
- Focuses on the two most difficult-to-obtain energy modeling inputs (particularly) air infiltration rate and thermal mass of a building

- Leverages the use of EnergyPlus (by proposing the hybrid method) at multiple stages of building life cycle (not just design but during operation such as the use of empirically validated whole-building energy models within model predictive system control applications).

- This is a fairly small project with potentially large impact.

2) **Project Weaknesses**

- The main weakness that this reviewer sees is a lack of clarity in descriptions of how this research will be included in EnergyPlus or other tools. It is not clear if applying this research method will require successive simulation runs, and if so, how the EnergyPlus engine will accommodate this within the restrictions of the current EnergyPlus framework, In other words, will a specialized GUI need be developed, such as a pre-processing utility, or will the feature be available in a manner similar to how other EnergyPlus features are made available, by adding specific object to the user's model. The success (or failure) or this project will be impacted by how the final implementation is included inside a distribution of EnergyPlus.

- No discussion of inputs required by Open Studio. Seems that the level of data on temperatures by zone will be a complicated input to manage in multi-zone buildings.
- Might be limited in application to buildings with EMS systems or some way of recording temperatures throughout the building.
- Seems to add a step in the typical modeling process, but improves the accuracy for existing buildings.
- Savings estimates are a guesstimate. No evidence supporting it.

- No clear weaknesses; the project team set out to create a specific tool for Energy+ and did so (making it much more discrete than many BTO projects).

- The application shows a weakness to state applicable metrics to evaluate the impact of the proposed hybrid modeling approach on substantially reducing the energy use of typical buildings compared to high-efficiency technologies available in 2010.
- The application didn't propose methods (accomplished or planned) for the integration of the new feature with the Open Studio ecosystem.
- Possible inter-lab collaborations are ignored.
- There is a lack of feasibility checking about how many percent of the existing building stock is ready for the proposed method, or how much financial or human resources are needed to get them up the required state is not investigated (software, hardware requirements, cost of smart thermostat implementation, etc.).
- The application should evaluate the real impact of the project to able to answer the first EERE question.
- The application is not successful in addressing some of the most fundamental barriers of energy modeling to be overcome with activities of ET program.

- No weaknesses to report.

3) **Recommendations**

- No recommendations at this time.

- Unclear to me how non-linear correlation of thermal mass and infiltration are handled.
- Also, unclear if procedure accounts for both positive and negative energy impacts of mass.

- I hope that the dissemination webinar is clear and made publicly available. I also hope that the transition to the Energy+ team will be sufficient for them to clear out any bugs or major issues that may result from implementation. That said, this project is near completion and on a great track.

- A point of reference/benchmark has to be established for tested infiltration rates from 0.16 to 5.00 ACH. Do these values corresponds to certain levels of construction air tightness qualities that affect uncontrolled air flow to and from the building envelope?

- Core zones of single story office buildings may have infiltration. But attention should be given to the fact that core (internal) thermal zones of multi-story offices (except for the top floor under the roof) don't have infiltration (no exposed surfaces). How does this condition affect the weight of infiltration rate within other factors influencing the energy model output variance for measured values?

- This is a very valuable project.

Project # 35510: EnergyPlus

A. Relevance

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

- As a key (technical) component used across EERE BTO to assist in goal setting, continued BTO support for EnergyPlus remains relevant and recommended for including within spending priorities.

- Fundamental tool that supports so many DOE efforts and programs outside DOE.
- This evaluation form is not relevant to this "program" because it is not a short duration activity focused on specific barriers. Instead it is core infrastructure and needs a different assessment method (see suggestion in final notes field).

- Energy+ is a critical resource that DOE produced and continues to keep up-to-date. While the tool has been implemented already, DOE's focus on continually updating Energy+ and improving its functionality significantly helps private sector individuals using the tool to more effectively, easily, and accurately model energy consumption and recommend energy efficiency measures in buildings. Additionally, the fact that Energy+ supports so many other DOE tools makes it critical to its energy modeling family.

- EnergyPlus development project is critical to the BTO and supporting the overarching goals in BEM sub-program. This is due to fact that this application not only focuses on improvement of the current restrictive data structure of EnergyPlus (migrating from IDF to JSON) but also pays attention to the collaboration for user interface integration (with vendors and particularly Open Studio environment) and extension that can foster the use of EnergyPlus in building design. Therefore, the application aims to increase the use of building energy modeling in design while proposing enhancements in model accuracy which considered as one of the key issues (empirical validation) listed in the proposal slides. The proposed features and updates of program capability and connectivity have potentials to support EnergyPlus which is currently market-viable but underutilized software product that can cost-effectively save energy to reach stated BTO goals.

- Energy Plus has become the market leading energy modeling engine. It is the basis for almost every technology evaluation in the BTO program, therefore not only relevant, but indispensable.

B. Approach

This project was rated:

1) **2.80** 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.

- From this reviewer’s opinion, EnergyPlus continues to attract 3rd party developers who are building solutions on top of the key EnergyPlus computation engine. As more (governmental and non-governmental) customers emerge, it will be important that the Energy Plus development team both include key stakeholders as part of the development roadmap and determine where priorities lie.

- No barriers identified in this presentation. The tool obviously is designed to overcome the major market barrier of capability to analyze energy performance with a high level of accuracy. It could also be addressing a more specific barrier of inherent limitations in the old DOE2 engine and other market tools. It clearly improves on that.

- "Critical market barriers" are not as applicable to this project, as it is an ongoing effort to continually improve a solid piece of energy modeling software put out the DOE. That said, the project does intend to continue addressing the issues that the market has identified and to continue building a tool based on market feedback from big players in the industry. I consider this project as important and relevant in supporting the continual improvement and expansion of a very useful software modeling tool.

- With the proposal of spawn-of-EnergyPlus, this application attempts to improve the integration of energy modeling tools with control design and implementation. Spawn compatible wrappers, increased modularity, and allowing model library integration through co-simulation with external solvers also support the tackle with the critical market barrier of insufficient energy model control design integration. Open Studio integration and request portal activities can be instrumental for dealing with the other market barrier of insufficient integration with existing design tools. On the other hand, no activity is proposed about how to support energy modeling with EnergyPlus under actual building operations such as taking into account the stochastic behavior of occupants into EnergyPlus modeling/simulation routines. The project also doesn't address how to deal with improving EnergyPlus capabilities for iterative/batch simulation purposes required for population-based probabilistic numerical optimization and uncertainty-sensitivity analyses. This could be significant to attack the problem of energy modeling program's providing point answers instead of ranges and distributions without accounting for uncertainty/variance in key model inputs.
- The project effectively addresses the market barriers that are identified in the proposal slides. However, not enough details/information is given about planned empirical validation activities which could be impactful in dealing with the market barrier of insufficient characterization of modeling engine accuracy. LBNL's Flexlab is depicted in the presentation slides but no information is given about any empirical testing and validation to reduce the degree of approximation in EnergyPlus simulations.

- Energy Plus in combination with OpenStudio has now become THE building energy modeling engine, also internationally. While the launch of the new website was not without hiccups, it is a good move towards a solid presence for the tool. Expanding the use cases is a good approach. Daylighting side (Octree) will be an interesting new addition. Taking advantage of parallel computing will add capacity to more complex simulation models. Replacing IDF will be an important next step for improved usability also the move to C++ is a strong development.
- The collaboration with Autodesk and integration of EnergyPlus into REVIT will provide huge new marketing potential. This will out rule many Autodesk competitors who have used Energy Plus earlier. DOE has to be careful to not support Autodesk too much without reward.

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.

- At the 2016 EERE BTO Peer Review, DOE clearly demonstrated their commitment to continued investment in EnergyPlus as the core simulation engine supported by DOE. Of particular note would be adoption by private sector partners (Trane and Carrier, via OpenStudio) continue to invest in collaborative relationships. Finally, announcement at the Peer Review of DOE's commitment to build out the SCOUT framework, which relies heavily on EnergyPlus computation for key input data, signals a long term commitment to DOE support of EnergyPlus, which the private sector will also benefit from.

- Good progress on stated approach and activities. Does not directly add savings but indirectly enables significant amount of savings. Attributing the savings to use of E+ is a challenge and no method was presented. No specific Market Goal specified, but substantial evidence of on-going progress. Significant number of major improvements underway, maybe too many at once.

- I believe that Energy+ as a whole has and continues to significantly contributed to the program's impact goals. I see the continued support, improvement, and expansion of this tool as one of the critical functions that DOE has provided over the years. Keeping this tool in DOE's hands has ensured regular upkeep focused on ensuring quality and scientific/mathematical rigor. It appears that the team is continuing with that effective trajectory.
- I'm not sure that I totally agree with the project's estimation for the impact / savings potential (plus it only estimated this for P-Tool, which is now outdated), but I also recognize the difficulty in making accurate estimations for tools such as this.

- The project can provide strong qualitative support to ET program performance goals. The increasing number of direct downloads are indicating an increased possibility of the use of EnergyPlus program. AIA 2030 commitment reporting statistics indicate that project outcomes are also providing some quantitative support to ET program's performance goals. Since these are the projects which states the use of EnergyPlus as BEM tool during design development and/or code compliance, green building certification schemes. It should also be addressed how the new features of EnergyPlus could accelerate energy savings with respect to 2010 high-efficiency technologies stated at the point of reference for ET program activities.
- The project's plans to get feedback for the user community, translation of IDF structure to JSON for increased adaptability and extensibility, and enhancing co-simulation capabilities (to support virtual rapid prototyping of unconventional building mechanical systems) indicate a substantial evidence for meaningful contributions to ET program's interim market goals. Particularly, spawn-of-EnergyPlus 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 has considerable effects on accelerated technology development.
- Energy modeling can catch up with the fast phased technology development in HVAC industry by being compatible for coupling with external solvers with HVAC and control models coming from manufacturer supported libraries. However, planned EnergyPlus development activities are not encompassing the BEM support for the design evaluation of net zero energy buildings which rely on building integrated solar photovoltaic systems. Currently, high-current, high-power solar PV modules cannot be simulated with EnergyPlus engine due to existing algorithm restrictions.

- Energyplus on github, LaTeX, Object oriented programming, Fortran to C++, Uservoice platform, JSON input scheme instead of IDF, External solver using modelica & standard simulation software…., Spawn compatible wrapper, code compliance check are all good and valuable new features. Congratulations to the development team for making Energy Plus even more robust and usable.

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.

- As mentioned earlier, the coordination of the EnergyPlus team with the OpenStudio team (with respect to software version releases) will significantly improve abilities for software developers to integrate their offerings with OpenStudio, and this leverage the strengths of EnergyPlus. This reviewer has experienced the difficulty of integrating (2) software teams (who share some development assets but certainly not all), and understands the benefits of coordinating the efforts.
- With respect to private sector efforts, announcements that Trane has released a beta version of an energy analysis tool based on EnergyPlus represent a signal that EnergyPlus continues to approach the level of quality necessary to be adopted by 'production' centric software vendors. It appears others (including the 800-pound gorilla, AutoDesk) are also developing software directly based on the core EnergyPlus calculation engine.
- Finally, although the presenter did not stress it, it is clear that DOE long term commitments to developing the OpenStudio API/SDK imply a long term commitment to supporting EnergyPlus.

- Key stakeholders identified. They are the enablers of building energy performance that leads to energy savings. The ultimate end user (building owners) is once or twice removed from the tool user.

- Cleary, input is provided from stakeholders, specifically from users. However, the mechanisms for receiving this input are mostly ad-hoc, or more open to any and all that are so motivated but not necessarily the appropriate experts on market applications or secondary tool end uses. I suggest creating a multi-disciplinary, multi-level advisory board with a technical cohort and a market actor co-hort.

- And a different mechanism for peer review is identified in my final comment below.

- Energy+ continues to do an excellent job of coordinating with key market stakeholders.
- The program has shown a keen ability to coordinate with the key industry stakeholders who are adopting the tool and spreading it broadly (e.g., Autodesk, Sefaira/Trimble), a number of other DOE program teams, and external collaborators like ASHRAE. Slight mark down, as the team was not able to adequately describe how it could prioritize its work with such a diverse array of stakeholders (with a focus on users and the companies that are using Energy+ like Autodesk and Trimble).

- The project understands the instrumental role that BEM play in supporting other BTO program's (CBI, RBI, Codes) activities and proposes collaborations with them. Apart from governmental interactions, the collaborations are also established between web-based BEM communities and some dominant industry vendors. Collaborations could be extended to some other national labs (LBNL, PNNL) to come up with fruitful interactions than can foster the integration of stochastic modeling of occupant behaviors and batch simulation capabilities into EnergyPlus environment. Continuous EnergyPlus development should be supported with collaborations about how to educate the modeler through on-line training and support systems.

- Lots of changes going on, it would be a good development to assess who is all connected to Energy Plus, uses the tool or part of the website like the weather files for example. It will be important to upgrade the user guides. The decision process could be made more transparent how does the team prioritizes issues? How does the relationship work with Autodesk? That is absolutely unclear and the use of energy plus should be more prominently featured by Autodesk, in kind support from Autodesk, Trane and Carrier is also not made clear enough in the presentation.

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.

- If the past is any reflection of the future, one would be wise to proceed cautiously when attempting to change core functionality of the EnergyPlus core, acknowledging the risk of delivery. While the feature adding JSON as an EnergyPlus input file format, at first glance, seems like a wise decision, more careful review reveals that it is likely the JSON format will simply be translated into EnergyPlus .idd format by the EnergyPlus input processor, negating much of the benefits associated with a migration from a less structured format such as the .idd file to a more flexible format such as JSON (or xml). This reviewer sees the benefit of this input file format switch (from the perspective of software developers working with EnergyPlus current input file restrictions) but does not fully believe the core calculation engine will see any significant benefits such as speed improvements, etc.
- The additional plans to in parallel develop and integrate the 'Spawn of EnergyPlus' will also, likely, produce unanticipated integration issues that will need to be solved.
- Given the growing number of software applications that are being developed 'on top of' core EnergyPlus functionality, it seems clear to this reviewer that management of the software development process will be a critical factor to the success of the project.

- Seems to be a risk of team being overwhelmed by the scale of improvements proposed simultaneously (JSON, SPAWN, Performance testing framework, object-oriented code). Integrating all these into the operational system will be risky unless staged over time.

- The team provided an exceptional description of their progress and path forward. It was very clear how Energy+ would evolve, why, and how with the team's vision. However, I could not mark this "outstanding," as the team was not able to adequately discuss how they have been and continue to prioritize the multitude of issues that they're working on at a given point in time (e.g., user errors, bug fixes, user requests, requests from big software company partners, conversion to JSON, Spawn of E+, etc.)

- The project successfully identified a diverse set of key decision points as items of future project development. Some items are not explained as in required detail such as empirical validation activities. Possible risks are not mentioned together with relevant strategies to mitigate them. BIM-to-BEM integration is posing constant challenges for the developers on both parties, more details and possible risks could be identified about improving EnergyPlus' performance for handling large BIM models.

- While the presentation does not specify very much about the planned future work, it is clear, that EnergyPlus is an ongoing project and the development team will be responsive to market needs and new technology developments. This is an ongoing project which needs to be sufficiently flexible for changes in the field.

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

***High*: 5** reviewers

- The EnergyPlus team continues to deliver (2) major releases per year on time. These releases are used both internally by DOE and externally by a growing number of software developers, with a larger percentage of them building on top of EnergyPlus through the OpenStudio SDK.

- *None*

- Energy+ is an exceptional, world-class energy modeling and simulation engine. It is unparalleled in the industry, and while it has its bugs, it far exceeds what others are doing.

- The key deliverables of increased adaptability, usability, and IDF-to-JSON update will be positively accepted by the target market since all of these features improves interactivity of the core EnergyPlus engine (which is powerful but hard-to-reach and being understood so far). Providing a feedback mechanism (e.g., request portal) will be significant to keep track of market needs and keeping up with the most recent technology and operational trends for better market penetration.

- EnergyPlus is the leading energy modeling engine and all the current changes and developments make it more flexible and versatile.

***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

- *None*

- The team appears to be focusing on the most important areas to see project and program success. The team should work to better prioritize the issues that they are tackling, but I am sure that the team's current and upcoming focus will benefit the appropriate objectives.

- Project activities are in line with the ET program objective of increasing the use of BEM in design while reducing modeling inaccuracy. Accomplished and proposed activities have significant potentials to attract more industry vendors focusing on EnergyPlus-design tool integration that could potentially result in extended impact for the use of high-efficiencies technologies to achieve substantial gains on energy savings.

- No energy saving calculations without Energy Plus. It is the essential tool to achieve BTO's and society's many energy efficiency and energy saving goals.

***No*: 1** reviewer

- The next few years of EnergyPlus development will test the management team as to their ability to prioritize limited resources to deliver against competing needs. It is this reviewer's opinion that a careful assessment of realistic project expectations and release timelines be considered before private sector organizations begin to react to a plan for this. It could be a major setback to the trust and faith of EnergyPlus if the Spawn of EnergyPlus project is not carefully managed,

H. Additional Comments and Recommendations

1) **Project Strengths**

- As 'best in class' software for determining predictions of energy usage, EnergyPlus remains a core component in DOE's strategy for providing platforms for software vendors to build off of. This is a major leverage point for software vendors, allowing them to avoid the expense of creating and maintaining a competitive calculation core.

- E+ solves a number of limitations of DOE2.
- E+ is an essential tool in the toolkit for improving performance of buildings.
- The 2015 and 2016 work supports need on-going improvements.
- Clear indication of market uptake and market dominance through use by Autodesk, Trane, Sefira, Canada, etc.)
- New performance testing framework is great.
- Shifting to the modular structure is great.

- Energy plus is a very valuable and powerful tool for the industry. The team continues to tackle pertinent issues. The team has been met with great success in uptake from the private industry - collaboration to make Energy+ more accessible is key. Energy+ continues to become more and more useful and accurate as time goes on.

- The project proposes EnergyPlus development features that can be impactful in tackling with multiple market barriers for the ET sub-program of energy modeling.
- The project has strength in collaborating with other BTO sub-programs to provide EM support for their activities. Similar strength exists in collaborations with industry vendors playing key roles in extending the use of EnergyPlus.
- Future plans are carefully selected and have potentials to serve the objectives of ET that requires accelerated improvements to implement high-efficiency technologies to building design for substantial energy savings.
- The projects characteristic have been reactive in tracking and responding to the needs of users and vendors is another strong point.
- Enhancing the co-simulation (coupling with external solvers) capabilities of EnergyPlus for rapid virtual prototyping of new HVAC technologies and building systems.

- As stated before Energy Plus has become the leading energy modeling engine and will continue to serve this role for many years to come with continued support from the DOE. It has become an international tool.

2) **Project Weaknesses**

- A potential weakness in the EnergyPlus project is the ever-increasing complexity that will be required to manage and prioritize the project as more software developers create applications using the core EnergyPlus engine. It appears, for a period of time, there will be some 'parallel' operation of spawn of EnergyPlus and traditional EnergyPlus - having a clearly communicated migration plan to all consumers of the software will be critical to avoid unanticipated issues related to migrations.

- Another potential weakness of the EnergyPlus project is poor user documentation. While documentation of individual features and model components is very good, aside from the engineering reference documentation, there exists little documentation describing how components interact with one another and when certain sections of the code trump others, etc. For example, the operation of sizing routines in EnergyPlus are not well documented, and recent changes to the sizing routines themselves, while clarifying how they interact with other sizing routines, do not explain well how certain fields, when auto sized will be in conflict with other fields, that are not auto sized. General guidance is best described as either auto size or hard size all values, but from a practical perspective, this is not always how users want to use the software. Better documentation, including realistic example files meant to exercise and demonstrate cross system functionality such as controls, might encourage more users to adopt EnergyPlus as a reliable calculation core.

- Could use a more formal and effective market-focused mechanism to help prioritize improvement projects. Perhaps a formalized representative advisory board.
- No mention of several critical analytic needs for advanced buildings market (e.g. natural ventilation, thermal mass, night ventilation of mass, etc.)
- Users of the outcome of the tool, are distant from the tool itself (and tool development team) due to third party interface tools, and modeling specialists, and therefore can't provide direct feedback on needs.

- The project team needs to more clearly list the ways that they prioritize issues within their workflow.

- EnergyPlus development features are excluding some significant improvement potentials that can be exploited with;
    - Increasing adaptability for iterative/batch simulation for population-based parametric search methods;
    - Taking into account stochastic modeling of occupant behavior instead of using fixed-predetermined, fixed schedules;
    - Providing EnergyPlus support for the most up-to-date renewable energy technologies (such as high-current, high-power solar PVS with large number of solar cells);
    - Focusing on simulation speed (runtime) improvements through fine tuning algorithms internal working processes or finding more effective methods of data transfer between different simulation modules internal to EnergyPlus;
    - Supporting BEM education to existing or new energy modelers through on-line training-oriented support modules particularly on the planned transformative features of EnergyPlus (etc. spawn-of-EnergyPlus, wrappers for existing lighting-envelope-airflow modules).

- There are no perceived weakness apart from the relationship with industry.
- With Autodesk as the largest commercial player in Building Information modeling, it has to be very clear that Energy Plus remains independent and open to technology change and also remain usable for other software developers. One avenue would be to strengthen also the ties to Sefaira/Trimble as one competitor as well as others.

3) **Recommendations**

- No additional recommendations at this time.

- *Recommendations on different review process.*

- The team could provide a better description of their overall workflow, including a prioritization of how they are tackling their major initiatives (e.g., JSON conversion) and day-to-day work.

- *None*

- Keep support for Energy Plus going strong!

COMMERCIAL BUILDINGS INTEGRATION

Project # 22296: Significant HVAC Energy Savings enabled by Practical, Low-Cost Air Treatment Technology

A. Relevance

This project was rated **2.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Strong relevance – this technology has the potential to significantly reduce air-conditioning use in buildings where the technology is installed. Because it is a very different approach than the standard solution of dilution of indoor air pollutants, it seems to be an uphill climb to get near term significant sales or any real market penetration.

- While this technology does appear to be focused primarily on mitigating substandard IAQ, it does have the potential to reduce HVAC energy consumption. From that perspective, it does support BTO's goals of reducing building energy use by the 2030 targets and beyond.
- Concerns:
    - The sorbent material's ability to perform reliably over its useful life is unknown.
    - The process for integrating the technology into existing BAS (other than Johnson Controls systems) has not been well defined.
    - The installation and servicing network has not been well defined.
    - The need for an exhaust vent for the air flush could be an impediment in many otherwise appropriate applications.

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.

- There seems to be a strong technical team in place, and a good product with significant energy savings potential, but there was not any demonstration of understanding the real and substantial market barriers to getting beyond a very small number of pilot projects.

- 1. Degree to which the project is focused on critical market barriers.
    - The potential impacts of some market barriers appears to have been minimized.
        - Sorbent's performance over time.
        - Integration of technology into existing BAS systems.
        - Installation and servicing network.
        - Exhaust vent requirements.
- 2. Degree to which the project's design addresses the market barriers identified.
    - The project does appear to have addressed the identified market barriers.

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 first pilot installation seems to be delivering substantial savings, but there also seem to be significant installation and practical barriers to wider acceptance and use of this new technology.

- 1. Degree to which the project has supported the achievement of the stated program performance goals.

    - While slightly behind schedule, the project does have one system successfully installed and is collecting data. The program does appear to be on track to monitor system performance, analyze the energy savings, overall economics, and verify Indoor Environment Quality improvements.
- 2. Degree to which the project will significantly contribute to the achievement of its program's interim market goal.
    - Project does appear to be on track to achieve its interim market goal.

D. Project Integration and Collaborations

This project was rated:

1) **1.50** 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) **2.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The linkage with utilities and Johnson Controls is useful, but it seems that many more partners and case studies will be needed to get beyond a very small (really negligible) niche market penetration.

- 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.
    - Installation and servicing of this technology was not discussed in depth. If this technology is to be deployed widely, an installation and servicing network will be required and the relevant trades will need to be engaged and accepting of this technology.
- 2. Degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.
    - Would like to see a roadmap for the installation and servicing of this technology.

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.

- While the technical work seems appropriate, with this being a demonstration/deployment project, it seems like more work is needed on market assessment, barriers, and a realistic commercialization plan. That seemed sorely lacking in what was presented.

- Future plans call for developing lighter sorbents and modular designs as well as improved electronics and controls – all of which should contribute to increased cost-effectiveness and wider applicability.

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

***High*: 0** reviewers

- N/A

***Average*: 1** reviewer

- I think this technology has potential to be especially valuable to the healthcare and educational sectors. I don't quite see the value prop for building sectors where IAQ is not a concern. Would it pencil out to install this technology instead of another technology that saves as much or more energy at a similar payback/ROI?

***Low*: 1** reviewer

- This seems like very early demonstration of an interesting new technology, but no real plan to move to significant market penetration, which seems to be the goal of the HIT deployment program.

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

***Yes*: 1** reviewer

- The technology deployment is getting appropriate emphasis, though market development needs more attention.

***No*: 1** reviewer

- I would like to see more emphasis on the details of deployment. The project is doing quite well in the technology testing areas.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Strong technical team; innovative product.

- Project has already demonstrated initial energy savings of 29%.
- The non-energy benefits (NEBs) of improved IAQ could be a great marketing tool for utility programs, especially in healthcare and education sectors. As participation in ET programs continues to decline, utilities are exploring opportunities for using NEBs to drive program participation.

2) **Project Weaknesses**

- While the initial collaboration with Johnson Controls and others seems useful, eventually linking or partnering with a major air-conditioning/air-handling company seems critical to getting toward any significant market penetration.

- It is not clear that the impacts of requiring an exhaust duct to vent air flushed from the system in mechanical room applications has been given sufficient attention. In addition to code concerns, the cost associated with running a duct to the outside could limit the number of potential applications.

3) **Recommendations**

- The project might benefit from having a market research analyst help to identify barriers to wider market acceptance, which seems critical to move toward any significant market penetration.

- Be planning now for the installation and servicing network. If the technology is to be successfully deployed, these trades will have to be on board and active participants in the process.
- Survey various code jurisdictions across the country to be sure you don't run afoul of some jurisdictions that limit your ability to flush the pollutants to the atmosphere. Regular, clear communications for all partners is going to be crucial to staying on track.

Project # 22297: Advanced Retro-commissioning Technology: Predictive Energy Optimization (PEO) and Automated Demand Response for Commercial Building HVAC

A. Relevance

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

- The "Predictive Energy Optimization" service offering seems to hold significant promise for cutting energy use and peak demand.

- This project supports BTO's goals of reducing building energy use by the 2030 targets and beyond in a unique way. It interacts with a building's BAS and provides monitoring and control capabilities that take the building's operations staff out of the loop for day-to-day system operations/optimization.
- In this case, the critical barrier is the operations staff inability to optimize operation of the building. Building IQ overcomes this barrier by seamlessly integrating with the BAS so ongoing building energy optimization occurs in the background w/out staff participation. If Building IQ's approach of taking building staff out of the building performance equation is successful, the opportunities for improving building energy efficiency will be enhanced.

- This project advances EE savings opportunity thru commercial building operation optimization. The result is EE savings and utility bill cost reductions for the building owner/operator.

B. Approach

This project was rated:

1) **2.67** 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.

- There was not strong demonstration of understanding the barriers to wide implementation of this service/technology. The presentation seemed to be a strong sales pitch about the opportunity, but did not acknowledge the real barrier that many building owners and operators are skeptical about the level of savings, especially the persistence of the savings over an extended period of time.

- 1. Degree to which the project is focused on critical market barriers.
    - The project focuses on the critical market barriers:
        - This is an unproven concept.
        - Requires a change in how building staff operate buildings.
        - Building owners/operators are generally risk adverse.
- 2. Degree to which the project's design addresses the market barriers identified.
    - Having the project's partner, LBNL, provide sub-metered based M&V will substantially address the 'new concept' barrier. Bringing utilities on board to offer incentives will also help to mitigate the 'risk adverse' concerns.

- Building optimization is an emerging market use connected cloud based solutions for building controls. This project clearly demonstrates savings opportunities. The researchers identified some market limitations with reaching certain building types, such as commercial building controlled thru REIT ownership. The market barrier does not pose any risk to this project's success, it only limits future penetration of this technology, because it limits the pool of potential commercial space participants.
- Project progressing as planned, except there have been issues integrating GSA facilities. This is not surprising since GSA uses a centralized data aggregation and system for most of their buildings. Building information and estimation needs to be coordinated thru the central system. They are working on this issue but at the time of this presentation, there was no clear resolution to integrating GSA buildings.

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.

- The project seems to be running significantly behind schedule. There were some reasons discussed during the presentation and discussion, but the schedule seemed unrealistic, and it was not clear what level of results and impacts would be demonstrated by the end of the contract.

- 1. Degree to which the project has supported the achievement of the stated program performance goals.
  - Program has met the performance goals as identified in the timeline.
- 2. Degree to which the project will significantly contribute to the achievement of its program's interim market goal.
  - Project has 12 of 14 sites fully deployed and operational.

- There is a substantial opportunity to deploy this type of technology in the market to realize financial and energy savings.

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.

- While the GSA Green Proving Ground, and the DC DGS are useful partners, it was not really clear how much those partners have engaged with the service/technology to date, as there have been significant delays in some of the installations and scheduled system startup dates.
- Also, it was very unclear what the roles are of the other project partners Siemens and Schneider – it was stated that both are also investors in BuildingIQ, and if these partners are significant investors the rationale for DOE support is not as clear.

- 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.
  - The presenter demonstrated a good understanding of the key stakeholders necessary to move the technology into the market. I have one observation: GSA / government/ university owned buildings are not representative of the larger world of commercial building owners who do not necessarily have to report 'up' to an institution energy manager. Marketing to skeptical building owners on a one-off basis will be more difficult. Utility incentives may help with this audience.
- 2. Degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.
  - Great collaboration with LBNL and GSA staff.

- The partner Key partners are composed of industry, government and LBNL. The group is focusing this predictive thru 4 main building categories:
  - Office.
  - Government.
  - Health Care.
  - Higher Education.
- They have limited penetration in the office market due to the REIT ownership structure. For the government space, the GSA system poses challenges, which they are working to resolve. The current best two opportunities are the Health care and Higher education sectors.

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 plan seems reasonable, but given delays to date, it seems that there will need to be significant extensions to the planned schedule.
- Project plan to roll out to all GSA buildings is well conceived and should be effective.
- The plan forward is to resolve GSA building data barriers. Twelve building are selected for the test demonstration. So far 2 of 12 building have results. They will continue demonstration in the remaining 10 buildings.

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

***High*: 2** reviewers
- Excellent. Whenever we can successfully convert building performance to an automated task from a human task we have made progress.
- *None*

***Average*: 1** reviewer
- It is not really clear what the added value of DOE support for the current work is when viewing the case studies that BuildingIQ has posted on their website - it seems like critical independent validation of project savings and persistence is the critical piece needed for market advancement.

***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
- *None*
- Yes.
- *None*

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- The technology/service approach seems valid, and there appear to be strong sales capabilities.
- Getting the building staff out of the task of building energy optimization.
- Proving the concept by validation with sub-metering based M&V.
- Partnering with LBNL and Jessica Granderson's team in particular. Brings credibility and transparency to the project.

- Partnering with GSA provides a large sample of building types while also offering the consistency of working within an organization that is on board with the project's goals.

- *None*

2) **Project Weaknesses**

- There was not any real acknowledgement about the fact that many potential customers are quite skeptical about long term savings prospects, perhaps in part due to over-selling of the benefits. Some of BuildingIQ's early customers have not expanded to service to other buildings in their portfolios, despite apparent significant savings and attractive economics in the early installations.
- Also, the need for DOE support is not really clear or well demonstrated – BuildingIQ has a fairly large number of case studies posted on their website, though perhaps independent validation of case studies by DOE/LBNL, along with GSA and DC DGS will be helpful.

- Unknown hurdles when rolling out concept to the larger non-institutional commercial building world.

- So far 2 of 12 building have results. They will continue demonstration in the remaining 10 buildings. Results to date show energy and cost savings. We need to see the results across all buildings to better determine the potential for this technology.

3) **Recommendations**

- *None*

- Reach out to some national account energy managers to get them on board. They have similar reporting structures to the GSA in a corporate energy manager who makes decisions for all buildings in the portfolio. Then sample some building owners/operators who are not affiliated with a portfolio based national chain or an institution to gauge their reaction to this technology.

- *None*

Project # 22298: High Efficiency Motors for Refrigerated Open Display Cases

A. Relevance

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

- This technology is relevant and the project has already delivered a strong success story for BTO.

- This project supports BTO's goals of reducing building energy use by the 2030 targets and beyond. This project has identified a niche market where its motor can successfully provide additional energy savings at the same price point of existing ECM motors. It has also successfully tackled and overcome potential 'installation' pitfalls by designing a shroud that facilitates ease of installation and protects the fan blades.

- This motor is unique in the marketplace. It advances the BTO objective of increased energy efficiency. In the refrigerated space, the motor provides average savings of 80% over existing shaded pole motors and 30% over ECM motors.

B. Approach

This project was rated:
1) **4.00** 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 is very sound. The manufacturer was very responsive to customer and stakeholder input early in the deployment and demonstration process, and seems to have come up with a remarkably successful product that is delivering significant energy savings and reaching strong market penetration in a very short period.

- 1. Degree to which the project is focused on critical market barriers.
  - The project has successfully demonstrated that it is focused on critical market barriers.
- 2. Degree to which the project's design addresses the market barriers identified.
  - The project's design addresses the market barriers identified.

- They have designed the motor as a retrofit package, complete with a near water tight motor, fan, and housing. This makes retrofit is designed to be simple and fast. The water tight motor is not a common practice among competitor's which creates a superior package demonstrating both high quality and energy efficiency.

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) **4.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project seems to be achieving market acceptance and substantial sales levels much earlier than expected. The success of the product is a great accomplishment for the project team.
- This seems to be a strong BTO success story that should get additional attention.

- 1. Degree to which the project has supported the achievement of the stated program performance goals.
  - Project is on time and on budget.
- 2. Degree to which the project will significantly contribute to the achievement of its program's interim market goal.
  - Project is likely to make a transformative contribution to or exceed the interim market goal.

- The manufacturer and partners have done a good job of developing a new commercially ready and deployable product.
- This project is ahead of near term target installations. They anticipate at least 10 large grocery chain site demonstrations. These are currently ongoing or planned.

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.

- There did not seem to be a large group of stakeholders involved, but the technology provider (QM Power) was apparently extremely responsive to what worked best for customers, adapting their product offering to make it easier for retrofits and simple installations. The level of integration and collaboration met the needs to have a very successful project, with strong ongoing market prospects and energy savings.

- 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.
    - Presenter demonstrated an excellent understanding of the key stakeholders necessary to move this technology to market.
- 2. Degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.
    - Excellent collaboration with supermarkets. Superior design of technology with shroud to protect the fan blades and the same form factor as existing motors removes nearly all the risk associated with getting installers on board.

- They have obtained UL certification.
- They have clearly demonstrated energy savings, thru field comparison trials.
- They have demonstrations lined up with 10 major grocery chains.

E. Proposed Future Work

This project was rated **3.67** 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.

- The proposed future work seems very reasonable, though the market reactions to the project so far somewhat call into question the need for any further DOE support for this technology. It is probably too late to take away the remaining funding, but the success of the technology introduction seems like further government support is not at all necessary.

- This project is well positioned to avoid nearly all potential risks that could impede full deployment of this technology.

- Continue installation demonstration projects
- Study results clearly show energy savings potential. Future work will continue to build upon and substantiate performance and energy savings.

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

***High*: 3** reviewers

- Strong sales levels and market penetration extremely quickly for a new product.

- This is an excellent example of the design and deployment a successful energy efficiency technology in an energy intensive application. This project has all the earmarks of being able to bring about market transformation in the fractional refrigeration fan motor sector.

- *None*

***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
- *None*

- Yes.

- *None*

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- QM Power has demonstrated significant savings with the new technology, and very quickly developed strong sales channels with major chains and other supply chain participants - a definite BTO success story.

- Excellent design of electronics to capture additional savings from ECM motors.
- Excellent forethought in adding the shroud to minimize damage to the fan blades and reduce installation time.
- Excellent go to market strategy
- Installation network is already in place because the motor was designed with the same form factor as the existing motors and incorporates a shroud that reduces overall installation time.

- They have clearly demonstrated Energy Savings and created a product that is retrofit ready. Retrofit involves removing old motor and fan assembly and replacing with new motor and fan assembly.
- There is a large market savings potential, with a low barrier to implementation. This is a good project for BTO to support from product development thru market commercialization and deployment.

2) **Project Weaknesses**

- None noted.

- None that are apparent to me.

- No serious weaknesses identified.

3) **Recommendations**

- *None*

- Stay on track and anticipate manufacturing and ramp-up difficulties.
- *None*

Project # 22299: Commercial Advanced Lighting Control (ALC) Demonstration and Deployment

A. Relevance

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

- Strong energy savings potential, and working to commercialize technologies for which BTO has supported RD&D for many years.

- This project advances the deployment of advanced lighting controls, a complex and confusing efficiency technology that has seen minimal market uptake.

- Solid State Lighting (SSL) is maturing into a mainstream product in many market channels. However, lighting controls are still in development and have relatively low market adoption. BTO has correctly identified a need in this market. There is potential for substantial EE savings in the SSL controls arena.

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.

- Their overall project approach seems very sound and well thought out. There is a comprehensive package of six major activities, though it was not clear exactly how the DOE funding was critical to the overall project given that others (utility sponsors) seem to be funding some of the activities without any DOE support.
- The barriers to advanced lighting controls are significant and should not be underestimated – there have been available technologies for some time, with regularly improving economics, but as light source efficiencies improve and lighting power densities are significantly reduced, there is less savings left to be captured from advanced controls. Sorting out appropriate levels of control that are cost effective, and easily understood by occupants and building operators, will remain a challenge.

- The approach is very sound. The manufacturer was very responsive to customer and stakeholder input early in the deployment and demonstration process, and seems to have come up with a remarkably successful product that is delivering significant energy savings and reaching strong market penetration in a very short period.

- 2. Degree to which the project's design addresses the market barriers identified.
    - While the project's focus on training installers will contribute to increased cost-effectiveness, I'm not sure how they are addressing the high cost of equipment.

- Currently, most utility SSL lighting controls projects are performed thru custom programs. This is a time intensive process and to date results in low penetration. The goal of this project is to move from a custom approach to a larger volume prescriptive 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) **2.67** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project appears to be running a bit behind – the only accomplishments to date described were meetings and some curriculum development. The demo sites seemed to be running behind.
- There was a "systems based energy efficiency program offering" that was described as being completed in December 2015, though no information was available on the project website. With the significant co-funding from other partners, one weakness of this project seemed to be that most of the outputs are only available to the project partners, not the broader public and marketplace – it seems that all material funded through DOE should be more publicly available.

- 1. Degree to which the project has supported the achievement of the stated program performance goals.
  - The project is making good progress towards its goals.
- 2. Degree to which the project will significantly contribute to the achievement of its program's interim market goal.
  - The following goals have been met:
    - Stakeholder engagement.
    - Training programs.
    - Two of five demonstration projects.
    - Replicable EE program offering developed.

- A lack of equipment standardization creates a complex market which leads to high design costs and low adoption. The researchers have correctly identified the market roadblocks and have formulated a good approach to begin moving SSL lighting controls into mainstream utility program offerings.
- This work is needed. No one can expect that all the SSL lighting issues will be solved with this project. It is a rapidly evolving and changing market place. This project is taking some much needed steps in the right direction.

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.

- There seem to be a large number of utility partners involved, which can be a strong motivation for technology adoption through the utility incentive programs.
- The project has a very broad and impressive group of collaborators, based on the NEEP/DLC success with other technology initiatives in recent years. The NEEP/DLC relationship with manufacturers through the LED certification initiatives is a powerful tool – it remains to be seen how successful the LED experience can translate to advanced controls deployment, which requires more of a systems vs. individual product approach.

- *None*

- They are focused on four key areas:
  - Developing new program offerings.
  - Training.
  - Industry standards.
  - Control savings standards.
- Each of these tasks are needed to further SSL control market adoption and advance associated EE utility programs.

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 proposed work seems reasonable, though there should be more requirement toward having project materials publicly available for stakeholders who are not directly involved as project partners.

- Demonstration sites are underway. It will be beneficial if the last five sites are implemented in time to gather data and analyze the results before the project end date in 2017.
- Pilot training programs and EE programs by end of 2016 should provide time for analysis of results.

- As stated, this project helps define a course for utility programs to advance SSL controls adoption and EE savings.

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

***High*: 3** reviewers
- Well thought out work plan with significant engagement by a large number of important stakeholders.

- If the project is successful, it has the potential to jumpstart the deployment of advanced lighting controls.

- Utilities EE programs are the core recipient of and driver for future adoption. The deliverables are in line with what utility programs need to advance SSL lighting controls.

***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
- *None*

- Yes, the project has engaged all the appropriate stakeholders and by developing a utility EE program template, has reduced the time it will take to get these technologies into programs.

- *None*

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- This project seemed to have broader partnerships and collaborations than other HIT projects – likely because NEEP/DLC is already working with many of the key partners and utility sponsors on other activities, principally the LED certification initiative.

- Project is taking a holistic approach by engaging so many stakeholders in the process. It has met the majority of its interim goals.

- See earlier comments.

2) **Project Weaknesses**

- As noted earlier, there are challenges to advanced lighting controls as lighting power densities are dropping, and there is less savings available from controls.
- There is a real need to focus on solutions that are incredibly simple and user friendly. Some earlier integrated advanced controls systems that came with a "set it and forget it" initial settings were quickly disabled by occupants after minor dissatisfaction with some of the control aspects.

- The low adoption rate of advanced lighting controls in utility incentive programs is also due in part to high equipment costs and it is not clear if the utility programs will be able to cost justify advanced lighting controls at a rate that will be attractive to building owners.

- This market is rapidly evolving and changing. This helps advance SSL Controls adoption, but the calculator and market approach may change over time and it would be advisable to manage this as a living project, with periodic review and calibration to changing market conditions.

3) **Recommendations**

- *None*

- *None*

- *None*

Project # 222100: Demonstration of micro-CHP in Light Commercial Hot Water Applications

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 BTO goals, though technology adoption seems somewhat of a long shot.

- Micro CHP is definitely a technology that should be developed and implemented to assist in reducing building energy use by the 2030 targets and beyond. It will become especially important to utilities as the concept of the 'Locational Value' of EE and DER is developed. As long as the application has a sufficiently robust thermal load, there is no reason not to deploy this technology widely.
    - Pros:
        - The plug and play configuration is a must for ease of installation and market uptake.
        - Having a well-respected national manufacturer of WHs and boilers as a vendor will also encourage acceptance among the Trade Ally network. Getting the trades, who will be installing these systems, to learn about, trust, and champion this technology is a must.
    - Cons:
        - Having a well-respected national manufacturer of WHs and boilers as a vendor can also be a detriment because this technology, initially, represents a very small fraction of its production and hence profit. They do not have the "succeed or die" incentive of a start-up and may shelve development if too many development problems arise or overall focus changes w/in the company.

B. Approach

This project was rated:

1) **3.00** 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.

- The approach - bringing in a major U.S. manufacturer of water heating equipment to develop micro CHP systems - is sound, though in the presentation there was not any clear evidence that this approach will lead to substantial market development of the new system. The AO Smith representative was very clear that there is a reasonable likelihood that they will not pursue this market.
- There was description of development of a simple, turnkey "plug and play" system solution, but the progress to date did not confirm at all that this is possible. In reality, having a CHP system requires additional trades and a great deal of system integration that goes beyond a water heater system. CHP requires more electrical wiring, as well as significant electrical interconnection switchgear that is not at all standard in most U.S. buildings. Electric utilities in many regions are opposed to customer sited generation, and there was not a clear description of how the approach in this project will overcome these significant barriers.
- The micro CHP market has been described as well advanced in Japan for quite some time, but has never really gotten any market traction in the U.S. It is not clear that this project will change that situation.

- 1. Degree to which the project is focused on critical market barriers.
    - Overall the project has addressed the major critical barriers. I have two concerns:
        - A. This technology is the marriage of two very complex technologies, a gas-fired engine and an electric generator, each manufactured by third parties. To get these two disparate units to work together as one turnkey unit is not a trivial undertaking. Significant run-time testing should be undertaken to identify any stealth effects of incompatibility that might develop over time and cause warranty issues down the road.
        - B. The difficulties involved in water heater/boiler mfg., building out a skilled CHP genset servicing network may impede the deployment of this technology.

- 2. Degree to which the project's design addresses the market barriers identified.
    - It appears that meeting CA's emissions regulations could be a major impediment. The presenter mentioned that while third party technology is available to improve engine emissions should the engine fail to meet requirements, the technology becomes cost prohibitive. Acquisition of third party technology appears to be the only solution, as A.O. Smith is not an engine manufacturer.
    - Given that CA regulations are typically adopted in other parts of the country, failure to meet the requirements will likely prevent adoption of this microCHP technology on a national level. I would have preferred to see the emissions question answered before the DOE funding was committed because non-compliance could prevent adoption on a national level.

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.

- Realistically, there has not been significant progress or impact since the project began back in 2014. There have been a few demonstration/pilot installation sites identified, though it appeared that the simple "plug and play" approach really will not be viable in any of those pilots.
- The most significant accomplishment seems to be having obtained the EPA emission certification, though it is not clear whether that will make a meaningful difference in overcoming many of the other barriers.

- 1. Degree to which the project ***has*** supported the achievement of the stated ***program performance*** goals.
    - Program has met the performance goals
- 2. Degree to which the project ***will*** significantly contribute to the achievement of its ***program's*** interim market goal.
    - The project appears to be well positioned to achieve the program's interim market goals. They have reached the heavy lifting part of the project – installation. This is the stage where the true customer value prop will emerge. Can installation costs be contained w/in cost-effectiveness limits? Can the various unanticipated hurdles be mitigated? A lot of beneficial learning will result from the next phase of the 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) **2.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- There seems to be reasonable integration with the two other manufacturers that are providing equipment which may be adapted for sale by AO Smith, but not a lot of work with other critical partners, primarily gas utilities who could be the greatest advocates and essentially a sales force for the new technology.
- It is not clear how previous relevant work by the Natural Gas industry is being used for this project.

- 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.
    - The presenter demonstrated a deep understanding of the key stakeholders
- 2. Degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.
    - I encourage the project staff to engage the specifying engineering and mechanical/electrical trades early on in this next phase. Poorly designed and performing systems and breakdowns tarnished the reputation and signaled the death knell of the original roll out of CHP systems in past decades. Engaging these stakeholders early, gaining their trust, support, and advocacy, will be a necessary component of a successful roll out of a micro CHP deployment.

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.

- Seems reasonable, but no clear path toward any new product or market adoption.

- Overall good job on future planning and mitigating risks. My main concerned, noted earlier, is the potential for failing the CA emissions requirements.

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

***High*: 1** reviewer
- I rate the value of a cost-effective micro CHP unit very high. Especially in the targeted plug-and-play configuration. This technology could become a major player for utilities as they continue to look for ways to effectively defer capacity building and solve the problem of commercial growth on constrained feeders.

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

***Low*: 1** reviewer
- *None*

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

***Yes*:** 1 reviewer
- Yes, for the most part. I continue to emphasize that a strong installation and servicing network with well-trained staff is essential for the uptake of this technology. It is complex and the trades are often reluctant to step out of the 'known' and into the unknown because they are risk-adverse. As water heater manufacturers well know - in breakdown applications, high efficiency water heaters only get installed if they are stocked on the plumber's truck when he gets to the site.

***No*:** 1 reviewer
- As noted in earlier comments, it is really unclear whether this will lead to any new market for micro CHP - the odds for success seem quite low.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The technology has significant promise for energy savings, but there are very significant barriers to any real adoption of this technology.

- Fielded by a nationally known and well-respected manufacture of gas-fired water heating equipment. This gives the project credibility from the start.
- Project has been well designed and well executed to date.
- Project offers significant opportunities for utility DER programs to reduce additional capacity requirements, especially with the development and quantification of EE and DER's localized value at the feeder level.

2) **Project Weaknesses**

- There was not much information provided that gave any confidence that the significant market barriers that have prevented any real adoption of this technology in U.S. markets will be overcome through this project.
- It seems as likely that this project is an interesting funding of a new product exploration for an already successful U.S. water heater manufacturer - not at all clear that this is a good use of DOE funds.

- Can the engine pass CA's emissions requirements?
- The morass of state level CHP regulatory requirements.

3) **Recommendations**

- *None*

- *None*

Project # 222101: Financial Management for Retail Energy Efficiency

A. Relevance

This project was rated **2.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Modest goals, routinely carried out. These are well-established ideas.
- While it does support BTO's objective or market engagement, there is not a clear metric toward BTO's energy savings targets, only a vague goal of "Energy savings" but specific percentage or savings not specified.
- Yes, relevant to BTO long term goals. Retail space represents a huge amount of commercial floor space that BTO is aiming to improve. RILA can bring best practices to very large scale and prove that retrofit solutions can be attractive to key financial decision makers (CFOs).
- The efforts of RILA does conform to the goals set out by BTO to implement commercial building integration. Specifically, they are helping to meet the Level 1 goals of proving to market leaders that retrofit solutions can reduce EUI by 30% in existing buildings, and accelerating ability of market leaders to reach EUI targets more cost effectively by developing solutions to key market barriers. RILA has identified a few key barriers, including obtaining financing to implement energy-saving measures, getting buy-in at "C-suite" level of CEO/CFO, and having building managers communicate benefits in language that CEO/CFO can understand (monetary savings, ROI, NPV, etc.) However, it does not meet the goals of proving and demonstrating that 15 high impact technologies can save at least 10% savings because there is no step in RILA's program for data collection, M&V, etc.

B. Approach

This project was rated:
1) **2.75** 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.

- There are a large number of retailers who have made sustainability and energy use reduction central to their operations. The team could work with these sustainability officers and use their tools and strategies.
- While key barriers were identified, and having a connection to the leading major retailers is critical, there is minimal definition of a strategy to influence the majority of retailers outside of the membership of RILA. There are limited diffusion activities. Lack of clarity about O&M versus retrofit/repair/replace approaches in the market. O&M doesn't need access to capital and can achieve up to 30% savings alone. While Market Leader examples (models) are a good place to start, there could be a refining and narrowing to a set of best practices to promulgate to others. At least it was not clear that was part of the plan from the presentation. It was only mentioned during the Q&A that there were tiered sets of solutions form least to most involved.
- Approaches like Strategic Energy Management (SEM) would be perfect for this audience. Creating a framework within which to implement Energy Management over the long-term.
- There was no clear causality from case studies and education to building owner commitment or real investment in EE.
- There is no interim market transfer goal to a broader group of RILA members. For example, the goal of 100 buildings could conceivably be accomplished just from one major retailer that owned their own buildings but that would not help the broader market. Instead there should be a goal for number of companies implementing EM work.
- Finally, data collection should be built into requirements of participation, rather than selectively picking a few projects to follow in detail.

- Project is focused on developing resources to address one of the key "sticking points" to adoption of EE retrofits in commercial sector because of lack of access to internal capital....making the financial case to commercial building owners/leases is crucial to unlocking investments.
- Their approach of developing case studies and information sharing/trainings is a proven approach to spreading the word within an industry. Experiences from their peers is often well received.
- RILA brings their relationships with most major retailers to the table to provide best practices.

- RILA's effort has identified key market barriers to scaling commercial building integration of energy efficiency technologies today. First and foremost is still financing to pay for improvements, and second is the ability for building operators/managers to communicate and create the business case to CEO/CFO to implement a project. But, they did not identify another key barrier in the case of the retail industry: lessee and landlord relationship. Most retail facilities are not owner-occupied, but leased out to the company or business. This in itself is another layer of complexity for the retail sub sector of the commercial real estate market that also needs to be overcome and this program does not address this key issue. But, they still did not address how to overcome some key barriers, like the funding of the projects. RILA is working under the assumption that their implementation models will work. What if they don't work? What if a building owner still is not convinced enough that the business case makes sense to implement energy-saving measures in their facility? Some building owners, irrespective of a sound business case, may still not be inclined to pay for projects that will be kept on their balance sheet for years. Also, by keeping this on balance sheet, it might hamper the ability for building owners to implement deeper, comprehensive energy efficiency projects all at one time, potentially leaving savings "on the table". Other financing models, like PACE which can be "off-balance sheet" in its approach, can be an alternative for building owners who do not want to self-fund these projects in localities that have established such programs. It is also unclear how they are developing their channel partners. What is the methodology for selecting one channel partner over another? Why is one a better relationship over another that can guarantee better outcomes? At the same time, there is a significant gap in their approach: getting building owners to make energy-saving improvements. How is this effort getting to the point to make energy-saving improvements? There is no indication that support will be given to put building owners in contact with energy auditors, building performance contractor community, etc. This seems to be a significant gap in their approach and it is unclear how this approach without the step of getting them to energy efficiency deployment will meet future goals down the line. EDF Climate Corps is a good first step to giving them technical knowledge on what opportunities to look for, but it does not end there. There still needs to be another step made to get the projects implemented.

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) **2.25** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Not very bold thinking.

- Q1. Very preliminary. No significant direct program accomplishments presented. Too soon.
- Q2. No interim goals stated.

- Good to see a couple implementation models have been developed. 25 companies committed to participate is another positive sign.

- Same comments as above.

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.

- See previous comments. Also, what about USGBC?

- Q1. There seems to be a missing link or lack of differentiation between owner-occupied retail spaces vs leased spaces. There are significant differences in financing needs, willingness to do work, split incentives, etc.

- This seems to be a strength of the project and RILA. They bring together the largest retailers to discuss industry leading practices, in this case around energy efficiency/management.
    - Does DOE have existing case studies that RILA could leverage?

- Key stakeholders, including landlords of retail facilities, contractor/auditor community, government/utilities for aligning incentives to outcomes, were all omitted from their analysis. A good exercise that should be undertaken between RILA and DOE is stakeholder analysis. This will allow RILA and DOE to identify who else might be important to this project and should be participating in the successful implementation of these models, based upon their levels of interest and power on a two-by-two matrix. Other industry partners, like EDF Climate Corps, can help with providing some technical support to identify potential opportunities.

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.

- *None*

- The project has potential to be influential in this market if the previous comments on approach, goals, etc. are considered.

- Clear 3 step process presented.

- There was little to no indication provided on what the future work would look like to build upon the successes of the BTO-funded program. As stated earlier, there is a significant gap between the outreach, education, and implementation model deployment to actual deployment of energy-saving measures installed in buildings. Unless this gap is accounted for in the approach and program implementation, the interim and long-term goals of the commercial integration program will fail to be met. In addition, there is no account for how alternative financing opportunities will be identified and deployed, even if a building owner is agreeable to the business case presented, but still does not want to fund the projects on-balance sheet.

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

***High*: 0** reviewers

- N/A

***Average*: 4** reviewers

- What are the goals of the RILA? They need to have their own education program.

- I think the value is very high, but I'm concerned about their ultimate adoption

- See comment above.

- The main deliverables of the finance workshops, two implementation models have been important to overcoming some of the key barriers identified. This has provided needed value within the structure of the project. However, there still need to be other deliverables created to overcome the major barriers also identified during 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*: 3** reviewers
- *None*

- *None*

- No further comments necessary.

***No*: 1** reviewers
- Consider working with business schools to get to future CFOs and mall developers.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Well thought out.

- Great access to leading retailers and a large segment of the market.
- Good idea to allow a number of models to be selected based on varying situations of the different companies.
- Excellent team.
- Access to CFO's is a keep aspect. But high risk in getting them to cooperate.

- "Insider" industry relationships with most major retailers.
- Leveraging best practices of industry leaders.
- Strong partners/subs.

- The project has identified several key barriers to commercial building integration of energy-saving technologies. They are taking a proactive stance to develop implementation model tools to help building operators/managers to convey a business case with language/wording that would resonate with CEO/CFO officials. Good channel partners have already been identified and relationships built to help begin the project deployment over the rest of the grant performance period.

2) **Project Weaknesses**

- No real innovation. Could be a part of any ongoing DOE education program.

- Lack of specific savings goal, even an estimate of magnitude.
- Lack of a goal on number of companies that are motivated to take action.
- Misses differences and potential impacts of low cost O&M strategies.

- Huge assumption that providing information on work done by peers will cause others to act. If this is tied to improved financial returns or competitive advantage, then maybe.

- I have concerns about ultimate adoption of implementation models. I didn't hear about any commitments from the retailers that they would in fact put the implementation models into practice.

- Some key stakeholders and barriers were not identified or addressed in this project. This includes landlords of buildings and being able to make the case to them to reduce energy consumption within buildings. The gap in the approach of getting building owners to commit to doing actual energy-saving projects has not been addressed currently, or in any future next steps beyond the project. The main impediment of financing projects has also not been addressed sufficiently in this project. Partnerships and connections need to be developed to establish these channels to overcome this priority barrier to deploying energy efficiency projects.

3) **Recommendations**

- The retail mall model has proven to be a huge energy and land waster. What are incentives for developers to change that model? This project just aims to improve the anchor stores.

- Consider Strategic Energy Management as a comprehensive framework for the companies to use for goal setting, and implementing measures over time.
- While lack of capital was identified as a major barrier, it is not clear that a Financing Guide and a Financial Calculator alone are sufficient. Hopefully there is also a simplified or relatively easy moderately accurate energy solutions assessment tool too.

- Include a link to best practices around accessing energy efficiency program promotions/incentives and/or other external capital available

- *None*

Project # 222102: Putting Data to Work

A. Relevance

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

- Appears to be moving towards a clearinghouse of information for different cities to use in the future. Heavy data use and interpretation should allow for solid metrics to be published and used by others.

- The project appears that it does and will support BTO's goals.
- The Institute for Market Transformation (IMT)'s work on disclosure aims to improve energy efficiency program design and expand the market for energy efficiency. If the program DOES achieve what it claims to, I see it as likely that they will expand EE programs in the two pilot cities, and think that it's feasible to achieve the goal of a 10% improvement in city-wide efficiency. It will be difficult to attribute city-wide efficiency to this program (versus other programs), so the tracking of this goal will have to be careful. The key to realizing this goal is working effectively with the right partners, which has yet to be proven.
- I felt it unfair to incorporate the lack of progress (because the project is in its early stages) into my score for this category, but I will comment that its early stages leave me (1) wondering whether or not it will attain the levels of efficiency sought AND (2) skeptical of the effectiveness of a toolkit to other cities (without the proper engagement of partners in each of those cities). While these are not realized concerns, they are concerns.

- Standardizing collection and format of building energy use data is a valuable outcome of this project and very relevant to BTO's goals of reducing energy intensity in commercial buildings. Disclosure of this data will lead to more investment in energy efficiency.

- Very relevant and needed.

- Benchmarking and providing access to this data is a good first step to considering energy efficient improvements to building stock. In addition, it ensures that time and resources are being devoted to the right subsectors of the real estate market to effectively reduce EUI in buildings across New York City. This will ensure that energy efficiency programs that the city will deploy, along with utility and state energy office partner programs, will run their programs in a cost-effective manner while optimizing energy consumption reductions in the existing building stock in the commercial and multifamily spheres.

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.

- The approach seems to be moving along very well in both theory and practice. Partnering with two major cities validates the program.

- The presentation did not adequately identify the key issues in enough detail to fully understand how this program will differ from other efforts from nonprofits and NGOs to assist cities with disclosure programs. The "key issue" (identified as Improving energy efficiency program design and delivery using building performance data to overcome market barriers to energy efficiency in the multifamily and commercial building sectors) does say what the initiative is going to do, but doesn't address what the market barriers are to energy efficiency in the multifamily and commercial buildings sectors. Overall, I would have hoped for the team to be MORE SPECIFIC about what the market barriers are, and directly discuss how they would be addressed (rather than saying that they would overcome market barriers). The presentation did not convince me that the team has a fully novel approach to making disclosure data useful and actionable, though I do see potential for this team to implement a novel approach.

- In theory, the two-pronged approach is effective and useful. However, my concerns about the effectiveness of the toolkit remains. It will be difficult to assure that the toolkit will be effectively disseminated to the proper organizations in other pilot cities. I would consider rating the second part of this question as "fair" if the project were not in such a nascent stage. Next year, I would look for progress in improving the approach for the toolkit (with a focus on implementation). The pilot phase appears to be well thought out, but again, will be measured by future performance.

- Key Barrier that they are addressing- Comm. buildings not adopting EE projects, engaging EE programs
- I see disclosure generally helping to motivate comm. building owners to adopt EE projects.
- I wonder, however, why this kind of data is not already easily accessible by programs (these buildings are their customers I assume). Not sure how this projects make the data any more actionable than the data programs already have

- It's early on in the project, but it needs more clarification on the specific needs and barriers for each target market. May need to focus on 1 market such as city officials only.

- While it is a good start to conduct data collection to determine target subsectors in the real estate market for energy efficiency program deployment, it is unclear though how the audits will be completed to then lead to energy efficiency retrofit completions. The project team acknowledges that questions remain to be answered on how to move from one point to the next. For instance, it was acknowledged that there are no targeted incentives to helping to pay for energy audits in buildings to conduct the benchmarking and data collection exercise. It is unclear what economic incentives there are to doing benchmarking and data collection without an extrinsic incentive to a building owner to conduct the audit. If anything, the current approach creates an economic disincentive to learning more about their building's energy use. It is important that this project work with utility or state partners to develop an incentive to paying for an energy audit. Most commercial building owners find audit costs as a disincentive to exploring doing energy saving opportunities, so this potential barrier must be factored into the approach.

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) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Since the data is shared with utility providers, it helps support future progress by showing the utility provider where incentives should be placed for largest impact.

- The project has not been active for very long, but seems to have forged the proper partnerships and support of partner programs to achieve success in DC and NYC. There are very few other signs of progress at this point, but given the comment above (about judging based on the amount of time that the initiative has been open), I would say that this initiative is adequately making progress given the early stages that it is in.
- In terms of achieving the program's interim goal, I believe that, if carried out effectively, the project will well track with the interim market goal related to EUI reduction in existing buildings. Again, I am a bit skeptical of the effectiveness that the toolkit will have bringing significant efficiency improvements to existing buildings *across the country*, but I DO think that the approach will be effective in DC and NYC, specifically. I would be "on watch" with regards to the toolkit, to make sure that it is put into the hands of the right partners in other cities to drive impact.

- Nice to see both DC/NY have joined the SEED collaborative, committed to use SEED/BEDES
- Not much other progress made.

- Potentially high impact if NYC and DC pilots are easy to replicate.

- The project has begun to see some accomplishments in developing the data collection and its integration with using DOE platforms. In addition, the project, should it meet its fullest potential, can outline a path forward to completing energy efficiency improvements in targeted subsector markets that stand the best chance to reduce EUI by the most amount.

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.

- 2 major cities, government offices and utility providers are all engaged in this process.

- I believe that the project is currently connecting to exactly the right people in the cities where the pilot programs are occurring. The presenter demonstrated a strong understanding of the city structures and the key non-municipal players that should be included as well. I believe that in terms of city collaboration for the pilot programs, the project is spot on.
- The first category did not receive an "outstanding" score because there was little-to-no discussion of key stakeholders to make the toolkit effective.
- The project staff did not demonstrate a clear understanding of how to coordinate with industry and other stakeholders - a question was asked about collaboration with the private sector, and while there was intent and explanation of collaboration with the private sector, there was not a clear-cut set of partners or roles for them to play in the project. This is a major weakness in the project, as deeper collaboration with the private sector, the implementers of energy efficiency projects, could lead to greater value for the pilot cities.

- Important players involved in the different regions.
- Have existing partnerships w 10 cities.
- Distinctive characteristic.....cross org collaboration (utilities, LBNL, Energy data accelerator, DC/NY, urban sustainability network, etc.).

- Excellent to start with NYC and DC, who already have experience with benchmarking implementation and have data and existing systems.
- Would like to see more info on the NYC and DC pilot designs. How they differ, what amount of resources are needed to implement.

- *None*

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.

- Clear path for the initial 3 year project and future work will be based off the success of the pilot. Most major cities across country should be able to use most, if not all information to move forward within their own sphere of influence.

- The team seems poised to carry out the city pilot programs effectively and to develop the toolkit. I believe that there is still risk that the city pilots could fall short of helping to achieve interim program goals (this wasn't a clear and apparent risk during the presentation, but one in my mind, since the project is still in early stages) and there is a risk (mentioned earlier) that the toolkit isn't distributed properly.

- *None*

- More detail needed on toolkit.

- It is unclear how the work from this project will translate into energy saving retrofits. It has not been outlined in this project how the data will be used to motivate building owners to make energy efficiency improvements to their buildings. If New York City or Washington, DC were to consider creating other incentive programs, a la PACE or other financing mechanisms to address critical market barriers, it is unlikely that building owners will make energy-saving improvements by the mere availability of data alone. Information is key and critical, but building owners need to be incentivized, as they may not have the capital to make key investments in reducing the energy consumption, even when knowing their energy use is high.

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

***High*: 2** reviewers
- When taking the large amount of data and being able to present it in quantifiable form, it allows others to see the exact cause and effect relationship.

- Benchmarking buildings help to provide data publicly about energy usage and where the best action can be taken to reduce energy consumption. This will be very helpful in reducing the EUI in buildings, which should help to meet the mid- and long-term goals of BTO.

***Average*: 3** reviewers
- The project did not discuss deliverables produced in sufficient detail to answer this question. It is a positive step that the team is participating in the ACEEE summer study, but it does not appear that there have been too many other key deliverables developed by this team of note (given the early stage of this project). The deliverable produced for this review was average - it did not fall short of providing a description of the project, but did not go into any level of depth.

- *None*

- Ambitious project to produce toolkits w/ significant detail for private stakeholders (real estate, contractors, financers?) and EE program administrators and city officials. Consider starting with city officials. Focus deliverables by target markets. City officials need much different resources and 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*:** 5 reviewers
- Yes, by establishing the SEED tools and BEDES language constants, it allows for the objectives to be precise and attainable.

- Yes, the key deployment activities received sufficient emphasis during the presentation, and the team's "two-pronged approach" was made very clear by the presentation.

- *None*

- More details needed on analysis. Deployment is clearer.

- No further comments necessary.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- 2 major cities fully engaged - NYC and DC.
- Both cities are increasing inventory associated with the project.
- Successful partnerships with government offices, utility providers and end users.

- The project is addressing a key issue that will be a focus for many cities over the next several years. This team is already demonstrating an ability to work with the proper stakeholders in each of the pilot cities. If successful, the team's toolkit will be a guidebook for the many cities that develop disclosure programs and resulting energy efficiency programs in the following years.

- Strong group of project partners...the right players are at the table.
- 2 committed cities.
- Supporting the use of SEED within cities disclosure ordinances.

- Potential impact is great. Good to start with city leaders.

- It is important to collect data on building energy use and see where it stands against buildings of the same subsector. It will show where work needs to be done to help reduce energy consumption in those subsectors that use energy more than other subsectors. The ability to use database tools to make this information is public is key to making building owners aware of their own energy use against their counterparts, and a good first step to taking necessary action to reduce energy consumption in existing building stocks in New York City and Washington, DC.

2) **Project Weaknesses**

- No real weaknesses presented. Seems to have been well thought out and key personnel are actively engaged in the process.

- The toolkit still seems unclear and lacks a firm implementation plan (so that it doesn't become a document that just sits on a web page unused for years to come). The team could demonstrate greater partnership with the private sector to see that energy efficiency programs that result from data disclosure are effective and benefit from the competition offered by the private sector. The team could more clearly demonstrate a path toward supporting the BTO's program goals (rather than simply stating that it will improve efficiency by 10% without further explanation).

- I would assume EE program administrators already have the building energy data, assuming these buildings are their customers. Unclear how this project will make the data more actionable for programs.

- Ambitious project to produce toolkits w/ significant detail for private stakeholders (real estate, contractors, financers?) and EE program administrators and city officials. Consider starting with city officials.

- As has been mentioned throughout, the project does not account for the economic disincentives that currently stand in the project's approach, both in collecting the data from performing energy audits, and completing the energy efficiency improvements to those buildings. Unless incentives are wrapped into the project and the future work that would be needed to complete the energy-saving projects, building owners will not likely take action on their own to reduce their own energy consumption. This would require the project leaders to work with their collaborators and stakeholders to reduce the costs to building owners to find out more about the condition of their own buildings.

3) **Recommendations**

- Ability to share what they have done to date to help other cities which are in the process of starting their own program.

- I believe that all of my comments above state my recommendations well. The key recommendations being a focus on substantiating progress toward goals with clearer actions / steps, demonstrating a plan to utilize the private sector, and more clearly developing an implementation plan for the toolkit.

- Clarify what the program toolkit will provide that goes above and beyond how EE programs already collect and screen energy data to inform program opportunities.

- Include a link to best practices around accessing energy efficiency program promotions/incentives and/or other external capital available.

- Focus deliverables by target markets. City officials need much different resources and solutions.
- Provide detail on toolkit.

- *None*

Project # 222105: SoCal Edge

A. Relevance

This project was rated **2.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Project is useful to spread use of GSA and DOE programs, but not clear what innovation is.
- Strong relevance to BTO goals – a creative combination of organizations, skills and connections to help catalyze adoption of new technologies, working with major real estate organizations participating in the LA Better Buildings Challenge.
- I am just not sure that the project's premise is correct. Just because a technology has saved energy in a Green Proving Grounds application it doesn't necessarily mean that it will perform in the same way in a different building application. This premise seems like a very broad, and unproven, assumption.
- Accelerating timeline of emerging technology adoption is very aligned with BTO interests/goals.

B. Approach

This project was rated:
1) **2.50** 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.

- Modest project.
- The team seems to have done a nice job identifying an "on-ramp" market adoption strategy for high potential new efficiency technologies, and their process of completing pilots and then working with building owner/manager partners to expand adoption of the technologies through their portfolios is a very sound approach.
- A critical barrier that is missing from consideration is the installation and servicing network. ETs are often complex and without buy-in from trade allies, including engagement and training, successful installation and commissioning of the technology may be difficult to achieve - and the projected energy savings will be reduced.
- Accelerate market adoption of best in class equipment/building practices by creating an on ramping process into programs.
- Development of technical specifications is crucial to EE program support. Issues being addressed- lack of objective standards (equipment/buildings).
- ID best in class technologies. Being accomplished through RFI (GSA Green proving ground, DOE performance metrics).

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) **3.00** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- *None*
- This project has only been running less than a year, so there are not yet significant accomplishments of impacts. They seem to have met key milestones with their RFI process, and a couple of initial

demonstration projects done or in the works, so the project seems on track to meet their stated goals and accomplishments.

- This is difficult to assess. The technologies, while noted as being chosen on the project plan slide (slide 16), were not identified. It is difficult to assess progress without knowing the complexity of the ETs.

- RFI complete.
- 6 pilots underway.
- Engaging business leaders/commercial building owners who have committed to reducing energy.

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.

- Good local engagement.

- The combination of LA Cleantech Incubator and the Better Buildings Challenge appears to be a strong and creative matching of the incubator of new, innovative technologies to interested and motivated building owners. It remains to be seen how deeply the owner/managers will spread the technologies throughout their portfolios, but it is a very sound approach with a group of key owner/managers in that region.

- This appears to be a project with a good idea and a lot of idealism but it lacks a practical roadmap to accomplish its goals.

- Focused on partnerships/leveraging partners.
- I'm concerned project is not leveraging Design Lights Consortium's QPL for LED lighting.

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.

- *None*

- Their work plan seems sound – perhaps a bit ambitious, but there were no big red flags identified in their planned work.

- *None*

- Metrics for success?

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

***High*: 1** reviewer

- The plan for this project is creative, and hopefully the deliverables will be well received.

***Average*: 2** reviewers

- Not a big stretch, but good.

- *None*

***Low*: 1** reviewer

- Unless the ET on-ramp can reliably deliver predictable energy savings from the commercial buildings it is targeting, its value is low.

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

***Yes*: 2** reviewers

- *None*

- *None*

***No*: 2** reviewers

- See above.

- The lack of addressing the installation and servicing network is a significant concern.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Great goals, but need to develop something beyond educating people about other programs.

- Creative, innovative team, with good connections to both the supply and demand sides of new building technologies. Potential for replication in other regions where there are clean/green tech incubators and an association/grouping of motivated building owner/managers.

- Accelerating market adoption of best-in-class building technologies, and creating an "onramp" for emerging technologies to enter the market is a great idea and is sorely needed in the commercial building sector.

- Pilots with property owners with large portfolios.

2) **Project Weaknesses**

- Presenters seem to be trying to rethink program after learning about state of DOE and GSA programs.

- Not clear how the approach will continue after DOE funding is finished – it is not at all clear that there is any sustainable business model for this to continue. Ideally utility funding might be the exit strategy, but availability of that funding is not clear.

- The desire to identify best-in-class technologies through RFI processes – leverage Green Proving Ground testing and research – leverage DOE performance specifications and engage utility partners to deliver reliable and repeatable energy savings is a significant undertaking. It has been accomplished by well-respected technology testing, analysis, and deployment facilities, particularly at CA utilities like SMUD, SCE, and PG&E. I am not familiar with any similar facilities at LADWP and without that level of testing, analysis, and deployment expertise, I don't see how this project can reliably and repeatedly accomplish its goals.

- I'm not convinced this project can be completed in 2 years, especially developing a standardized process for EE programs to on-ramp super-efficient, emerging technologies.

3) **Recommendations**

- Need to identify innovative approaches of their own. Maybe work with GSA and DOE to assess progress and programs/suggest future directions for them based on LA needs.

- *None*

- *None*

- Leverage DLC's QPL for SSL.
- Conducting a handful of pilots may not be enough to develop a single "on-ramp" process.

Project # 222106: Envision Charlotte Project

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This program is a great model for reduction of resources by end users. They have broken out their approach to 3 areas of interest: Behavioral change, operational energy efficiencies and capital improvements. To make the project successful, it takes effort and progress on all three of these areas.

- There is a clear and direct link between Envision Charlotte's efforts and the BTO's goals of improving energy efficiency in commercial buildings.

- The project seems to directly align with BTO's focus to reduce building EUIs nationwide. The project is VERY targeted to one region, which does prevent it from having a significant dent in the goal, but its replicability could lead to greater impact toward this goal. Given the project's focus on the Charlotte region, I cannot rate it as "outstanding" as it is not critical to the BTO and its goals.
- If possible, I would rate this project between "Good" and "Outstanding", as the Envision American project, based on Envision Charlotte, brings this project to a greater scale, which may be critical to BTO.

- Goals are well articulated and measurable.

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 approach is very well thought out. The City of Charlotte has the luxury of having many forward thinking businesses within the city limits allowing for the program to not only succeed, but to grow.

- A couple aspects weren't clear from the presentation, and perhaps there was just not enough context described in depth to understand how this program works.
- One, I was left wondering how energy efficiency measures would be financed, and whether Envision Charlotte was partnering with institutions or entities that could provide loans or other incentives to make energy efficiency upgrades financially attractive to building owners.
- Two, more information about proven occupant engagement strategies would have been helpful—I am skeptical about the level of interest or engagement of most tenants who may not have much of an incentive to contribute to energy savings.
- Three (and this is very common), beware of acronyms and industry speak! Even in a peer review with the Department of Energy Building Technologies Office crowd, you don't necessarily know that your audience is familiar with the same acronyms as you are. Engagement with all different sorts of partners involves clear, easy-to-understand communications tactics, so don't risk alienating your audiences with language that is too "inside baseball."
- Four, and this was touched upon in the slides/presentation, you'll need to be sure that the facilities managers/building operators have a clear mandate from the owner to implement temperature policies (avoiding space heaters, adjusting the thermostat) so there aren't problems with occupants erasing the progress you've made.

- Focus on critical market barriers: The team did an excellent job of identifying a number of barriers related to each "approach" utilized in the project. While I'm sure that I could identify some additional barriers, the team clearly has a thoughtful approach to identifying and overcoming these barriers, that is also clearly re-considered as the project advances over time.

- I believe that the team's project design is effective, but could be more effective. The Data Foundation and Energy Roundtable approach does not have a clear plan for scaling. While I greatly respect and support the partnership with the University, it appears that this program may be limited by the pace and resources available by a University course each semester. I also look to see the other approaches proven more clearly over time. Overall, interesting, but slightly unproven approach. I look forward to seeing how successful the training and behavioral change programs are over time.

- Explained key barriers of different levels of capacity and knowledge of the different building owners. And how the approach must be tailored.
- Behavior change piece is more challenging to measure.

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.

- By partnering with Duke Energy and UNCC, the program is moving forward and has a good working base of participants. Clear goals are established and progress is being made towards achieving them.

- Again, as reviewers, our understanding of the project could be severely limited by the number of slides allowed, but I have every confidence that Envision Charlotte will move ahead as planned.

- The project, and its influence on Envision America, seem to have great impact on the stated program performance goals. The envision program has already led to ~17% energy savings on average in the buildings touched thus far. If expanded to the 200 greatest energy consuming buildings in Charlotte... and similar impact in other Envision cities...this would greatly support BTO's programmatic energy reduction goals.
- The team clearly needs to do some tuning to achieve 20% (the stated goal) and to scale in other cities, but appears to be well on its way.

- Great to focus on operational and capital improvements. Excellent.

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.

- All parties involved are actively engaged and are steadily working towards their goals.

- Your involvement with UNC and Duke Energy sounds like there is a good set of partners working together. As some of the reviewers observed after a couple presentations, Envision Charlotte and the City of Milwaukee could likely benefit from exchanging some notes about their processes.

- The team showed a strong understanding of the diverse networks of stakeholders related to the city and the local utility, but could do a better job of interfacing with the private sector. There appears to be extensive collaboration with the city, Duke Energy, key city partners, and the University, which are all outstanding partners. However, private industry should be involved and leveraged to drive creative energy efficiency solutions and business models.

- Good history of working with Duke Energy. UNC collaboration seems to be working well. Is QA/QC with students challenging?

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 goal of expanding the program within the city was evident and the fact that Duke Energy wants to move it elsewhere in their footprint speaks to the success of this program.

- It seems too early in the process to know how well the project's proposed future work has been designed.

- I would rate future work on the "Data Foundation & Energy Roundtable" and the "Building Retuning Training" as good. These efforts appear to be headed in the right direction, engaging most of the key stakeholders, and headed toward solid support of the program goals. Time will tell whether the programs deliver as expected and continue improving. Some risk remains as to whether or not the training approach will be successful.
- I would rate future work on the behavioral change program as "fair". I am concerned about the effectiveness of the behavioral change program. The presentation and Q&A did not instill confidence in me that the behavioral change program would be effective. These types of programs are very difficult to apply effectively.

- Scalability will be difficult because approach must be tailored to specific building stock. Good demo project.

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

***High*: 4** reviewers

- Anytime a project is successful, the results are desirable for others looking to undertake a similar project.

- Based on the ratios of where energy efficiency measures make the deepest impact, I would assume the target audiences are in order as follows: owners (for upgrades), building managers, and occupants. There was not a lot mentioned about the process of engaging building owners; only that there was likely to be competition for participation. There was also not a lot mentioned about the technologies themselves, nor specific case studies of what has worked. So I would characterize this section as "high" because of my assumptions that Envision Charlotte has these bases covered.

- It's difficult to comment on the deliverables to key target audiences/markets without seeing other presentations.
- This presentation was excellent and addressed all relevant aspects of the project.
- I am confident, based on the team's success thus far, that the deliverables produced for other key stakeholders were of great value.

- They team seems to be very aware that the owners need different types of TA.

***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 program has already made an impact on energy reduction across the city.
- Yes, with a caveat that it seems too early to tell, and again, there wasn't enough information that the slide presentation allowed to confirm.
- The project is laser-focused on the deployment activities that would most effectively achieve the goals that the project laid out up front. If realized, they will help the BTO achieve its programmatic goals.
- Team knows its market.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Successful partnerships with Duke Energy and UNCC.
- Potential Smart Phone app forthcoming.
- Good process involving UNCC students to collect and analyze data.
- By now, there are plenty of examples of tried-and-true energy efficiency upgrade programs for buildings of all sorts, and Envision Charlotte takes the best of what's been done and throws an extra benefit of having students involved in the process of building managers' efforts. Good information is disseminated, students receive a new skill set, and the program has the potential to scale in different ways.
- The project is strong in general.
    - The team has taken a very targeted approach to tuning buildings to achieve significant, and almost free energy efficiency.
    - The team has clear metrics to measure its success in pilot buildings in Charlotte.
    - The team has made an impact in inspiring the greater Envision America program.
    - The hands on approaches address some of the key market issues.
    - Engaging the local university is a key "plus" as well.
- Building retuning and training is vitally important.
- Would love to see outcome on different building types and owners' sophistication. Small to med without BAS.

2) **Project Weaknesses**

- None.
- As mentioned above, I am concerned mostly about translatability of ideas in a jargon-heavy field and appropriate ways to engage building occupants. The mention of a smart phone app was not convincing to me; in many cases, unless conservation is written into employees' job descriptions or is part of their review criteria, throwing more information at them is not likely to be effective. There needs to be more thought into a variety of awareness and incentive programs about energy conservation.
- I have doubts about the behavioral change program and its effectiveness.
- Private industry to should be more actively engaged to provide best practices for building retuning and offer services that go beyond building retuning as a source for efficiency improvement.

- More info needed on the behavior change program.
- Does the project team think that one program or approach is more impactful?

3) **Recommendations**

- Hopefully, upon conclusion of this project, it can be shared with other cities to help maximize the effect, not only in Charlotte, but across other cities as well.

- Take a look at Harvard University's Green Office Program for an example of ways of engaging and rewarding office workers in a holistic approach toward sustainability. There may be some ways Envision Charlotte could customize their own green office certification program to build awareness around energy conservation efforts and tying them in with a wide variety of ways sustainability can reach people's hearts and minds.

- My recommendations are clearly outlined above, with the key recs to be:
    - Engage private industry effectively.
    - Create a more tangible and sure-fire plan for the behavioral change program. If it doesn't look like it can be implemented effectively, re-allocate the funding to a more effective program.

- Consider what the behavior change program can achieve realistically.

Project # 222109: Accelerate Performance

A. Relevance

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

- Excellent.
- Well thought out.

- It supports BTO's interest in promoting innovative intervention strategies, specifically exploring a way to take DOE's procurement strategy to scale. While the goal is 100 buildings as per BTO requirements, the actual savings are speculative with no specific goals or targets set per building project, just an open range of 15-30% reduction in consumption. And savings may not materialize during the BTO funded period because projects may take longer to be completed and one year post occupancy measurement. This may need a longer timeframe to be successful.

- Provides process improvements for how new commercial construction can go well beyond code...performance based procurement. This type of construction supports BTO's long term goal of reducing EUI in Comm. buildings. Provides opportunity to demonstrate that new buildings can be built to consume 50% less energy (than code).

- The project which employs performance-based procurement to ensure energy consumption is at its lowest in new construction projects. It incentivizes building owners to think about making new buildings more sustainable by keeping their EUI as low as possible so as to not to add the issue of how much energy existing buildings use already today. Thus, this performance-based thinking in designing buildings is an important step in reducing EUI into the future.

B. Approach

This project was rated:
1) **3.25** 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.

- Gets right to the idea of simplifying innovation and implementation.

- Few barriers identified, other than utilities and owners being risk averse. Solution through utility deployment is the focus. Not clear what barrier that overcomes other than having an entity identified to be responsible for pushing the procurement model. Also, utilities historically have been unable to get in early enough in projects to influence the contracts or team selection. Not sure how this project overcomes that. And what happens if a project doesn't meet targets. Does the utility get reimbursed for any upfront incentives paid?
- There are other barriers that could be identified such as financing, measurement or verification of accuracy of resulting performance, contractual liabilities, duration from design to measured savings and length of contracts, etc.
- Also, there seem to be 2 different cash flows that may or may not be integrated depending on the teams involved. 1) Utility incentives to owners (project requirements) and 2) Owner procurement requirements and payments to D&C team.

- Critical barrier- business customers not asking for high performance buildings and energy efficiency is not being considered in new construction until too late in the process.
- Project wisely leveraging energy efficiency programs and their related resources
- Resources being developed will clearly include energy efficiency performance right into RFP.
- The issue of connecting with commercial NC customers early enough in the process is a tough one to overcome. They might need to emphasize strategies to reaching them early enough.

- The approach in addressing the key market barriers to designing buildings to be more sustainable and energy efficient is good by using incentives from utility partners within the pilot territories. However, there is a major drawback to having this project be partnered solely with utility programs. Utility incentive programs are rate payer-funded, but are budgeted each year. This limits how many buildings can be served by an incentive program and potentially impacts the project goal to serve 100 buildings over the three-year performance period. This is not to suggest that projects cannot be completed under this model, but that there will be limitations on being able to serve all buildings being targeted for this project. In addition, not all utilities are created equally, so some might have large enough budgets to help support much of the cost of implementing energy-saving measures inside of the building. But, thinking about other financing mechanisms to leverage this model should be considered in territories where such clean energy financing options are available.

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) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- They are "planning for the next hundred years." Getting utility companies in early on the design.

- Interim goals seem to be achievable. Already have 3 utility pilot commitments with 11 projects in pursuit or discussion phase. Long-term goal doesn't seem achievable within the timeframe of the program (3 years).

- Already have 3 efficiency programs signed on to pilot tools. No reason to believe these will fall through.

- The project has already identified a number of different pilot partners with a thinking toward portfolio owners. This would ensure that the project managers are thinking about multiplicative impact and considering multiple new construction projects under one ownership. At the same time, the project managers are in talks with utilities to explain the concept to them and are underway on bringing those partners on board.

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.

- A model program.

- Banks and financial institutions were omitted in portfolio owner and utility portion of presentation. Most large projects need financing. Banks will want to have a say in procurement contracts.

- Working closely with the key programs in the regions they are targeting. Efficiency Programs have included in long term plans.

- The project is partnering with relevant stakeholder partners in the case of the Illinois pilot initiative and it is very well designed. However, it seems more work needs to be conducted on gathering more stakeholders on the ground in Minnesota, Colorado, and Connecticut. It is likely the project team has more knowledge of the Illinois landscape, as opposed to the other targeted territories, and more time may be needed to scope out the stakeholder landscape in the additional project territories.

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.

- Would be interesting to consider UESC approach to financing for new work.
- Good within the scope of work presented. Other issues remain about activities and impacts beyond the 3-year horizon.
- Will be addressing key issues that energy efficiency programs will need to address in incorporating these tools into their programs (i.e. savings, costs, cost effectiveness, other evaluation issues).
- The largest issue seen is overcoming the limitations in the potential funding source from the utilities. At the moment, this is not addressed in their planning, and it needs to be addressed to ensure that the goal of 100 buildings can be met within the project period. While this structure helps to limit costs, an economic incentive needs to be given to building owners to make newly constructed buildings sustainable and energy efficient. We are still not at the point in the energy efficiency market that people will willingly pay for implementing these measures into new construction without more assistance. Until it is no longer cost prohibitive, it will need to be heavily incentivized, and it is difficult to know if the utility incentives will be enough to achieve this.

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

***High*: 3** reviewers
- *None*
- Utility program design/structure will be a great resource. Should shoot to answer difficult evaluation issues that programs are faced with.
- Having an alternative form of funding newly constructed projects be energy efficiency would be helpful to reduce EUI for future generations. It is important that the future building stock uses less energy per square foot than the existing built environment. This project does target to the right audiences, but as mentioned earlier, the project should consider other additional avenues to help pay for these projects.

***Average*: 1** reviewer
- Too early to say.

***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
- Looking forward to next stage.
- *None*
- *None*
- No further comments necessary that what was explained above.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Excellent, well thought out and implemented.

- Good area to work on. Has potential to significantly improve project performance levels.
- Interesting approach attempting to use utilities to promote the DOE/NREL procurement contract mechanism.
- Great way to get EUI valued in the value engineering process.

- Building off of NREL's positive experience.
- Bringing this new approach at a time EE programs are in need of new savings.
- Could be a game changer when it comes to commercial building procurement processes.
- Demonstrates that with thoughtful planning, energy performance does not need to come with a premium.

- No further comments necessary, they are articulated in the comments above.

2) **Project Weaknesses**

- None.

- Timeframe is too short in relation to project cycles and utility planning processes to realize significant impacts.
- No clear link between the savings projections (target) and the BTO goal of 100 buildings treated.
- Utilities may not be able to intervene early enough and with enough "incentive" to influence procurement contracts.
- Unclear what the actual mechanism is to get the utility pilots to happen (other than negotiation).

- *None*

- No further comments necessary, they are articulated in the comments above.

3) **Recommendations**

- Consider green lease language at some point. GSA Green Building Advisory Committee, led by Ken Sandler, is looking into this, with a possible tiered approach.

- Ask team to link barriers to strategies and give them 2-3 more years to achieve results.

- *None*

- No further comments.

Project # 222106: Better Buildings Challenge - Milwaukee

A. Relevance

This project was rated **3.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Once this project is a bit more mature, the relevance will be on target. Currently it appears to be in the infancy stages of the program.

- Like Envision Charlotte, the City of Milwaukee's energy efficiency upgrade plan for commercial buildings is exactly in alignment with the DOE's BTO goals.

- The project appears to align well with the BTO's goals. The project aims to increase the effectiveness and adoption of a number of diverse energy efficiency programs in Milwaukee, which should help the BTO to achieve its larger programmatic goals related to reducing EUI in commercial buildings.
- That said, the project's problem statement and direction are relatively open-ended and ambiguous. I would recommend that the project team look to be more specific about their exact goal and attempt to apply a metric (efficiency improvement, number of buildings improved, etc.) to more directly lead to the ultimate impact that this project well have toward BTO's goals. It's great that there are "project measurements" described later, but they should be incorporated into the goal.

- *None*

B. Approach

This project was rated:
1) **3.75** 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.

- Approach seems to be on target for the early stages. They are moving in the right direction to get the program off the ground.

- The City of Milwaukee appears to have given thought to nearly every potential barrier that could impede progress toward their overarching goals.

- It's clear that the project team has clearly and thoroughly thought about the potential market barriers at hand. The presentation included a clear understanding of the barriers presented, a synopsis of the Milwaukee buildings market to be affected, and a preliminary demonstration of how addressing these barriers could lead to impact.
- The project's design appears to address the market barriers identified at face value, but it is difficult to see that the project is taking clear action toward each of its key "approaches." The logic model / flow chart of the approach section is very thorough, and I expect good results, but it is difficult to award a project with an "outstanding" rating before the rubber hits the road for this project (it is in its early stages).

- *None*

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.

- For the age of the project, they have a good base knowledge, direction and path to their goals.

- It's unfortunately far too early for the presenter to have identifiable progress to report on at this BTO Peer Review meeting.

- If possible, I would provide this project with "N/A" for this section. Given the parenthetical at the top about judging the project based on the amount of time it has been active, I would rate "good" only because there appears to be a clear plan for the project to deliver progress toward the relevant goals. It's very difficult to award the project with "outstanding" given the very recent time scale for project startup and the lack of progress that the project has made as a result.
- The one relevant progress milestone that I see in addition to the planning is that the project has already signed up 6 buildings for its pilot program.

- Very early in the project.

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.

- As it is early on, they are still engaging others to participate in the program. I believe their current progress shows good momentum to gaining the correct level of support.

- The City of Milwaukee has an impressive array of partnerships, clearly understanding and involving the many different potential contributors to the project throughout Wisconsin.

- The project appears to coordinate well across a large field of stakeholders. The presenter demonstrated their team's ability to properly utilize stakeholders as necessary to maintain a process that appears uncomplicated to its users, despite the diverse array of stakeholders involved in implementing the associated energy efficiency programs. The program seems to have a complex logic model that, if successful, results in a relatively simple process for the customer.

- Strong industry and community teams.

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.

- Once the initial program is established and has a proven track record, I believe other businesses will want to become a part of this.

- The overall approach to the complete project cycle is very thorough, giving thought to the degree of attention each step requires. There has clearly been a lot of good input in the project's design.

- Given the early stage of the project, the team does seem to have a clear handle on what the next steps are. I believe that the plan is logical and focused on a detailed plan, though I do expect the target to start moving once the team really dives into implementation. The proposal for future work presents a "broad strokes" vision of what the project should look like, but I would like to see more details.

- *None*

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

***High*: 3** reviewers

- By engaging not only the public offices, but the private organizations as well, the project can grow quicker and reach more people. Education and familiarity always help a program sustain or grow.
- Hopefully, incentives for converting buildings to more energy efficient operations will become a trend within and outside of Milwaukee, and that this group will be able to share their successes.
- The presentation and the charts therein (which have been used as part of Milwaukee's program) are high quality, clear, and helpful.
- That said, this question could also be construed as irrelevant, as we did not see any of the deliverables produced by the project to other / third-party audiences or markets.

***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

- Clear goals are established in 5 different areas. All goals appear to be measurable and attainable.
- Yes; again, it's clear that a lot of thought went into this project, and I look forward to seeing its successful deployment.
- I believe so. The project well-defined 5 key areas for focus that are addressed by an apt deployment activity. Again, only time will tell whether the implementation of the project and its logic model support this.
- Recognition, technical assistance and to a lesser degree financing are all key to driving retrofits and operational improvements. The project helps provide all three.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Clear goals and objectives. Appear to be attainable.
- Using existing DOE tools; proven software.
- Student involvement in the process. Shadowing auditors to gain a better understanding of the process.
- A very solid plan and many partnerships makes this project exceptional.
- The project paints a very detailed picture of its approach. The presenter was able to substantiate the project's approach with a clear understanding of how partners/stakeholders would be incorporated. The project approach appears to be thoughtful and well considered.
- *None*

2) **Project Weaknesses**

- Early on in process so no real results to date.
- Many partnerships can be tough to manage; it would be helpful to know how many staff persons are available to keep these relationships working in harmony.
- The project could use additional detail in a few areas, primarily (1) proposed future work and (2) problem statement. These sections are currently vague and relatively wide open. The early stage of this project also makes it difficult to adequately evaluate, as the project has spent most of its time in an ideation phase.
- *None*

3) **Recommendations**

- This group should reach out to Charlotte and have a conversation as to how Charlotte built a successful program.
- Regular, clear communications for all partners is going to be crucial to staying on track.
- My recommendations are clearly outlined above. Most prominently:
    - Proposed future work could lay out a more detailed plan moving forward.
    - The problem statement could be tied directly to metric-based goals that show how this project will help the BTO to achieve its goals.
- *None*

Project # 25136: OpenStudio

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Key infrastructure tool.
- Essential user interface enabler to E+.
- Allows free market development of apps the market sees a need for.

- OpenStudio is a critical resource that DOE produced and continues to keep up-to-date. While the tool has been implemented already, DOE's focus on continually updating OpenStudio and improving its functionality significantly helps private sector individuals using the tool to more effectively, easily, and accurately model energy consumption and recommend energy efficiency measures in buildings.
- OpenStudio in particular brings the abstract Energy+ into the hands of many more practitioners who do not have time to learn the intricacies of an engine like Energy+, and need a more user-friendly interface that will allow for easy energy modeling.
- Additionally, the fact that OpenStudio supports so many other DOE tools makes it critical to its energy modeling family.

- The proposed Open Studio core platform and the tools built on this foundation have significant potentials to positively affect market infrastructure geared towards greater investment in energy efficiency. The project pursues the development of freely available, integrated set of computational platform (with standardized data structures), offering easy-to-use functions for the assessment of Building (and group of buildings under a single management) energy performance. This can strongly support performance-based building design and transaction approaches. The project has achieved and it is proposing tasks to develop design decision support resources applicable to a range of stakeholders to effectively understand and incorporate the value of energy efficiency into commercial building market. This quality is critical in support of BTO’s goals.

- The DOE has become a major developer of energy modeling software engines and is providing huge benefits for the energy modeling industry by providing the OpenStudio Core platform. The presentation could have made the market impact more clear.

B. Approach

This project was rated:

1) **3.00** 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 questions on barriers don't apply (NA) - No market barriers identified.
- OS is designed to enable effective use of E+. It meets that need.

- "Critical market barriers" are not as applicable to this project, as it is an ongoing effort to continually improve a solid piece of energy modeling software put out the DOE. That said, the project does intend to continue addressing the issues that the market has identified and to continue building a tool based on market feedback from big players in the industry. I consider this project as important and relevant in supporting the continual improvement and expansion of a very useful software modeling tool.
- I believe that this project has already identified and overcome the market barriers to broad adoption and usefulness for the audience it intends to serve.
- The ongoing upkeep and improvement of this tool continues to prove that it is focusing on the key areas that its users demand improvement, and the key areas where DOE needs support for other tools that use OpenStudio in one way or another.

- The team has a great and clear way of organizing its work flow to focus on bug fixes, user requests, and the longer-term ongoing projects that make OpenStudio exceedingly useful.
- It appears that this workflow continues to focus on features that the industry finds useful - and the presentation made it appear that the tool includes new features to help users achieve their end goals, but also has enough customization to allow the user create custom measures, use sensitivity analysis, or perform other functions to maintain a necessary degree of flexibility.

- Identified collection of software technologies within Open Studio ecosystem successfully attacks the informational market barrier which prevents building owners having adequate performance-based information about high-efficiency technologies and operations. Proposed applications that arise from measures + Open Studio integration (such as optimization - uncertainty - calibration packages) can tackle the barrier of accounting for uncertainty in valuation of the energy efficiency in commercial buildings. Proposed calibration package can serve for EM&V area (to affect market infrastructure) which has to develop standardized, low-cost but high-quality approaches for assessing the savings from energy efficiency measures.
- The project could offer some advancement in the proposed high level deeding decision support tools such that the split incentives of building owners and renters (on energy and financial gains of building efficiency improvements) could be reconciled. Such functions could be incorporated into COFFEE program. High impact technologies (HITs) are instrumental in achieving significant building performance improvements to reach BTO's overall energy savings goals. They also become more critical in design, construction and operation of net zero energy buildings. This project could offer some software technologies focused on identification and prioritization of HITs with the aim of reaching net zero energy levels. This could also serve the aim of faster adoption of market ready HIT applications. The project's plans to overcome the identified barriers are sharply focused.

- Good suggestions were raised in the peer review to develop a tracking system for measuring success.
- It was unclear how open studio relates to other industry standards like the IFC validation schema
- gbXML input – output.
- Suggestion to measure and report more on impact / metric industry impact, who is using the tool.

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.

- Performance goals are not identified but development and improvement goals were presented. Significant progress has been made.

- I believe that OpenStudio as a whole has and continues to significantly contributed to the program's impact goals. I see the continued support, improvement, and expansion of this tool as one of the critical functions that DOE has provided over the years. Keeping this tool in DOE's hands has ensured regular upkeep focused on ensuring quality and meeting user needs. It appears that the team is continuing with that effective trajectory.
- In widely supporting other DOE programs (many of which are based on OpenStudio), OpenStudio will accomplish a great deal more than the sum of the initiatives that go into OpenStudio's direct functionality.
- I am confident in and excited by all of the current and future plans for OpenStudio.

- Strong qualitative support to CBI program performance goals exists. It is apparent that project (with the introduction of Open Studio measures and particularly TPEX approach) will serve for the easier (therefore rapid) adoption of currently market viable but underutilized energy efficiency technologies by the commercial building market. The project can play critical role in pulling recently commercialized but underutilized technology into demonstration (which naturally paves the way to deployment). A good integration potential lies here with the outcome of ET program activities. All of these help driving adoption

of technology solutions with collaboration with market leaders (particularly for HIT applications). However, the project doesn't give predictions of expected increases in the use of Open Studio based design decision support systems and how this increases could result in EUI savings (current or projected to 2020). There is not a metric of assessing the success of the proposed applications. It is difficult to relate project outcomes with some quantitative performance goal metrics as identified by BTO in CBI program definition.

- The application has a good quality in its potentials to make meaningful contributions to CBI's interim market goals. This is due to the fact that 'measures" can achieve faster adoption of high-efficiency technologies with its ease of use and mobility in terms of data exchange. ECM package optimization can help pinpoint cost effective high-efficiency solutions (to extend limited first-cost driven decision making methods). Cloud-based large scale analysis can show market leaders the scalability and transformative impacts of high-efficiency solutions and EDAPT further extends similar capabilities to utility incentive programs. Two areas are missing that prevent outstanding contributions. First one is lack of proposing design decision support tools dedicated to net zero energy commercial buildings and second the project's not focusing on HIT applications for accelerated achievements of planned energy efficiency savings in the commercial building stock.

- *None*

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.

- Key stakeholders are primary developers of other tools that use OS as a gateway to E+. These are well known and represented in staff work.
- What is not so well known is the needs of users of the outputs of derivative tools (i.e. the ultimate end users, designers, owners, operators, etc.). Most of this is left up to the 3rd party developers to determine, which is an appropriate strategy as long as no gaps exist (i.e. where developers fear to tread due to poor market outlook for a certain app, etc.).

- The project clearly demonstrated who many of the key stakeholders are that they are working with, but failed to get to a more helpful level of detail about the many roles that these stakeholders may take in the process. That said, it was clear how a few stakeholders would play a role in the process.
- It is clear that the staff collaborates with an extensive network of external stakeholders and DOE stakeholders to collect key information, become useful for industry partners, support DOE programs, etc.

- No stakeholders that can be thought of are omitted from the proposal presentation. Collaborations are established with all BTO labs and some key market leaders (which is significant for project proposals under the CBI program). Furthermore, the well-stated open and collaborative approach to software development partners renders the project with superior quality from the point of project integration and collaboration.

- It might be considered to increase industry cost share.

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.

- Automated baseline is critical, will reduce model building time significantly.

- Evolution of EDAPT is good and will provide access into utility program world.
- TPex is good if enough manufacturers will use it.
- Multi-cloud access functionality will be critical.
- Missing: a way to identify or discover cross-over functionality with other major tools (Asset Score, Energy Star Target Finder, etc.)

- The team well described some of the near-term opportunities, and explained that some if its current work will be ongoing. I am particularly excited about the new (upcoming or current?) feature of creating "baseline" buildings based on ASHRAE 90.1 and other standards.
- The team also seems to have a clearly thought out method for prioritizing its work - balancing day-to-day bug fixes and user requests with the longer-term vision.

- The proposed works depend on the past progress of Open Studio and aligning with parametric analysis tool (PAT) with OS Server Code will definitely result in efficiencies of entire workflow together with code reductions in SDKs. Some other achievements with potentials of overcoming market barriers are the increases in the content of ECMs in the measures in addition to automated baseline generator measure (which can save substantial amount of time and effort needed for developing baseline models for comparative tasks of design decision support processes). However, it is not clear what feature of baseline model will be automated. For instance, automation of HVAC component modeling for baseline energy models could be extremely challenging. Further details could give whether advancements in calibration procedures will take place or not. This could be significant in supporting HIT market simulation activity of "real building demonstrations" so as to overcome building owner's uncertainty about how the ECMs will perform in real world settings. Similar focus could be given to ECM package optimization and uncertainty analysis functions as well.

- The future work was not spelled out well enough. Especially what is meant by community scale modeling, which will have a huge impact if done well.

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

***High*: 4** reviewers
- *None*

- OpenStudio is a world-class tool that has grown immensely over the years to support a new wave of professionals who now have more ready access to powerful simulation tools like Energy+ through the use of a great interface like OpenStudio. It is clear that as the interface has become more robust, the team focuses on larger issues that aim to strengthen the combined power of OS and Energy+.

- A wide range of project deliverables are produced from open studio core and these deliverables have potentials to positively impact (1) other BTO programs, (2) key market leaders, (3) utility companies and ESCOs, (4) governmental institutions, municipalities, (5) students and researchers as well. Using the same core based on open source extensible platform, a number of different design decision support tools have been generated for different viewpoints. High level to detailed analyses approaches share the same data structure to operate at different levels while saving the compatibility between them. This certainly augments the value of deliverables produced for the key target audiences of the project.

- Open studio is the main platform for building energy modeling tools and platforms. Even Autodesk is now collaborating with the DOE.

***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

- *None*

- The team appears to be focusing on the most important areas to see project and program success, and shows a strong likelihood to continue on a positive trajectory.

- Particularly the proposed work on OS measures in addition to community scale modeling and EMS-based control research (with NYSERDA) enhanced the relevance of project's objectives receiving sufficient emphasis. Additional work could be directed to developing computational support of model calibration using monitored building energy data as well as giving emphasis of HIT applications design support via Open Studio measures.

- Energy modeling is the core of energy efficient design and is needed to evaluate equipment usage in the whole building context.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Essential infrastructure.
- OS is an innovative approach aligned with market actor capabilities.
- The wide number of spin-off tool developers is evidence of interest, need and usability.

- OpenStudio plus is a very valuable and powerful tool for the industry and many DOE programs. The team continues to tackle pertinent issues. OpenStudio continues to find more and more applications within and outside of DOE. The continued support of OpenStudio allows more users to utilize the advanced functionality of a useful tool like Energy+.

- Extensive and strategic collaborations and partnerships with key market leaders who can first to adopt new software technologies which can accelerate embedding them into standard practice in the broader market.
- Varied sets computational tools (from individual measures to large-scale analysis for prioritization) built on the same framework (and using DOE-endorsed EnergyPlus simulation engine) have significant strengths in providing stakeholders with low-cost, easy-to-use, adaptive and extensible (via open-source platform) ways to assess, compare and validate (via open-studio server calibration) building energy performance.
- Open-studio's inherent flexibility fostering quick development of novel desktop, mobile, web-based tools in an integrated fashion has strength in promoting the use of underutilized EnergyPlus simulation engine (which is being continuously developed with efforts from the ET program projects).
- All of the identified future work plans possess significant improvement potentials to overcome the stated market barriers. Open studio measures with the inclusion of automated baseline energy model generators have strong potentials to tackle BEM challenge of missing or brittle automation of common energy modeling tasks.
- Responsiveness to individual and private program developers is improving the creativity in integrating analytical quantitative tools with design decision support approaches.

- The project strength is obviously the core engine: Energy Plus. The Department of Energy has managed to become a market leader in energy modeling tools.

2) **Project Weaknesses**

- Accuracy verification or validity of added features or code is left up to external developers. How does this effect OS quality and version control?
- TPex doesn't have a mechanism to verify manufacturers' inputs.
- Market diffusion is left up to the developers of market facing tools (i.e. out of DOE's control).

- The project appears strong. The team could better describe its key external collaborations, though this is not a major flaw.

- The project doesn't clearly identify key technical risks that can be experienced as well as possible mitigation strategies to address them.
- The project has a weakness about establishing identifiable metrics to evaluate the success of the proposed applications/new software technologies in terms of achieving the interim market goals of the CBI program.
- The project also shows a weakness in adequately addressing the specific design decision support needs of net zero energy buildings (keeping in mind the 2050 target point).
- Similarly, the project doesn't address computational support (open studio-based measures) for characterization and prioritization of HIT applications for impactful energy efficiency savings in commercial building stock.
- Relatively more emphasis could be given to calibration procedures in support of M&V applications to foster the confidence of relevant stakeholders in high-efficiency technologies.

- The strength can also be its weakness. If there is little competition, will the project continue to be developed?
- It should....

3) **Recommendations**

- *Recommendations on different review process.*

- Continue using an organized and well-thought-out process to address day-to-day and longer-term projects.

- *None*

- Keep it going strong, keep it open.

Project # 25150: Building Energy Asset Score

A. Relevance

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

- It is clear that a multi-layered, simple-to-thorough tool has long been needed to assess and score the energy efficiency of commercial building spaces in ways that LEED certification has obscured and Energy Portfolio Manager has not yet been able to address.

- This project appears very well aligned with BTO's goals, but I could not go as far as saying that it's "critical to the BTO."
- If successful, this project can have significant impact toward achieving BTO goals.

- This project is critical to the BTO and fully supports BTO's goals. This is due to the proposed Asset Score's inherent character of providing easy-to-use building energy performance assessment functions (that are applicable to both residential and commercial building types) that are tailored to serve for high-level decision makers who usually don't want to deal with complex and time consuming energy modeling procedures and who are at the same time influential people that can incorporate the valuation of energy efficiency in real estate transactions. In doing so, Asset Score has significant potential to serve for overarching long term BTO goal of reducing the energy per square foot of the U.S. buildings (both residential and commercial). Asset Score's being established on EnergyPlus simulation engine via Open Studio core is also very relevant to the BTO program goals related with building energy.

- *None*

- A 'building asset scoring tool' is significant relevant in the market place, but most importantly it should be considered by more building owners. It seems that the target of 1% of commercial buildings by 2020 is low considering the overall BTO energy saving goals. It does not seem to help, that Energy Star has a similar, but not exactly the same tool. This will cause confusion in the market place. Communication needs to be improved.

- High impact, applicable to wide audience and large number of buildings.

B. Approach

This project was rated:
1) **3.33** 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.

- I was particularly thrilled to see the variability of how the Energy Asset Score's assessment tool could be done with rudimentary information, and sharpened with additional inputs. This is a large and complex undertaking, and understanding how building managers may either balk at a complicated input process was certainly evident by this project.

- The market barriers are useful and relevant, but I feel that the team is omitting barriers related to the USEFULNESS of the tool for key players that will lead the identified partners and new players introduced to the tool to adopt it. That is, the team could focus more on creating a tool that would be desirable and even needed by other players. The barriers identified by the team don't get the root of identifying how the team can more readily disseminate the tool.
- The project's design very well addresses the barriers identified, and appears to work toward addressing these barriers and others.

- Particularly the feature of identifying energy improvement opportunities based on the current (user defined) energy performance of a building definition appears to be instrumental from informational feedback point of view. That is basically attacking the barrier of especially building owners and operators having incomplete information about the performance of high efficiency technologies and energy efficient operations. Asset Score project can also be taken as a tool that is helping building owners and operators to track their building portfolio's energy consumption levels and compare them with other portfolios (via standardized scoring method), all of which can help them valuing their improvements from the point of energy performance. On the other hand, by nature Asset Score provides deterministic point answers to energy performance (usage + scoring) which isn't very helpful for accounting for inherent uncertainties in valuation of energy efficient buildings. Probabilistic variations and ranges of building performance levels with certain levels of confidence could be provided for such an approach.
- The project contributes to overcoming most of the barriers identified. However, it is not clear how to minimize data collection burden while setting up building models with Asset Score.

- *None*

- The automated energy plus model accuracy and sensibility analysis seems to make sense and the approach was presented as a rigorous methodology. While the asset score is different to the energy star portfolio manager, this is not immediately obvious and can cause confusion. It is good to think about a combined marketing of the two tools between the agencies (EPA and DOE). It is not clear who would use which tool and when.
- The DOE might also want to consider comparing with the European system of energy certificate, which is mandated. While this reviewer understands that mandating an energy certificate is not an option, the integration of both tools could be very valuable
- 1: Asset score for Real estate transaction period
- 2; Energy Star for operation comparison
- But it will be important to harmonize the integration of the tools, so that the scores can be compared and connected for example through a factor or efficiency comparison by EUI and type

- Good approach. Really like simplified interface and scoring improvements.

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) **3.17** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- It is very easy to see how, in addition to the residential model of the same, the Energy Asset Score has the potential to transform the real estate market, in terms of making apples-to-apples comparisons of what to expect from purchasing and operating a building. Hopefully the transparency enabled by this project will make energy efficiency at the forefront of market decisions.

- I believe that the project has great potential to impact the program performance goals if effective. However, I do still have some doubt as to whether or not the tool will reach enough of the market to achieve project and program goals. The team has aligned with a number of stakeholders who should benefit the project, but it is in an early enough stage that I cannot be sure that this will occur.
- The future of the project has a great deal of promise, as it focuses on gathering best practices and lessons learned from industry partners who have committed to using the tool. If implemented correctly, industry and government partners should be inspired to utilize this tool across their portfolios.
- In its worst case, this tool could just be seen as another optional assessment tool for government buildings that is "lost in the weeds," as agencies already have to use a number of tools to evaluate their environmental and financial performance.

- Connectivity with Open Studio ecosystem of software technologies via OSM model download is a significant accomplishment. Similarly, iterative simulation capabilities with Asset Score preview is an important step towards performance-driven design decision support for energy efficient building design. A number of critical and impactful HVAC modeling capabilities and EE measures have been added. Individual advancements are much needed and in line with current state-of-the-art high performance building technologies applicable to both residential and commercial buildings. All of these can provide some quantitative support to the stated performance goals. Furthermore, this project provided some solid metrics about the market impact by giving number of buildings scored with Asset Score with area and location information. However, accomplished capabilities on high performance HVAC systems and other EE strategies are not prioritized and categorized as standard vs. HIT applications which can support more accelerated energy saving gains given the same amount of time to reach percentage savings targets. For example, Asset Score could feature 15 different HIT in the actionable strategies provided to the users as design improvement options. Therefore, Asset Score could serve the 2020 15 HIT application demonstration goal of BTO - CBI program.
- Substantial evidence presented that Asset Score project can make meaningful contribution to CBI's interim market goals. The reason for this is that current features are showing promising traction from the building industry and planned activities includes some key advancements such as including on-site renewable energy technology integration and enhancing current APIs with links to SEED and BPD which will certainly extend current standardization efforts. One significant leap towards impactful contributions could be adaptability with Open Studio measures for quick and automated evaluations of EE technologies and operations on the existing building assets to give some differentiated perspectives on an alternative upgrade option. It is not clear whether this functionality is planned or not but having the modeling capabilities of a group of buildings could also be another step of extending current simulation-based decision support functions.

- *None*

- The accomplishments:
  - Component ranking.
  - Asset score preview.
  - Batch analysis.
  - Building scheme XML via API.
  - Preview seems pretty important.
  - Defined schedules / average assumption.
  - Weather coefficient look up table adjust EUI.
- Seem to all be well integrated and working well. Progress is visible.
- The most benefit will come from implementation of the Standard energy efficiency data (SEED) scoring with Cities 10 cities are interested in piloting asset score. SEED for city data management and implementation of the asset score into larger real estate portfolios as indicated by the workshop at the white hose.
- Would it be possible to enforce the use of asset score for real estate transactions?
- As mentioned before the competition with EPA portfolio management data base needs to be resolved.

- Really pleased to see the evolution of the tool to add preview and batch analysis capability.
- One challenge will be to get uptake in use. Will DOE put resources toward increasing # of users? 21 committed - how to get to thousands?

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) **3.17** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The project managers are seasoned experts in creating complex tools, and have proceeded with a great deal of consultation and collaboration.

- I believe that the project is working with the proper stakeholders and using them very effectively.
- For development, it is great to see that the team is in communication with the OpenStudio team and PSD regularly and has done a great job working with them.
- The deployment team and organizations committed to using this tool should be especially highlighted as some of the most important stakeholders included in this effort. These stakeholders are critical to the broad success of Asset Score, and ensuring that they are happy with the tool and inspired to apply it beyond their 10 committed buildings should be key to the project's success.

- Asset Score project demonstrates a deep understanding of key stakeholders for the acceleration of market penetration. Focusing on market leaders is key to CBI's program objectives and Asset Score project accomplishes that aspect. In addition to this, the project can increase stakeholder interactions with architectural design firms and demonstrate some inherent capabilities of Asset Score to be used as a design development tool (applicable to early, schematic design phases of an architectural project). Existing collaborations are fairly well coordinated. It's difficult to deduct proof the presentation the level of closeness of such collaborations.

- *None*

- While many stakeholders are participating in the development of asset score, the target is low and the competition with EPA needs to be resolved.
- Collaboration with larger real estate companies should be pursued and the value in the market tested on a much larger scale.

- Good start. Needs more outreach.

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.

- With the core building evaluation criteria in place, it is a natural next step to develop more customized building uses.

- The tool is doing well at overcoming obstacles related to the technical implementation and steady improvement of the tool. However, the team should focus more directly on working with key industry stakeholders and improving the tool to meet their needs (in addition to incorporating feedback from government organizations who are also committed to using the tool). Testing the viability and importance of the tool should be more of a focus than the technical side of implementation (though that does have a purpose as well).

- The reported/presented future plan items are effective for overcoming the current market barriers. The outstanding future plan items are adding the functionality of modeling on-sire renewable energy systems (which are the inseparable part of net zero energy buildings) and increasing connectivity with DOE's SEED and BPD. The project doesn't indicate possible technical risks and some strategic decision points about how to mitigate them effectively. There may be the risk of resistance to use Asset Score because of its not accepting geometric building models from some other design oriented tool (CAD tools, BIM tools, etc.). Geometric model importing functions can be considered for Asset Score tool. This situation indicates one of the BEM challenges of insufficient integration of BEM tools with existing design tools.

- *None*

- The proposed SEED project seems to be most promising. All other future goals, like a mobile app seem to be obvious. Also the assessor qualifications seem to be essential to have more impact with asset score in the future.

- Good next steps.
- Good to add mobile capabilities for table data collection.
- Interested in learning more about SEED and city AP and reporting platform for cities.

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

***High*: 5** reviewers

- As I mentioned above, this project is a crucial piece in the puzzle of transparency and helping bring energy efficient buildings to the forefront of real-estate market decisions.

- The Asset Score tool appears to be a functional simplification of key energy analysis tools from the DOE, appears to be user-friendly, and appears to meet its key purpose while having a well-polished appearance. Not having used the tool, I can't be certain of its functionality, but it appears to be high-quality.

- The value of Asset Score project deliverables to the key market is high. This is due to the fact that Asset Score tool features are in line with the needs of the market which are; (1) low-no cost application, (2) ease of use, less number of inputs during model development, (3) fat response with some sort of a standardized easy to recall performance metric.

- With the goal to only impact 1% of commercial buildings by 2020, the goals seem to be not very ambitious. Yet the value of the delivered tool can be considered high.

- Love the tiered approach of simplified inputs for preview and full score. Low barrier to entry. Aligns with residential asset score.

***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*: 5** reviewers

- The usability and customization of the software will reduce barriers for users.

- Deployment activities are relevant to receive sufficient emphasis. This is due to the fact that Asset Score directly attacks one of the most significant BI market barriers: information inadequacy in building energy performance evaluation. Asset Score recommendation mechanism is critical to inform user about possible high efficiency technologies and energy efficiency operations that they can achieve. Users can easily (virtually) deploy these and immediately see the effects on whole-building energy performance by the help of a standardized scoring system which sets a common/fair ground of one-to-one comparisons. Awareness about existing performance level and recommendations for how to improve these performance levels are provided with the same software technology of Asset Score tool.

- *None*

- The performance evaluation of buildings as a whole system is essential to the achievement of the BTO goals to reduce building energy performance as indicated. This reviewer is therefore not quite clear why the

goal for this tool is set so low. It will be difficult to achieve the BTO goals, if energy remains so cheap and no incentives are put in place to conduct and asset score rating.
- Without major marketing efforts, it will also be challenging to implement the tool in the market on the side of such popular tools as LEED certification. Maybe a path forward could be to connect asset score to the LEED certification process, because that is established and the major score in the market for architects and other building construction experts.

- Good info and presentation on the testing of data models.

***No*: 1** reviewer
- While I think that many key areas are being emphasized, the team should again focus more on collaborating closely with its users (in industry or the public sector) to ensure success. The tool is currently a great representation of what the team thinks that the industry needs, but a more active approach should be utilized to ensure that it is meeting needs.

H. Additional Comments and Recommendations

1) **Project Strengths**

- I'm confident that this project has undergone the amount of thought and detail that's required to pull off such an immense task.

- Great technical tool that boils down the value of efficient buildings to a simple, user-friendly interface. Focus on ongoing improvements to tool. Team addressing potentially large and impact audience.

- The project exhibits strengths in tackling with the informational barriers which prevents key stakeholders (building owners, real estate managers, architects, ESCOs, etc.) to use high efficiency technologies an operations due to their lack of robust ways to asses and compare building energy performance. This is provided by no cost, easy-to-use Asset Score tool which can generate comparable, standardized metrics for a wide range of building types and use cases.
- Asset Score's building performance scoring method is based on solid statistical analysis technique (developed in collaboration with NREL) which improves confidence in the outputs generated by the system.
- Asset Score seems to provide flexibility to give answers to analysis questions at varying levels of complexity/sophistication (very high level analysis to detailed analysis as more building model parameters become available to the user).
- Open Studio OSM model file generation improves connectivity to other design decision support tools within the same ecosystem of software technologies.
- The planned future work of establishing assessor qualifications and protocols for quality control is necessary and cannot be seen at other similar decision support programs.

- *None*

- Asset score as a tool to compare the physical characteristics of a building by use type is an interesting idea and should be valued, but at the same time, it is also a very abstract concept, because a buildings real performance can only be evaluated during operation and thus this reviewer would suggest to report the asset score alongside an operation score.

- *None*

2) **Project Weaknesses**

- I was unable to detect many.

- The project does not focus enough on incorporating the feedback of its key users moving forward. The tool should focus more on continual improvement based on feedback and market needs. The tool seems too focused on improving surface-level usability features rather than improving functionality based on feedback from key users.

- Lacking geometric model interoperability with other design tools (particularly CAD and BIM tools) through the use of standardized data structures (such as gbXML or IFC).
- Net zero energy building design features and design improvement strategies to reach net zero energy level are not existing and they cannot be found within presented future plan items.
- Asset Score can have increased connectivity with Open Studio ecosystem of tools if relevant capability to share and execute Open Studio Measures were realized.
- Emphasis could be given to architectural design companies as an extension of collaborations to reach key market leaders.
- Asset Score only provides deterministic point answers instead of revealing a range of variance for a specific building model set up to reveal uncertainties and to evaluate possible risks associated with a proposed design solution.
- Asset Score could provide recommendations with EE measures that can rendered as HIT applications, at least 15 different HITs could be established to indicate demonstration activities for CBI interim market goals.

- *None*

- The weakness lies in the fact that the tool is not integrated with the Energy Star portfolio management data base. This will cause confusion in the market place. The agencies should collaborate to develop a strong assessment tool for the building's physical properties as well as its operation.

- *None*

3) **Recommendations**

- *None*

- Please ensure that there is a deep focus on meeting the needs of the core audience and existing partners. The 21 collaborators who made commitments could easily stop using the tool after testing it with 10 buildings if there is no clear value proposition or the tool just seems like a burdensome additional step for those who already have similar, but less energy-focused asset scoring tools.

- *None*

- Coordinate closely with EPA Energy Star for buildings, which is exceptionally widely used and well regarded by the commercial real estate sector. Minimize confusion between the two tools.

- The assessor qualification certificate will be essential for the success of the project. The development of the tool seems to have been quite expensive and the costs of $7million is not immediately obvious.
- The development cost must have been higher than visible.

- Consider import and export for open studio, SEED and city integration.

Project # 25301: Assessment of Advanced Measurement and Verification Methods (M&V 2.0)

A. Relevance

This project was rated **3.43** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project is well positioned to provide valued measurements of performance improvements, which are key to DOE's EERE BTO stated goals in the MYPP. The outcomes of this project, if achieved, will result in increased market based activities which improve the confidence of technologies via verified performance activities, thus leading to increased investment in energy efficient technologies.

- Accuracy in pricing expected savings is a crucial component in incentivizing energy efficient upgrades in buildings of all types. Tools like this one will go a long way toward ensuring that there is confidence in EEM product viability.

- Effective procedure to test market-based tools is a key first step to ensuring quality tools and accuracy in market application. Broad dissemination potential already demonstrated by list of partners and stakeholders. But no direct savings yet. Savings in general seem to be indirect since the M&V process is a post-measure strategy. However, it is critical to guide operations and future retrofits.

- Having accurate M&V tools is essential to reducing risk in energy efficiency measure installation, which can reassure clients and investors alike.
- I feel that the tool is critical to the success of BTO's overall goals and the energy efficiency market at large, BUT the tool does not directly support BTO's goals. Improving the accuracy of M&V tools does not directly increase energy savings for individual projects, but could indirectly lead to greater confidence and in turn more efficiency projects.

- Savings verification are the core of the BTO program goals, therefore this project is extremely relevant to the mission of the DOE BTO program. In the end, it all comes down to the evaluation procedures for buildings in operation. Thus transparent and replicable test procedures for Meter based measurement and verification (M&V 2.0) should be a core mission of the DOE BTO.

- Automated EM&V verification methods are critical for EE program implementation. EERE investment is this initiative is key because the private sector won't do this work.

- Automated M&V from connected devices is another emerging trend. With the growth in connected devices, this is a logical progression. Validation of energy savings is a key component of EE delivery programs.
- It should be a no-brainer to operate the building correctly, therefore this project is essential. Advanced energy occupations t has high payback.

B. Approach

This project was rated:
1) **3.14** 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 appears to be focused on solving the technical issues related to developing rigorous test protocols for credentialing M&V tools - and has been successful in this. However, the project does not seem to have carefully considered how the test protocols and frameworks will be adopted or seeded into the community in a manner that supports longer term (i.e. permanent) use. The infrastructure and support networks required to provide a longer term lifelines for continuing this work will need careful consideration and planning.

- To the extent of my knowledge, which is limited in this arena, this approach is brilliant, as it addresses a significant concern of building owners in terms of needing to have confidence in their investments in energy efficiency measures.

- No specific detail on barriers in the presentation.
- General overarching barrier of time-consuming, low accuracy methods currently available.

- The project, unlike other BTO projects, is laser-focused on one issue: proving or disproving the accuracy and effectiveness of M&V tools to increase confidence in M&V and automated M&V tools. For this reason, the questions in the "approach" section of this review are somewhat irrelevant, but that does not change the fact that this project is laser-focused on addressing a tight cluster of market barriers.
- The project itself does an outstanding job of focusing on those barriers, as the team identified a solid methodology for testing the capabilities of common automated M&V tools in accordance with M&V 2.0.
- The team does not receive "outstanding" for the second question, as they still seem to grapple with answering "What are acceptance uncertainties and confidence levels for regulatory community? How good is good enough?" The team did a great job of testing several methodologies and determining that they are within those accepted levels of uncertainty and confidence levels BUT if they want to see successful future deployment of the tool, they will need to help bound the maximum level of uncertainty allowable.

- The project introduces Statistical cross validation and Uncertainty as risk management tools. This reviewer only recently learned how powerful mathematical tools can be in supporting physical model predictions, therefore this approach is at the top of scientific knowledge as we know today.

- Identified the market barrier of uncertainty for confidence levels in regulatory community. Anticipate these data are not readily available.
- Transparency is key.

- The approach seems reasonable and valid. The research demonstrates that a lot of work has been done to demonstrate the validity of different models.

C. Accomplishments/Progress/Impact

This project was rated:

1) **3.43** for the degree to which it ***has*** supported the achievement of stated ***program performance*** goals, and
2) **3.14** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project has successfully demonstrated achievement of both near term and is well positioned to deliver intermediate goals. Concerns exist regarding the project's ability to reach long term goals. These concerns lie mostly in the ability for the test procedures to find a more permanent basis including continuous maintenance which will support longer term adoption of the test methods. Simply publishing the test methods will not lead to large scale usage of them - an organization needs to feel a sense of ownership around them.

- *None*

- Significant quantitative progress. Limited deployment in the field tests but early enough in the project.
- 10 tool developers represented and 4 organizational partners signed up. Likelihood of follow through is good.

- There is very strong evidence that the project achieved what it sought to achieve based on the presentation and the team's data. The team seems to have met success and to have published its findings. The high quality of progress and accomplishments thus far lead me to rate the project as "outstanding."

- The determination as to whether or not the project WILL continue to contribute to the program's interim market goal is "good" and not "outstanding" because the team as (1) the team has not provided formal guidance on the acceptable level of uncertainty for an M&V tool that goes to market and (2) the team has some open questions as to what body will certify M&V tools as being acceptable (though they have made progress in this direction).
- I consider this project a very likely successful contributor to the program's goals.

- Working with 10 model developers seems to be an appropriate choice and using a mathematical model baseline projection minus the metered equals savings does make a lot of sense in this context. The test procedure for statistical cross validation and how to train the model are appropriately described and spelled out well.

- Great that methods are published thru peer review.
- Median errors and range of median errors are small. Impressive.
- Engaged range of collaborators and stakeholders.
- Identified potential home for testing procedures ongoing thru standards org.
- Would have liked the project team to identify future barriers or limitations.

- To date, the project progress is in line with the goals.
- The next steps and future plans portion was weak. The presenter did not articulate the deliverable and clearly show how the next steps will advance the effort.

D. Project Integration and Collaborations

This project was rated:

1) **3.29** 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 presenter demonstrated positive integration and collaboration with software developers and pilot participants. The also presenter discussed a critical next step as determining an appropriate independent entity to transfer the test procedures to - to support ongoing software tool validation. This is analogous to the role that ASHRAE plays (using NREL staff and DOE funds as subcontractors) to maintain the ASHRAE Standard 140 software validation efforts. This reviewer believes this will be a critical path item contributing to the success or failure of this project.

- *None*

- Project demonstrates a good understanding of the market players and tools available.
- Significant collaboration with partners and even with proprietary tool developers.

- The team appears to have a great understanding of the technical and market collaborators who would be key both in terms of providing M&V tools, helping to test uncertainty, and supporting the project in the future (including potential partners to take over the evaluation process). The team also appears to be engaging key market stakeholders as is needed to achieve buy-in, test a variety of tools, ensure that their process is justified, and alert the industry of their findings.
- The list of collaborators and external presentations is impressive, noteworthy, and has likely helped the team to receive the feedback and support necessary to achieve success.

- The project engages in good, well thought out industry collaboration and is well connected with utilities companies and energy end users.

- Engaged range of collaborators and stakeholders. Was there a reason why regulatory stakeholders didn't have formal collaborative role earlier?

- Project results, to date, demonstrate good collaboration.

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.

- The proposed future work listed for this project is critical to long term market adoption of the test procedures. A difficulty that this reviewer sees is that many of these automated M&V tools are deployed as web-based tools - which means the underlying code can be changed and deployed very rapidly. In scenarios like this, it is not clear the frequency of software retesting needed, considering major, minor or other software changes. (Note: based on personal experience, this reviewer noted that the difficulties achieving cost-effective methods for long-term deployment and testing of evolving difficulties.) Conceivably, the ASHRAE Standard 140 team will also need to find ways to deal with these issues as more software is delivered via web clients as compared to desktop installations of a particular version.

- *None*

- Appropriate set of tasks and momentum exists to carry the project forward.
- Some risks not fully considered (or at least, not presented) such as regulatory requirements affecting utility implementation, or timeline and process for identifying independent entity to be the implementing body for the tests.

- As stated earlier, the future of this tool has some uncertainty, as a regulatory body has not been identified to take this team's work forward AND the team has not yet defined the level of uncertainty that is acceptable for an M&V tool.
- The team seems focused on tying up these questions and others, and I expect them to be successful.

- The proposed future works seems to be slightly unclear and it seems that the intended collaboration with ASHRAE are not yet well established. This seems to be all still not well thought out. While the project team used ASHRAE guidance for uncertainty in the savings as a function the model fitness in the data in the pre-period……depth of savings you are expecting to observe, the obvious collaboration with ASHRAE does not seem to be well established yet. ASHRAE has a very well established technical committee on measurement validated models....

- Logical and achievable.

- What happens with the study results? Will there be a ranking of the best M&V algorithm/method approaches? The next steps were unclear.

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

***High*: 6** reviewers

- The research conducted as part of this project is of the form that either would have never been conducted by the private sector or, if it had been conducted, would have never been shared into the public domain. For that reason alone, the project has produced very valuable sets of deliverables, including test standards.

- If the tools work as well as they are expected to, there is a significant reason to expect that this project, in conjunction with the Energy Asset Score and other projects in development, will be a game-changer for boosting energy efficiency in commercial buildings and beyond.

- See previous comments in A above.

- The presentation indicated a high quality of rigor and significant communication with the industry. The project appears to be well-regarded, impactful, and focused on an important topic.

- The utilities companies will benefit greatly from this tool.

- *None*

***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*: 7** reviewers
- From a technical perspective, yes. The project has been very successful in attracting interested stakeholders to participate in pilots, provide datasets, etc. The key research areas are receiving sufficient emphasis.

- This project has had a clear and specific focus, I suspect from the get-go, which has helped prevent it from experiencing "scope creep" or other challenges to more experimental, softer science types of projects. You've done an excellent job on what must be a monumental and very technical task.

- Yes, but others should be considered as well, such as:
  - Regulatory agency reaction and needs and link to utility ability to require tested tools.
  - Logic model or path and criteria for identifying and selecting 3rd party organization to implement testing.
  - Interface between automated M&V tool and on-board diagnostics of equipment.

- The project is focused around one key research area, and has done better than any other project that I have reviewed at being laser-focused on that single area.

- Actual energy savings can only be verified in building operation, therefore the development of a fine-tuned strategy for measurement and verification is essential to achieve the DOE BTO energy saving goals.

- Yes, this project has clear bounds and clear goals for next steps for testing and implementation.

- As stated research to date appears good with tangible and solid results. However, what the next steps are was unclear.

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

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project has provided a much needed analysis of the capability of interval meter data to be used to provide accurate estimates of savings. Prior to this project, many claims of savings (when interval meter data were being used) were met with suspicion, as the underlying tools were using black-box or grey-box non transparent algorithms that were difficult at sometimes impossible to inspect. This project has significantly raised the confidence (no pun intended) of users of these black-box or grey-box tools for the purposes of automated M&V. In addition, the project has also exposed the 'capability' of public domain and transparent methods of determining estimates of energy savings. This also raised the confidence of users of

these approaches as to the credibility of the predicted savings outcomes. Finally, this project exposed that differences in savings estimates (comparing the black box/grey-box tools to the open source tools) are not large in magnitude. That distinction is an important contribution to the body of M&V knowledge that the private sector would have never been able to arrive at.

- This is a very impressive project with far-reaching implications. The flexibility of the types of M&V tools to evaluate potential savings is a terrific add-on, and the fact that you've been able to get within such a high degree of accuracy is fantastic.

- Critical area to be working on. Timely. Cost-reduction is essential to move forward in the market.
- Researchers have deep understanding of the technical issues.
- Significant outreach already to national and regional organizations and conferences.

- Necessary and useful third-party evaluation of key tools for employing EE. Seemingly rigorous methods used. Great use of external stakeholders for validation, feedback, and testing. Excellent external communications. Vision for this project's future promotes third-party validation of M&V tools in industry.

- The strength really lies within the application of mathematical models for measurement validation within the building energy performance realm and the collaboration with utilities companies.

- Has potential to offer EM&V at significant savings of $ and time. Testing procedures that are rigorous and third-party neutral are essential.

- Work to date is solid.

2) **Project Weaknesses**

- This reviewer sees the ability for the project to successfully transition from DOE funded support to a more holistic and self-sustaining mode to be a project weakness. This will be a difficult transition to make, for many reasons both technical and political. The project needs to direct focus and effort on developing a strategic plan which, if properly executed, will lead to a long term 'home', allowing the important research that has been conducted to continue to influence future investments in technology.

- I don't have enough subject-matter expertise to comment on the project's weaknesses based on the information given.

- Unclear what the resulting savings can be on average or by building type. Will this just improve the certainty around reported savings or will it actually lead to more savings.
- No delineation of criteria to be used in determining appropriate entity to take over and implement testing.
- No marketing strategy stated for market requiring or expecting tested tools, or having tools that are rated, etc.

- The team has some important unfinished work; namely the two key points mentioned above:
    - 1. The level of acceptable uncertainty for M&V tools has yet to be defined, and
    - 2. The team has yet to directly engage an organization to take over the role as third-party validator.

- The project should do what it plans in collaborating with ASHRAE, no other perceived weakness as this is a very thoroughly presented project with a modest budget and good outcome.

- Would like more details on accuracy in absence of 15 minute interval data. Hourly and monthly data, for example.

- Where is the project going? What are the key deliverables going forward? Was the key deliverable the study to date? Then that needed to be said. How will they take the study results and create a tangible plan to advance automated M&V.

3) **Recommendations**

- No additional recommendations at this time.
- I would say that translating some of your messaging could be a challenge. The graphs on Slides 8 and 10, for example, needed some additional labels for explanation. I mention this because reaching a wider and more general audience with this information will require absolute clarity in communications.
- It would be helpful if an estimate of additional savings that can be claimed with the use of tested/certified automated M&V tools. This could be similar to the add-on savings determination used for commissioning.
- Would be good to include discussion of acceptance and comments received from the publication of the test procedures.
- None that are not already known to the project team. Please continue with the excellent work.
- This is a very thoroughly presented project with a modest budget and good outcome.
- None. This project seems on track for successful completion.
- See above.

Project # 25480: Better Buildings Workforce Guidelines

A. Relevance

This project was rated **3.17** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- This project is attempting to close a difficult gap - creating new national level guidelines on workforce credentials, within a framework of existing guidelines and credentials that have been developed by many market actors. The need for the activity is clear, and the challenges towards achieving.

- Program helps to create job titles, training, certification, and job paths for critical positions in the energy field.

- Coupled with other presentations we saw today, it's clear that workforce development is among the many tools needed to boost the energy efficiency improvement economy, with the added benefits of providing a clear path toward careers for individuals in the clean energy sector.

- The project aligns well with training a workforce that can help bring our buildings to a higher level of efficiency, and maintain them at that higher level. I believe that there are already a number of existing credentials that may have well met the needs of this program without the need to develop new workforce guidelines, but the project still does add value.

- *None*

- The development of adequately trained workforce is extremely relevant to the BOT program. While some researchers might see the salvation in new technology, it is possible to develop net zero building today with just existing technologies, informed users and educated building operation professionals, whose skill set is defined through this program. It might also seem obvious, that buildings should operate as designed, but well, they don't, thus building code enforcement and building envelope and equipment commissioning should be at the forefront of what DOE does.
- The skilled professional to operate buildings should become a norm in the goal to achieve energy reduction.
- It should be a no-brainer to operate the building correctly, therefore this project is essential. Advanced energy occupations t has high payback.

B. Approach

This project was rated:
1) **3.00** 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 project has successfully identified a key market barrier - a lack of national guidelines for energy related professional credentials. The project's approach of building a generalized framework which can be leveraged by others to drive credential acceptance is an intelligent approach.

- The program has already created successful job titles (C.E.M.) and has set up the process to establish other titles. Working with DOE, learning institutes and third party vendors to ensure total process is covered.

- I do believe there is a job market out there for individuals with technical skills in the clean energy sector, and that developing streamlined curriculum and certification/certificate programs through community and technical colleges is an excellent way of delivering that offering. I would have liked to hear more specifics on demand for workers in this field, however; having witnessed a great deal of ups and downs in the job market of late, including demand for technical workers in the renewable energy field (and the collapse of Next Step Living in Boston), it seems important to have a solid understanding of what kind of future lies ahead for workers trained for clean energy jobs.

- Many of the barriers identified focused on barriers to building energy efficiency rather than barriers that relate specifically to workforce skill building and training. The presentation discusses that this project will address a barrier related to the quality, consistency, and scalability of an energy professional workforce, but does not directly dig into these market barriers (rather it jumps right into the logistics of implementing these guidelines without truly addressing significant barriers). The project moves ahead assuming that development of new workforce guidelines is decidedly going to have significant impact.

- *None*

- The claim was made, that accredited workers save energy, this should be validated and communicated with guided case studies to convince the not-yet convinced construction industry.

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 has met key milestones, and the presenter explained that the project is tracking to meet milestone #3 regarding BBWG certificate development. The project has also identified long term outcomes which appear achievable.

- Working on legislation, successful titles already created, outreach programs, etc.

- I have no concerns about the project's ability to be completed and meet its goals.

- The project thus far has not contributed very much to the program's goals. A number of guidelines have been developed, the project has received pre-accreditation, and at least one certifying body will adopt these guidelines. However, little progress has been made thus far toward meaningful program-level goal progress. Workers have not been trained or entering the workforce, and the team's progress thus far has not included as much of the "boots-on-the-ground" action necessary to drive impact. This project is nearing its end and should have more concrete progress to report.
- I believe that the project has a greater likelihood of supporting program goals in the future. Once the first group of workforce professionals is trained using these guidelines, I hope to see resultant impact and continual improvement.

- *None*

- BBWFGuidelines are accomplished.
- Energy manager certification program is installed.
- Accreditation requests are coming in, but it remains to be seen, if a voluntary development and implementation will provide the desired outcome.
- All credentials are valuable and needed in the construction industry.

D. Project Integration and Collaborations

This project was rated:

1) **3.83** 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) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- As the product here is a set of 'voluntary' guidelines, achieving consensus and buy-in from key stakeholder is a key driving factor relating to project success. The project, through the Commercial Workforce Credentialing Council, has successfully performed outreach to key public and private sector stakeholders. The project also appears to have coordinated well with existing credentialing programs, as they have identified both existing ANSI approved credentials provided by AEE (CEM) and ASHRAE (Commissioning) programs, and have closely coordinated with those program requirements.

- Collaboration is extensive. Working with DOE, ANSI, third parties, colleges, etc.

- This project has clearly involved a number of stakeholders and advisors, which there was not enough time to discuss at length during the presentation.

- The team appears to be well aligned with a number of public and private-sector stakeholders that can help influence the program and drive it forward.
- I would have appreciated more detail about how the team was collaborating with government agencies like the GSA and DoD to support job requirements.
- The list of partners involved is extensive, but more information could have been provided about coordination and work with these stakeholders.

- *None*

- The right partners have been chosen and are collaborating with the Better Buildings workforce development team.
- Overall the right partners have been chosen, but this reviewer is concerned, that no larger AEC firm is involved on the Board of Advisers. The designers are critical in setting the mindset for engaging educated professional on the construction site. Engaging the AIA is already a good start, the next step should be a workshop with AEC firm representative to make them aware of the new credentials, so that they start to request them on their jobsites.

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 project proposes to BOP certificated by the end of FY2016, and then to transition into a support an outreach mode of operations. Specific support and outreach tasks were not discussed during the project presentation, but it is expected that they will also in include marketing and communications which provide recognition to accredited programs that meet the voluntary guidelines. From this reviewers perspective, the more difficult tasks relating to this project are complete - the future work, while necessary, is minimal in effort.

- The ability to create needed job titles that will be professionally recognized and have a substantial process to attain the title.

- *None*

- According to the pure metrics above, the project scores "Good," as it identifies many of the barriers that need to be overcome. However, with the time remaining in this project, I fear that there are significant risks relating to the ability of this team to complete their work and provide enough support to their partners to carry on their work beyond the allotted funding period. The team seems focused on the right next steps, but lacks the time to adequately carry the work on.

- *None*

- It would be beneficial to show some marketing efforts for the new workforce accreditation. This reviewer is pretty sure, that not many community colleges have heard of this program yet. See above re: AEC firms, the project needs to engage in many more marketing efforts with AEC firms to change the mindset.

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

***High*: 5** reviewers

- The project has successfully delivered voluntary guidelines which private sector entities have begun designing programs to meet. This represents a successful delivery of the project deliverables.
- Current CEM designation is recognized by ANSI and worldwide.
- Accreditation of institutions and certification of common clean tech jobs will hopefully usher in a workforce that's prepared to implement energy-efficiency measures and improvements to sustain the advances we've seen in the past ten years.
- *None*
- Energy efficiency and energy savings can only be realized with educated professionals commissioning and operating as well as auditing buildings.

***Average*: 1** reviewer

- Approach and process well thought through and communicated well. The quality and caliber of their collaborators would signify that this team has been effective at communicating with and to them.

***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

- The project is rapidly approaching the final phase of 'support and outreach'. As mentioned before, the presented did not elaborate on the breadth and depth of planned activities relating to support and outreach, but the project has $175K allocated to this final project year. From this reviewer's perspective, it would seem to be adequately funded to offer sufficient support and outreach activities.
- Very good process to continue to add new titles and associated training, skill sets.
- Based on the "next steps and future plans," among other parts of the presentation, the project is moving forward having examined the multiple angles required to make it a success.
- I believe that the key areas/activities are receiving sufficient emphasis, although I believe that the project lacks the time and resources to adequately tackle the necessary research and deployment to see the project through to full success.
- *None*
- Very relevant as energy savings are only realized by educated professionals in the operated buildings. The best technology is not worth anything, if it is wrongly operated.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project has achieved the original and difficult goal of creating sets of consensus based voluntary guidelines for credentialing the workforce through certificate and certification schemes. As such, this is a successful project. The strength of this project is the mechanism developed and executed to ensure that the voluntary guidelines are maintained and remain relevant in the marketplace.

- Good collaboration with organizations.
- Proven success.
- Potential legislation to have certified professionals on staff in order to be awarded work.

- This project tackles the multiple barriers for implementation, starting with scoping out and quantifying the types of knowledge, skills, and abilities each of the identified job types will require of its workforce. It's also helpful to see that there are two tiers for each job classification, enabling some workers to try out the field before investing in full certification.

- Excellent collaboration with a great group of stakeholders. Addresses a key concern in the buildings industry and in the federal energy space related to workforce training. Seeks to build off of the success of existing accreditations.

- *None*

- This program is absolutely essential to bring new technology and strategies into the construction industry, because in the future, it will be even more important to commission who technologies work in integration and not as separate add-ons to the building as a whole.

2) **Project Weaknesses**

- The project's weakness is its inability to act fast enough to ensure that it remains relevant when operating adjacent with more agile, and perhaps more robust private sector developed schemes for certification and credentialing. The project needs to ensure that nimble responses to changes in industry practices, technology, means and methods with respect to the specific JTA analyzed remain relevant.

- Time consuming ANSI approval.
- Educating work force on titles and what they mean.

- See above for comments on the wily job market.

- Project lacks the time to see workforce training to fruition. Progress thus far does not demonstrate clear impact on workforce. Skills to be learned by workforce in support of this are not totally clear. Unclear what will happen if loose ends remain open when this project ends.

- *None*

- The weakness lies in the construction industry itself and the lack of central guidance to improve building construction on the site itself. The state commissioning agencies need much more resources to enforce codes and new practices.

3) **Recommendations**

- No additional recommendations at this time.

- Ability to educate others on titles, certifications, etc. and what it takes to become certified. Organizations that are unaware will not put enough emphasis on the title.

- The presentation was very jargon/acronym-heavy, a shortcut I'm aware is tempting when presenting to an insider audience, but I would strongly suggest viewing your communications as an opportunity to walk anyone, with any background, through the project from the perspective of not knowing the context as well as you do on the inside.

- The team should aim to develop metrics that measure the success of their workforce training once implemented. Ideally this could somehow show the improvement in workforce skills, but at its very least should track the number of government and private sector employees seeking this accreditation.

- *None*

- The DOE should work towards enforcing codes across all states and make better building practices common and acceptable across the U.S. That would improve building energy performance tremendously.

RESIDENTIAL BUILDINGS INTEGRATION

Project # 11119: Healthy Efficient Homes Research & Standards Support

A. Relevance

This project was rated **3.75** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Healthy efficient homes is probably the most important and least understood aspect of low energy development, especially in the minds of homeowners. Homeowners rely on the market to deliver what they expect, which is a healthy indoor environment, but there isn't a reliable way to measure and compare. This research project is directly relevant to BTO goals.

- IAQ issues that arise with tight construction represent critical barrier. This project works to provide solutions.

- Important work especially for the low-load home.

- The building community does not understand the relative risk of tight homes and the impact of designed ventilation. Initiatives that demonstrate the need and how to achieve it are important to acceptance.
- A clearer understanding of how great the risk of poor indoor air quality is needs to be presented, based on various building tightness and ventilation approach. Builders need to understand the risk to support the solutions.

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.

- Critical barriers are keenly focused in this approach to addressing indoor IAQ. High value targets for assessment and control of indoor IAQ parameters are identified and a plan to develop an across-the-board assessment tool is on the horizon. Project also recognizes the importance of addressing ventilation in the context of IAQ and pollutant removal. Project design captures focused efforts that address a wide range pollutants, identifying bellwether pollutants that serve as surrogates for broader spectrum indoor air quality contributors.

- Conducting the right R&D to establish informed standards.

- Understanding the moisture and IAQ needs of the low-load house and how address these needs with minimum first cost and energy cost is one of the primary issues in these homes.

- When looking at the participating partners they include Manufacturers of products and entities that are in the business of selling energy efficiency. Many builders see this kind of approach as self-serving. I do not see builders mentioned even once, yet they are the audience that needs to "buy into" the need and to understand the risks if not properly addressed.
- In the field test homes that demonstrate real world results needs to be included, in multiple climate zones.
- I do not see any cost impacts discussed.
- What is the impact on net energy used with different ventilation and air tightness strategies? If the home is tighter but requires more ventilation do I still save energy, if so how much?

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.

- Changes in the residential ventilation and HVAC industry are slow in coming. The project has played an important role in filling the information gaps that have the potential to lead to changes in industry standards, but game changing results remain elusive, and will likely require an interdisciplinary approach between the IAQ/ventilation and building science industries to come to fruition. The project is certainly advancing the bar, to the point at which the industry will no longer be able to carry on with business as usual and will be forced to adapt.

- *None*

- *None*

- Maybe it is too early and future work will bring focus. The results so far appear to be developmental and do not indicate clear cost/benefit solutions.

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) **3.50** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Key stakeholders are well known to the project applicant. Perhaps too well known. Project applicant knows well the process for improving residential HVAC and IAQ. The area reviewed would do well to allow a continued presence of interlopers.

- Who's who of Industry are all involved

- Researchers have been actively involved with the standards setting organizations. They also are receiving sizable cost share support from a number of other parties.

- Include the building community not just researchers and manufacturers.

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 is directly link to past work, as well as a critical component of the success of this long-term program.

- *None*

- Proposed work is well thought out and builds well on work already completed.

- Future plans appears to be addressing much of the concerns mentioned in the review.

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

***High*: 3** reviewers

- Without the deliverables provided by the project, the market would be lost in a sea of competing marketing slogans.
- *None*
- Results will be used to improve related standards.

***Average*: 1** reviewer

- More work need to be done before the deliverables are useful/meaningful.

***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

- There can never be enough emphasis on the area of adequately designed and operated residential HVACs systems. The project represents a long road, whose way points are just being established. We need to continue to support such efforts.
- *None*
- They will reduce the energy used to insure IAQ requirements.
- *None*

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- In general, the project greatly benefits from years of direct engagement with the industry and ASHRAE to address long standing and anecdotal "issues" with respect to the advancement of the state of the art of residential HVAC and IAQ. Continued participation in these venues and feeding the industry information to address concerns is critical to the ongoing success of energy efficiency, HVAC, and IAQ efforts.
- Clear focus on kitchen-originated IAQ challenges. Strong R&D capabilities.
- Well qualified staff with good track record.
- The work of this project should deliver a good understanding of the risks associated with tight homes and the need for designed ventilation. The partnerships are the right companies to develop market solutions. The resources have the needed expertise to arrive at best solutions.

2) **Project Weaknesses**

- The major weakness with the project is entrenched business interests and the power they wield. Maintaining a persistent presence in the market addresses these concerns as well as provides a location to go to address such concerns.

- *None*

- None

- The level of risks are not clearly demonstrated. One example of homes in California measuring Formaldehyde is presented. The real risk based on variables is not substantiated broadly. No cost benefit information is included.
- A better understanding of Builders views would be informative to the research teams.

3) **Recommendations**

- *None*

- *None*

- The development of an IAQ scoring tool for range hoods is very important of low-load homes. Staff participation on IAQ standards committees will enable them to quickly move the results of this work into a position to impact the market.

- The project work is needed and may be critical to not having significant health impacts on homes built to more energy efficient codes. However many in the industry simply do not understand what the potential risks are and therefore will likely fight the adoption of new requirements that cost dollars. Find a way to better educate all in the chain to home owners, including homeowners.

Project # 11122: Buildings America Envelope and Advanced HVAC Research

A. Relevance

This project was rated **2.50** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- Research program is a hands-on, near market ready program that fits neatly within the existing building market segment and cold climate new construction market. The project uses sound technology and targeted advancements to produce reliable energy savings and better indoor environmental control than is currently offered in the market for comparable heat pump technologies. The technology shows real promise, but may have limited market appeal or be slow to be adopted. Market analysis and a plan for market penetration would be a good complement to the technical research findings.

- Heat pump systems provide a big opportunity to reduce electricity use in major regions of the country. However, there are already commercialized products on the market coming close to the design targets of the ccASHP being field tested.
- See system performances on NEEP's cold climate air-source Heat pump Specification; http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump.
- I'm not sure DOE funding necessary.

- This project is actually two separate projects. AS-IHP and CCHP. Low score is based on the fact that the AS-IHP was developed and field tested by Lennox in the early 1990's and never brought to market and the CCHP is not likely to have much market penetration since it is competing against gas heating which has both lower first and operating costs.

- The cold weather air to air system would seem to have limited applicability. Certainly important to the population in extreme cold but to a relatively small percentage of housing across the country. Humidity control in hot, humid climates is an increasing risk especially with very tight homes and the introduction of ventilation. Does the research address this concern?

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.

- Reviewer would like to see some assessment of needed training/technological barriers to full scale implementation. In addition, reliability of a two compressor system vs. a single compressor system should be addressed. Finally, market size and penetration should be addressed.

- Emerging technologies need demonstration.

- The stated problem "… is to increased market awareness of home builders, contractors, and homeowners and ensure performance when integrated with other building systems." While testing of a lab prototype in a lab house will provide date for the latter issue, it will not contribute much to the first point.

- Because these systems are likely to have significant cost impacts, evaluation of cost to performance is critical. No information is provided on the potential cost to operational savings.
- Testing in Fairbanks should be supplemented with testing in a more typical zone for these systems, such as Ohio.
- How robust is the dehumidification system, will it require additional capacity.

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) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Research program represents significant advancement in the state of the art for heat pump systems. Including water heating along with temperature and humidity control is unique. The project thus far demonstrates the technology's applicability in a severe cold climate - would be good to see program move to the next stage of field trials and add demonstrations in more populous cold climate locations and mild climate locations in the continental U.S. such as the upper Midwest and pacific northwest.

- Field tests for AS-IHP begun, awaiting field tests for ccASHP.

- These products should not have been passed on to the RBI program for field testing until there were preproduction/production models available to be tested in homes. No builder is going to be interested in a product based on lab tests of a lab product.

- Success is more likely with the integrated hot water system because it would serve the area of the country that most new homes are built. Cost of equipment vs. operations costs will have to be justified.

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) **3.25** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- The technology shows promise and relevant industry participation is evident. The presentation perhaps assumed knowledge of industry participation or market awareness that would have been good to touch on during the presentation or in the written materials. It would have been good to hear more about the retro-fit market segment and applicability of technology to that market - perhaps an additional industry partner or two focused on the retro-fit market would help round out the potential scalability and market penetration.

- Working closely with two manufacturers and communicating to important industry stakeholders.

- Both of these products had a manufacturer sponsor. The work presented demonstrates a successful prove of concept in both cases. ORNL researchers have done a good job of developing the product and testing. There is a large gap between this work and actually bringing the products to market and ORNL staff do not seem to know what or how much remains to be done.

- While I would typically suggest more builder involvement this project is at a stage where that is not needed yet. Good Manufacturer involvement.
- Not sure there is a benefit to posting on the solutions site yet. The solutions site should focus on what is commercially available today. If future products need to be communicated it would be better in a separate location.

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.

- All in all, this reviewer is impressed with the potential of this new heat pump and water heating technology. The research investment thus far demonstrates a good deal of value for the research dollar and proposed future work promises even more value. The plans clearly build on past progress and are sharply focused on a few barriers, but a little more background on other barriers touched on above, which are perhaps non-technical in nature, would be good to be incorporated into the research program moving forward.

- Behind schedule on ccASHP field tests.

- Upon completion of testing in 2016 no additional work is proposed. Concur with this plan.

- Future work planned should bring greater clarity to the potential of these systems.

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

***High*: 1** reviewer

- Expanding the cold climate range of heat pump technology will provide homeowners, builders, and utilities with an additional HVAC system option that didn't otherwise exist. The outcome of the research program and field tests will provide a significant amount of data to allow homeowners, builders, utilities, and manufacturers to make more informed decisions regarding their HVAC system and which system will deliver the most comfort for the most value.

***Average*: 3** reviewers

- *None*

- The target audience is listed as builders and homeowners. Test results from a single lab model tested in a lab will not be of much interest to either of these audiences.

- *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*: 3** reviewers

- There is a high degree of confidence that the next stage of the research program will address key research areas and deployment activities to bring the technology closer to market readiness.

- *None*

- *None*

***No*: 1** reviewer

- There are no deployment activities in the work done nor plans for any in the future.

H. Additional Comments and Recommendations

1) **Project Strengths**

- Expanding the reach of proven heat pump technology will be an important tool for utilities to have at their fingertips in the future as they seek additional ways to shave peak demand loads. Using existing technology means little additional training for a ready workforce.

- Seemingly strong in-field testing procedures.
- AS-IHP concept presents a creative solution.

- The AS-IHP seems to have good potential for application in both low-load and even as a retrofit heat pump water heater in most homes as long as the water heater and HVAC equipment are close to each other.

- Integrated HVAC and Hot water systems makes common sense. The dehumidification aspect needs to be clearly understood as to whether it can address all humidity risks with or without supplemental support.

2) **Project Weaknesses**

- Market penetration could be challenging for a variety of reasons - 2 compressor system vs. 1 compressor system; applicability to retro-fit market; and advancements in mini-split system manufacturers/installers.

- Concerned ccASHP is a technology that the market is already providing.

- Lennox developed and field tested a preproduction version of this product in the 1990's but never brought it to market. Need to understand what drove this decision at that time and if conditions have changed so they are ready to begin production of this product.
- Initial work on the CCHP was started when natural gas prices were high. Do not think the product can penetrate the market at gas prices any time in the near future.

- The need for Cold weather heat pumps is limited. Not sure the effort is worth it, better to provide more support for the warm weather integrated system.

3) **Recommendations**

- *None*

- *None*

- Recommend you see if you can contact Dutch Uselton who developed the original AS-IPH product for Lennox to learn why the original product was not brought to market and what has changed. It appears that this product could be retrofitted to any HVAC system. Should do a study to determine the benefits with each type of system as this may greatly increase its market potential.
- As with any research like this the results for both products should be well documented and stored where they will be available in the future when conditions change.

- HVAC systems sometimes run into challenges with working over the long term. Testing of environmental stress and operational stress must also be demonstrated to gain builder acceptance.

Project # 12204: Energy Savings with Acceptable Indoor Air Quality Through Improved Air Flow Control

A. Relevance

This project was rated **2.25** for the degree to which it supports overall Building Technologies Office (BTO) goals and objectives.

- The research program was quite narrowly focused on improving the combustion safety test methodology. The field test sampling size was small, for a variety of legitimate reasons, but it ultimately just provided a tantalizing glimpse of the possibilities for simplifying the test, as well as uncovering installation errors that cause spillage. RBI's reduced EUI goals could certainly benefit from limiting the number of false positives of existing homes to allow for some level of air sealing and insulating, and the general public would greatly benefit from close inspection of their systems to ensure they are installed correctly.

- Combustion test failures are a clear market barrier/concern to air sealing existing homes.

- Good study. The issues are important in both new and retrofitted homes.

- The concern of false positives is less than ten percent of all homes tested. If half of the results were changes it would still not make a meaningful difference in overall results.

B. Approach

This project was rated:
1) **3.00** 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.

- Though the sample size was small, the consistency of results was telling. All in all, the research program did an excellent job of outlining the limitations of the data sets available and identifying the type of information that would be useful to be able to further analyze the market potential for reducing false positive combustion safety tests.

- Not enough information about ability for new test to ensure safety is maintained.

- Identifying safety issues when there are combustion products in the home is of primary importance, however false positive measurements can result in opportunities to save energy being missed. This is especially true in the retrofit market.

- It does not appear to be a critical market barrier to energy retrofits.

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) **2.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- Because of the limited field testing, and the stated limitation of data sets from several more states or from state weatherization programs, the fact that the research program is over left this reviewer thinking that the end of the research was premature. If the industry is satisfied with more conservative results from current combustion safety testing procedures, then the simplification of testing and potential reduction in false positives offered by the research project may never realize an impact. The real story behind this research project has to do with identifying and fixing problems with installed systems.

- *None*
- Project has been successfully completed and results incorporated into related standards and programs.
- The number of homes affected is too small to have a meaningful 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.

- Key stakeholders were generally well represented, and collaboration with industry and relevant stakeholders apparent and benefitted the project.
- *None*
- A number of the parties with an interest in these issues were involved with the research.
- *None*

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.

- Though the project is finished, additional relevant areas of furthering the study are identified.
- Project is complete...ideas for further work shared.
- Project has been completed, but researcher suggested a need to verify result in a broader array of houses.
- *None*

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

***High*: 2** reviewers
- The study scratched the surface of the potential for improving false positive combustion safety test rates. Perhaps more importantly, the study revealed other system deficiencies for failures that were not anticipated.
- Results are being integrated into standards and best practices.

***Average*: 1** reviewer
- *None*

***Low*: 1** reviewer
- The simplified test protocol will not likely have a meaningful impact on most results.

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

***Yes*: 3** reviewers

- The project was narrowly focused on its target, but yet open enough to be able to draw legitimate inferences from the results for further study.
- *None*
- *None*

***No*: 1** reviewer

- The issue of lack of house diversity needs to be examined and corrected.

H. Additional Comments and Recommendations

1) **Project Strengths**

- First study of its kind to address reducing false positive combustion safety tests. Discovered through field testing that many failures are due to system install deficiencies, not exhaust ventilation.
- New test procedure developed and accepted by BPI.
- Work addresses an important issue with large energy savings impact.
- The project did substantiate that the need for beta testing was minimal.

2) **Project Weaknesses**

- Small field test.
- Unclear how effective the new test procedure is at allowing combustion systems to pass that would have previously failed...doesn't seem significantly easier.
- As indicted by the researcher, results should be verified in a broader array of homes.
- The impact of this project does not seem significant enough to be high on a list of potential work.

3) **Recommendations**

- *None*
- *None*
- Consider a way to get data from programs to verify the results in a bigger variety of homes.
- The project did identify the importance of careful visual inspection of systems to confirm the correct installation of primarily venting. In most cases a test would not be needed.

Project # 12205: A "Plug-n-Play" Air Delivery System for Low-Load Homes and Evaluation of a Residential Thermal Comfort Rating Method

A. Relevance

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

- High degree of congruence with BTO/RBI roadmap.

- Addressing comfort delivery in low load homes (NC), a key barrier to future adoption.
- Traditional duct systems come with a host of problems that prevent realization of performance/comfort.

- A simplified duct design that is air tight could change the industry if this work is successful.

- The development of smaller duct distribution systems to support bringing ducts inside conditioned spaces is the most relevant outcome of this project. It does seem that alternatives to plastic ducts have not been evaluated. It is known that there are barriers to the use of Plastic in HVAC systems and that reality is not being addressed. It should be part of the research.

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.

- Barriers and limits to implementation are very thorough. Difficult to imagine additional barriers. Research project is sharply focused on addressing barriers in a cogent and logical fashion to reach market. Relation to existing PEX plumbing market and challenges provides a good model. However, at this stage of the project, a more advanced understanding of how to overcome ductwork fire code challenges or significant progress towards that end would be expected, as well as an assessment of the energy needed to operate such a system and its relation to other systems on the market.

- Strong approach/planned outputs.
- Demonstrate effectiveness of plastic ducts.
- Characterize pressure/airflow relationship.
- Characterized installed performance.
- Compare to traditional systems.
- Develop install guidance.

- Concept is good. As researcher is aware, need to find a product that meets fire code and is flexible to make installation easier.

- The code barriers are larger than the technical barriers. Solutions that can address the need for smaller diameter ducts systems should focus on materials and performance acceptable in the code, unless the logic as to how and why the code should be changed is also presented.

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) **3.50** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The project is showing great promise and progress towards delivering a novel and easy to install/use duct system. The potential ease of installation/system set up and reduced overall cost is a potential boon for getting ducted/conditioned air to all parts of a home to improve overall IAQ. Would really like to see some market tests and additional builder feedback.

- Still have a lot of work to do in the next 6 months, but should result in a number of very useful resources/learnings.

- If this work is successful it will have a large impact on design and installation of HVAC duct systems in low-load homes.

- Since the work is ongoing it is difficult to assess the potential impact. I am not sure how manufacturers or builder can be engaged, even on a test level, without addressing the code barriers.

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 thus far is appropriate given the stage of development. It is expected that collaboration will expand as system parameters are more defined and approaches to implementation are ironed out and tested.

- Best practices research alliance.

- Good mix of collaboration for this stage of the research.

- It is not clear as to how broad the inputs of potential manufacturers are. I would expect that manufacturers would have resources and expertise to lead research in this area.

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 shows expected levels of increased intensity and focus on addressing market barriers. The potential is promising indeed.

- Zone dampers are huge opportunity to build into future demonstrations.

- Researcher seems to have thought through the issues and planed future work to address problems.

- Not to be redundant but the code barriers must be addressed. What other system solutions are possible, Ducted Mini splits for example. Should there be an evaluation of potential solutions first before this level of research.

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

***High*: 3** reviewers

- Easy "plug and play" duct work system has the potential to revolutionize the residential HVAC duct work industry.

- Small diameter plastic ducting could be a solution to avoid excessive leakage associated with traditional ducts. Demonstrating these types of systems and communicating to the builder community will be very valuable.

- Only a few months of work have been completed on this project. If successful this approach could have a large impact on the energy use in low-load homes.

***Average*: 1** reviewer
- Nothing so far that is actionable.

***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
- Key research areas and deployment activities are identified, but some remain - namely the ductwork material and energy required for the system to perform.
- *None*
- It is early in the research project. A lot depends on finding the types of duct materials that are easy to install.

***No*: 1** reviewers
- Code acceptance of the materials is critical.

H. Additional Comments and Recommendations

1) **Project Strengths**

- The project represents a potential and relatively simple solution to a long-term, vexing problem of good HVAC duct design and conditioned air delivery.

- *None*

- Duct sizing and losses are important issues in any HVAC system especially the low-load home.

- Documented results of how a plastic duct system will perform.

2) **Project Weaknesses**

- An important weakness at this stage is not having a clear plan on addressing the duct work material fire code/building code limitations.

- *None*

- The researcher needs to address ways to modify the system to provide the correct amount of heating and cooling to each load in the home. For the low-load home this will probably require automatic dampers on each duct or zone. The return air duct system also needs to be considered. While this is a potential problem with conventional ducts too, as HVAC systems produce colder supply air, prevention of condensation on the outside of ducts is important. Most conventional ducts have sound proofing/insulation that helps with this problem which this system does not have.

- There has not been a case made that this approach should be high on a list of potential solutions. It may be but alternatives should be looked at first.

3) **Recommendations**

- *None*

- Would be helpful to develop some kind of quantification of potential per home savings compared to traditional ducting.

- *None*

  I would like to understand if this approach can work when it would be cost effective to consider as the best solution. How small a load? When would equipment be broadly available in the market for this type of system?

Project # 15116: Advanced Technical Solutions for Zero Energy Ready Homes

A. Relevance

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

- Program squarely marks key issues identified in BTO/RBI plans/roadmaps. Addressing indoor comfort and humidity control is critical to achieving energy reduction targets. The research program significantly adds to the knowledge needed to reliably address humidity control in low load homes. Should probably also consider thermal buffering in addition to moisture buffering, or at least some assessment of the characteristics of thermal buffering and its relative effect on comfort in low load homes.

- Goal- Ensure HVAC designers and builders have the tools necessary to design and install optimal comfort solutions that address the needs of high-performance, low-load homes.
- Space conditioning solution packages for low load homes major component of BTO MYPP. This project aims to provide tools/info to develop such packages.

- This project addresses issues important to the development of comfortable low-load homes. However, a lot of work in this area has been done over the years starting in the 70's when passive solar homes were being built. Many of the lessons from those years are not used here and the cost of developing these modeling tools to confirm what is already known is quite high.

- *None*

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.

- Barriers to implementation are the gnarliest part of any research and implementation program. Focus on ACCA manual J and S practices is key for reaching better builders. This reviewer would like to see some assessment of the size of market not using ACCA manuals and how to reaching builders/contractors that don't use ACCA approaches.
- On the issue of addressing market barriers identified, the research program is on the mark and tightly focused on addressing barriers.

- Developing tangible resources/outputs/recommendations to further inform improvements in HVAC system modeling/design for home building industry.

- Question whether a new modeling tool will result in a change building practices since we have known how to build low-load passive homes for 40 years.

- Occupant behavior.

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) **3.75** for the degree to which it ***will*** significantly contribute to the achievement of its relevant ***BTO program's*** interim market goal.

- The research program has squarely addressed and will continue to address gaps in knowledge regarding low-load homes, especially with regard to properly sizing equipment for latent and sensible loads.

- On schedule to meet all deliverables on time.

- Evaluation of moisture adsorption/buffering of a building is very useful. It is more important to consider the thermal buffering capacity which is totally neglected.
- While this research covers some important issues, there is much to be done before it is put into a useful tool that can be used by a building designer or HVAC contractor. NREL has a history of developing models that address important issues and are good tools for the researcher, but are never incorporated into tools used by the trades.

- *None*

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) **3.00** for the degree to which the project staff collaborates or coordinates with industry or other relevant stakeholders.

- Project integration and collaboration is appropriate for this stage of the project and is expected to ramp up moving forward as data and knowledge are developed to inform product manufacturers regarding the types of products that will be needed to serve the low-load home market.

- Nice to see they are working with manufacturer partner, although it does seem that the group of partners is fairly small. Don't have any specific groups that I would recommend including.

- While there is general reference to collaboration, there is not much evidence of a real exchange with builders and other labs. There should be partnering with ORNL and LBNL staff who are doing work in the same and related areas.

- *None*

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 plans are well defined and coordinated to reach appropriate partners and milestones.

- *None*

- High costs, no cost share and little or no collaboration indicated.

- *None*

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

***High*: 2** reviewers
- Project deliverables are information that has heretofore not existed. This information will be critical to right-sizing of equipment for latent and sensible loads in homes, which will save money and energy while improving comfort.

- *None*

***Average*: 1** reviewer

- It appears the work will produce modeling tools that can be used by researchers, but not tools easily used by HVAC contractors or building designers.

***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 keenly focused on RBI/BTO research areas and deployment activities with respect to further defining air conditioning loads in low-load homes.

- *None*

- Moisture and thermal loads buffering are an important part of ensuring comfort in the low-load home.

***No*: 0** reviewers

- N/A

H. Additional Comments and Recommendations

1) **Project Strengths**

- Better defining the latent and sensible load control needs of low-load homes is critical to the future of low-load home construction. Relatively little information has been developed over the years and this research program squarely addresses this lack of information.

- Deliverables being completed on time and with specific guidance on how various modeling programs can be improved. Should inform manufacturers' development of new products/designs.

- The issue of moisture management especially the buffering capacity of the building is particularly important in the low-load house.

- *None*

2) **Project Weaknesses**

- The main weakness of the project is a heavy reliance on computer modeling, which is understandable at this stage, but will need to be kept in check against as much real world experience and data as is available or will be developed through the research.

- *None*

- A more important consideration in the low load house is the thermal buffering capacity and this is not being addressed. The apparent lack of communication with trades and builders to get an understanding of the real world issues is also a concern.

- *None*

3) **Recommendations**

- *None*
- *None*
- Highly recommend evaluation of the thermal buffering capacity of the house and consideration of changes to materials used to increase both moisture and thermal capacity in low-load homes as a way to decrease the number of hours the house operates outside of the comfort range without the need to increase HVAC size and complexity.
- *None*

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