U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2018 Buildings Technology Office Peer Review Report

APPENDIX

November 2018

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

2018 Building Technologies Office Peer Review Report

APPENDIX

April 30 – May 3, 2018
Arlington, Virginia

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Notice

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Final List of Reviewers

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Elling, Jennifer
Xcel Energy

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University of Cincinnati

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Pate, Michael
Texas A&M University

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US General Services Administration

Pyke, Chris
U.S. Green Building Council, Global Real Estate Sustainability Benchmark

Reeve, Hayden
United Technologies Research Center

Roy, Robin
Next Energy US LLC

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University of Maryland

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U.S. Department of Energy

Walter, David
U.S. Department of Energy

Wang, Jialiang
University of Cincinnati

Weber, Robert
Bonneville Power Administration

Wen, Jin
Drexel University

Weston, Theresa
DuPont Building Innovations

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, as well as recommendation for project improvement. Please refer to the Project Evaluation Form on page 4 for full evaluation criteria.

Scores were based on the following criteria and weights:

Score 1: Approach (30%) – Degree to which the project's approach contribute to overcoming barriers, technical challenges, and mitigating project risks.

Score 2: Impact (20%) – Assuming that the **project-specific goals** are met, degree to which the project is **expected to** contribute to **program goal(s)**.

Score 3: Progress (15%) – Based on current project efforts, degree to which the project has met **project-specific goals**.

Score 4: Collaboration and Coordination (20%) – Appropriate to the current project stage and level of development, degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

Score 5: Remaining Project Work (15%) – Degree to which the project has logically planned remaining work to meet the **project-specific goals**. This criterion is not applicable if a project has ended.

For each project, scores for the five criteria were used to calculate a weighted average using the equation shown in Figure 1.[1]

$$\left[\left(\frac{\sum_1^n Score\ 1}{n}\right)x(0.3)\right]+\left[\left(\frac{\sum_1^n Score\ 2}{n}\right)x(0.2)\right]+\left[\left(\frac{\sum_1^n Score\ 3}{n}\right)x(0.15)\right]$$
$$+\left[\left(\frac{\sum_1^n Score\ 4}{n}\right)x(0.2)\right]+\left[\left(\frac{\sum_1^n Score\ 5}{n}\right)x(0.15)\right]$$

(n equals the number of reviewers per scoring metric)

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

[1] For projects that were already complete at the time of review, a weighted average score was calculated based on the first four evaluation criteria only.

Project Evaluation Form

This evaluation form was used by reviewers to provide ratings and comments for projects showcased at the 2018 Building Technologies Office Peer Review.

Evaluation Criteria: Building Technologies Office (BTO) Program Peer Review 2018

A. Approach (30%): Degree to which the project's approach contribute to overcoming barriers, technical challenges, and mitigating project risks.

1. Poor - The project's approach is **not likely** to contribute to overcoming barriers, technical challenges, and mitigating project risks.
2. Fair - The project's approach is **somewhat likely** to contribute to overcoming barriers, technical challenges, and mitigating project risk.
3. Good - The project's approach is **likely** to contribute to overcoming barriers, technical challenges, and mitigating project risk.
4. Outstanding - The project's approach is **highly likely** to contribute to overcoming barriers, technical challenges, and mitigating project risks.

Comments on Approach:

B. Impact (20%): Assuming that the **project-specific goals** are met, degree to which the project is **expected** to contribute to **program goal(s)**. (Note: Program goal(s) were provided to reviewers separately.)

1. Poor - The project is **not likely** to contribute to the program goal(s).
2. Fair - The project is **somewhat likely** to contribute to the program goal(s).
3. Good - The project is **likely** to contribute to the program goal(s).
4. Outstanding - The project is **highly likely** to contribute to the program goal(s).

Comments on Impact:

C. Progress (15%): Based on current project efforts, degree to which the project has met **project-specific goals**.

1. Poor - The project has demonstrated **little or no** contribution to the project-specific goals.
2. Fair - The project has demonstrated **modest** contribution to the project-specific goals.
3. Good - The project has demonstrated **significant** contribution to the project-specific goals.
4. Outstanding - The project has demonstrated **excellent** contribution to the project-specific goals.

Comments on Progress:

D. Collaboration and Coordination (20%): Degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders. (Note: Projects should be scored appropriate to the current project stage and level of development.)

1. Poor - The project staff demonstrates **little or no** strategic collaboration or coordination with relevant stakeholders.
2. Fair - The project staff demonstrates **modest** strategic collaboration or coordination with relevant stakeholders.
3. Good - The project staff demonstrates **significant** strategic collaboration or coordination with relevant stakeholders.
4. Outstanding - The project staff demonstrates **excellent** strategic collaboration or coordination with relevant stakeholders.

Comments on Collaboration and Coordination:

E. Remaining Project Work (15%): Degree to which the project has logically planned remaining work to meet the **project-specific goals**. (Note: Not applicable if a project has ended.)

1. Poor - The project plans are **not likely** to meet the project-specific goals.
2. Fair - The project plans are **somewhat likely** to meet the project-specific goals.
3. Good - The project plans are **likely** to meet the project-specific goals.
4. Outstanding - The project plans are **highly likely** to meet the project-specific goals.

Comments on Proposed Future Work:

What are the project's strengths? Please be specific:

What are the project's weaknesses? Please be specific:

What are your recommendations to improve the project? Please be specific:

Reviewer Comment Summaries and Raw Reviewer Comments

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

Emerging Technologies
HVAC, Water Heating, and Appliances

Advanced HVAC Technologies

Project #312106: High-Efficiency Low-GWP Compressor

Presenter: Parmesh Verma, United Technologies Research Center
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers offered mixed reviews of this project's approach to designing and demonstrating a high-efficiency compressor for small-commercial rooftop units (RTUs) utilizing working fluids with low global warming potential (GWP). Three reviewers commented positively on the new compressor design, its high level of performance compared to existing technologies, and the rigor with which the project team tested the technology. Two reviewers, however, expressed that not enough information was provided for them to substantively evaluate the approach. Most reviewers similarly found the project's weaknesses difficult to identify based on the data presented, but one reviewer did highlight that in order for the new compressor design to work well and cost-effectively, significant RTU system redesigns would be required.

Most reviewers commented that the project had hit its targets and met its project-specific goals, though one reviewer noted that an efficiency target was not hit for one of the Air-Conditioning & Refrigeration Institute's standard operating conditions that was tested (i.e. ARI-B). Another reviewer commented that they felt there was insufficient enough information to judge the project's progress.

Reviewers were unanimous on this project's potential to achieve significant market impacts, in large part because of the new design's use of low-GWP fluids and nonflammable, environmentally-safe refrigerants. Two reviewers highlighted the favorable market trends for this technology, predicting that compatible high-efficiency compressors will become valuable as the market moves toward low-GWP fluids, and also pointing to this technology's potential application in a variety of products.

Reviewers were divided on the project's collaborations. Two reviewers approved of, and applauded, the project team's partnership with Carrier, commenting that having an original equipment manufacturer with significant market share on board could provide invaluable information on market forces, manufacturability, supply chain issues, as well as aid with commercialization. In contrast, one reviewer felt like the project team was not transparent about partner relationships, was critical of the fact that coordination with entities outside of Carrier was absent, and even identified the project's close partnership with Carrier—and the fact that results from this federally-funded project could only be shared with Carrier—as a weakness that might hinder the long-term impact of the technology.

Weighted Average: 3.05 # of Reviewers: 5
Approach: 3.00 Impact: 3.40 Progress: 3.00 Collaboration/Coordination: 2.80 Remaining Work: N/A

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- It appears that the project team is putting substantial rigor in testing the new technology.
- Difficult to comment on approach as very little information on the technical approach was given,
- N/A
- The cost of cooling and dehumidification is because of the electrical power to operate compressors. This project is developing a new compressor that has a higher performance compared to existing technology.
- Collaborative internal team maximizes design and implementation. Use of existing supply chain encourages realistic component cost estimates.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.40** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Project is having substantial potential to be rolled out to various products.
- High efficiency compressors will be valuable technology as the market moves to low GWP fluids.
- Great potential impact.
- The impact of the compressor being developed here is large in that it not only reduces the cost of system operations, but it will also allow for the use of both nonflammable and environmentally safe refrigerants.
- Successful completion of specific goals sets up follow-on project for system demonstration and field trials. This contributes to program goals of developing high efficiency low-direct GWP cooling RTUs for the light commercial market.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- Difficult to judge - little detail.
- Progress reported seemed to be in line with the expectations of the program, though there was a 3 month extension to the project and the ARI-B efficiency target was not hit.
- Good progress on proposed outcomes.
- The project appears to be on schedule and the project is highly likely to meet all of the project goals.
- Has met project-specific goals.

D. Collaboration and Coordination

This project was rated **2.80** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Unclear, or I missed that part in the presentation.
- UTRC is well positioned with Carrier as a collaborator. Having an OEM as a partner is very valuable in understanding market forces, manufacturability, and supply chain issues as technology gets adopted.
- The coordination with other entities is poor, no partners outside of UTC. The lack of transparency and availability of information from a project that is federally funded is disturbing.
- There are a number of strategic collaborations that are helping with technology development and assisting with commercialization.
- Collaboration between internal business units contributed to project success.

E. Remaining Project Work

This project has ended, and therefore was not rated for the degree to which the project had logically planned remaining work to meet the ***project-specific goals*.**

F. Additional Comments and Recommendations

1) **Project Strengths**

- Project rigor, market leader has good market share, leading to large potential impact.
- Compressor technology that appears to be a good match with low GWP fluids.
- The potential impact is huge and the team seems to have demonstrated competitive efficiency with a prototype which is exciting.
- The projects' strength is that the technology developed will reduce operating costs, and could assist the phase-out of environmentally harmful working fluids.
- Radical departure in compressor design deviates from the typical incremental improvement approach and has the potential for technology transformation.

2) **Project Weaknesses**

- Can't judge since little detail disclosed.
- Technology requires significant system redesign in order to make compressor work well and to make it cost effective.
- The federal funding of technology development that can only be shared by a single entity is alarming and may hinder the long-term impact of such a technology. At the very least it reduces the potential energy market to that consumed by Carrier.
- There are no major projects weaknesses.
- Difficult to assess with data presented.

3) **Recommendations**

- It would be outstanding if details are published after the project reaches market introduction. This may be a good publicity for DOE.

- N/A - project is complete, but it would have been nice to see more technical details. I know there are issues with business sensitive data, but very difficult from the data presented to understand technical positives and negatives

- A project of this nature should require more partnership and/or collaboration to proliferate some of the key technical outcomes to the world in a way that makes them useful to more organizations in addition to UTC.

- The project has progressed satisfactorily and the technical challenges that have arisen appear to have been addressed and solved.

- N/A

Project #32226m: Fuel Cell Cooling, Heating, and Power (CHP)

Presenter: Moonis Raza Ally, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers expressed general concern with this project's approach, finding it only vaguely described, with two reviewers commenting that the project's plan and direction were unclear. All reviewers noted that the strongest aspects of the project were its ability of generate electricity and cooling using one source of fuel, while lowering costs and reducing harmful working fluids. One reviewer warned, however, that the approach should not be dependent on fuel cells—as fuel cells only have a 2-3 year stack life—instead recommending a focus on microturbines. One reviewer suggested that the team investigate the effect of the project's liquid desiccant's on health and fire risks, as this could be a potential publicity nightmare, while another reviewer stressed the importance of investigating a lower cost liquid desiccant.

Overall, reviewers found it difficult to determine the progress of the project based on the Peer Review presentation. Based on the presentation, however, most of the reviewers agreed that the project appeared to be on schedule to meet projects goals. Furthermore, reviewers generally agreed that, if the project were successful, it would have a significant impact in displacing global-warming-potential refrigerants, help flatten the electricity demand curve, and minimize the use of natural gas for power. Two reviewers were hesitant that the project would mature to completion and have an impact, however, noting that the milestones identified in the project are focused on monitoring the dehumidification performance of the system and performing modeling.

One reviewer commented that the project's collaborative efforts were not clear, and two reviewers had trouble identifying the specific role played by ORNL in the project. However, several reviewers applauded the project's three major partners, as well as the existence of a CRADA.

Weighted Average: 2.96 # of Reviewers: 6
Approach: 2.60 Impact: 3.00 Progress: 3.00 Collaboration/Coordination: 3.40 Remaining Work: 3.00

A. Approach

This project was rated **2.60** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Insufficient detail to judge on technical issues. The overall concept is a very promising approach.
- Technical approach overall seems good as long as it is not dependent on Fuel Cell technology. 2-3 year stack life almost seems like it immediately disqualifies fuel cells. Presenter mentioned that micro turbines are better from both a durability and initial cost perspective. Perhaps that should be the focus moving forward?
- The testing of the unit is a good idea but it is not clear precisely what ORNL is doing aside from testing in the psychrometric chamber.
- The approach presented is quite vague. NG-powered primary driver (FC or MT), desiccant dehumidification and heat exchanger. So the project seems like an integration of power generation, cooling, heating and dehumidification under one umbrella. The concept and prototype has been developed by the Be Power Tech Inc. The practical role of the Blue Frontier is not clear. ORNL's role is energy simulation and LD selection. It looks like ORNL has completed some prior work that is not a part of the presentation materials (prior tests are mentioned on slides 11 and 13 stating that there were some "prototype tests at ORNL provided valuable information...").
- This project innovatively approaches multifunctional fuel cell Cooling, Heating and Power (CHP) by integrating natural gas – driven liquid desiccant air conditioning and onsite fuel cells for power generation.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- If it works, then this project will not only displace GWP refrigerants but also increase primary energy efficiency through “site of use” combined cooling and power generation.
- Adoption of this technology should help to flatten the demand curve.
- A combined air-conditioning and power generation system is an interesting idea but it isn't clear from the outcome of this project that there will be enough maturity in this product to compete and make an impact
- The impact is not clear. Slide 9 states "IF the project specific goals are met", however, the presentation does not specify any goals. Based on Key Milestones the project is focused mostly on monitor the dehumidification performance of the Be Power Tech system (assuming) and perform some modeling (not specified in the presentation). There are only 2 Key Milestones listed - there are no future milestones (while planned end date in 2020).
- The impact of this project is huge because of the reduced reliance on environmentally harmful refrigerants and the direct conversion of natural gas to power.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals.***

- The results look very promising. Due to limited detail it is unclear if the performance also is achieved under part-load conditions.

- Progress was not presented clearly, it seems as though completed milestones are presented with future tasks making it difficult to tell where they are in their schedule. Very likely that project is on track, just difficult to tell from presentation

- Seem to be meeting project objectives.

- Based on presentation materials it looks like the project is on schedule, however, the schedule charts missing some months and Go/No-Go decision point.

- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.

D. Collaboration and Coordination

This project was rated **3.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- No additional comments

- Having a CRADA in place seems like a very good indication of strong collaboration and coordination

- Good

- It is not clear - the roles and responsibilities of the project team members should be more defined. Org-chart would be helpful. Engagement should be more specified rather than just stated such as "...utilities are supportive..."

- This project has significant collaboration with three major entities, namely, ORNL, Be Power Tech and Blue Frontier, LLC.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The proposed investigation of lower cost liquid desiccant options is a vital step to make this technology competitive.

- Not entirely clear if the shift to micro turbine was part of the original scope of the project and if not, what effect it has on the remaining work. It was listed as an item, but the effect on total project schedule was not clear

- The pivot to different power generation technologies and new LD fluids seems very risky

- It is a lot to do!

- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.

F. Additional Comments and Recommendations

1) **Project Strengths**

- On site generation of electricity and cooling at high primary energy efficiency with no moving parts.

- A unique approach to meeting latent load without requiring reheat

- A neat and novel technology.

- The approach to deliver the key residential/commercial services (electricity, heating, cooling) using just one source of fuel (i.e. natural gas) is attractive.

- The project's strength is that the R&D, along with the technology developed, could lower costs while reducing the effects of environmentally harmful working fluids.

2) **Project Weaknesses**

- Liquid desiccant's effect/risk on health and fire risks not well investigated. Prior to field demonstrations it should be tested if or if not evaporation of liquid desiccant through the membranes or through leaks can pose a health risk. Bad publicity due to health issues in field demonstrations has the potential to "kill" this technology.

- Not clear that the can meet the objective of 44% primary energy savings at installed cost target
- Fuel cell approach does not seem likely to penetrate market with current lifetime of the fuel cell

- The direction seems poor, it isn't clear who is performing what and why the pivots needed to occur.

- Vague plan, unclear roles/responsibilities and lack of the specific technical solutions to review. However, the reviewer may be just not informed enough due to confidentiality or prior art that is not a part of this year review

- None

3) **Recommendations**

- Prior to any field studies make sure that the technology poses no health risks, both during regular operation or during fire events. A field study gone wrong may easily kill this very promising technology - which would be a shame given its potential and DOE's investment into it!

- More focus on micro turbine

- The pivot to different power generation technologies and LD working fluids seems very risky and a decision that warranted much more discussion in the presentation.

- There are few more attractive concepts that may produce combined power, heating, cooling and drinking water by using the only fuel source as natural gas. The project team may be interested to explore more options rather than switching from FC to MT

- None

Project #32292: Residential Gas-fired Cost-effective Triple-state Sorption Heat Pump

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

Brief Summary of Reviewer Comments

Reviewers generally found this project's approach to be appropriate for developing an innovative heating and cooling technology that mitigates many of the difficulties with ammonia absorption by removing many moving parts. Three reviewers applauded the project's creativity in overcoming some implementation difficulties associated with gas-fired heat pumps, while another saw this project as a promising step towards the use of natural gas as a transitional fuel before converting to renewables. Given the project's thermodynamic complexities, however, one reviewer questioned how challenging it will be to optimize the system to meet efficiency goals. One reviewer highlighted that, while the system's vessels are hermetically sealed, an ammonia leak still posed a risk, while other reviewers also expressed concern with the use of an extremely toxic working fluid. To address this concern, reviewers suggested investigating another potential working fluid.

Although most of the reviewers noted that this technology could perform with a competitive seasonal COP, two reviewers flagged that its use of ammonia in residential applications would limit its market acceptance. One reviewer described that the project's impact may also be limited by the use of a secondary loop in applications currently using direct expansion (DX).

Reviewers found strong collaboration with partners, including relevant industry, commercialization, and academic partners. Similarly, reviewers agreed that the project was making good process according to its project milestones, particularly on the breadboard design. Overall, reviewers found the remaining project work to also be on track, thought one reviewer warned that industry partner's use of a stage gate process while making commercialization determinations may cause a schedule slip.

Weighted Average: 3.34 # of Reviewers: 5
Approach: 3.40 Impact: 2.80 Progress: 3.00 Collaboration/Coordination: 4.00 Remaining Work: 3.40

A. Approach

This project was rated **3.40** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Ammonia based gas fired heat pump; ammonia unit placed outside of occupied space
- Approach definitely mitigates many of the difficulties with ammonia absorption or adsorption technology by removing a lot of the moving part complexity
- This is an excellent approach, a breadboard system is a fantastic way to disseminate the bugs in the program.
- The gas fired triple-state sorption heat pump is an innovative and cost effective approach to heating and cooling.
- Innovative approach to development of high efficiency gas powered heat pumps. Design minimizes moving parts to simplify and reduce maintenance problems in situ. However, the ammoniated salt and matrix heat transfer process is complex system performance is unproven. Although the vessels are hermetically sealed, an ammonia leak does pose a risk.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.80** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Due to the toxicity of the working fluid I doubt that this technology will achieve market acceptance. I most certainly would not want the risk of getting sued over someone getting hurt while trespassing my property and getting exposed to a leak.
- Even if the project goals are met, there are significant headwinds that will make it difficult for this technology make the projected impact:
    - 1) Acceptance of ammonia in residential applications - codes, service, installation, eventual quality and reliability issues
    - 2) Secondary loop in applications currently using DX
- Good potential impact.
- If this system can be validated to have a performance of 1.4 seasonal gas COP at acceptable price premiums, then the impact will be tremendous.
- This project has the potential to create market transformation for gas-fire heat pumps if project-specific goals are met.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- Unclear from presentation, but it appears that the contractor makes good progress
- Progress seems in line with schedule and milestones
- Good progress on the breadboard design.

- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.
- On track.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Good interaction with various partners.
- Great team of collaborators from material suppliers to OEMs, to distributors
- A really nice team including relevant commercialization partners.
- Key partners in this study are impressive, including Saltx Technology, AB, Rheem Manufacturing company, and Purdue University.
- Complex partnership between ORNL, industry and academic partners requires superior project management. Close integration of team facilitated by bi-weekly meetings and assignments appears to be keeping project and partners on track.

E. Remaining Project Work

This project was rated **3.40** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Looking forward to the laboratory results.
- Mostly clear objectives in remaining work, but the commercialization determination line item by industry partners using typically stage gate process leaves some room for schedule slip caused by that process (i.e. recycled stage gates)
- Excellent plan.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- On track.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Overall this seems a very promising concept for moving towards natural gas as transitional fuel before fully converting to renewables.
- Unique technology that gets passed some of the implementation difficulties typically associated with gas fired heat pumps
- An interesting and novel technology idea with a great team, good approach, and promising impact.
- The project strength is the use of a gas fired triple-state sorption heat pump as an innovative and cost effective approach to heating and cooling.

- Having Rheem on board brings a high level of manufacturing expertise and helps to mitigate risk as project develops and technology moves into commercialization.

2) **Project Weaknesses**

- The working fluid and its extremely high toxicity poses a risk, especially if the system malfunctions. Rheem (or whoever ends up commercializing this) will need to very, very(!), carefully conduct a FMEA and risk analysis. Even if the manufacturer is correctly insured against low risk high impact catastrophic failures (e.g. gas burner did not turn off, vessel explodes), this may still be the end of the technology. As a result, I expect costly redundant safety measures which will lead to a relatively costly product – despite ammonia itself being a cost effective and efficient working fluid.
- The proposed concept only allows discontinuous operation. If combined with thermal storage, then this should not be a problem but will further increase cost.

- Headwinds with market penetrations associated with ammonia and secondary systems in residential applications

- More modeling details would have been helpful.

- None

- This is a complex thermodynamic machine that has many moving parts (that don't move spatially but do interact). It will be challenging to optimize system performance to meet efficiency goals.

3) **Recommendations**

- I'd strongly recommend investigating other potential working fluids. Ammonia is an excellent working fluid but I am doubtful that any manufacturer is willing to push this to the market with the risk of high impact failures. Even though Rheem is supporting this: They may not yet be fully aware of the associated risk and discontinue support once the DOE funded period is over. I'd hate for this just being a publicity stunt.

- Get an early handle on how to address servicing in technology design.

- Presenting/performing the modeling efforts will be helpful in the future.

- None

- None.

Emerging Technologies
HVAC, Water Heating, and Appliances

Assorted HVAC&R Technologies

Project #32226h: Innovative, Low-Cost Ground Heat Exchanger (GHX) for Geothermal Heat Pump Systems

Presenter: Xiaobing Liu, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Most reviewers agreed that the project team's approach to the development of a cost-effective ground heat exchanger was acceptable. Three reviewers commented on the approach's potential to drive market transformation through the utilization of natural convection and phase change materials that could break through cost and site restrictions that currently hamper the widespread adoption of ground source heat pumps (GSHP). Several reviewers voiced concerns with the project, however. One reviewer found that putting a large thermal mass (i.e. the PCM) inside of an even larger thermal mass (i.e. the ground) seemed counterintuitive. Another reviewer questioned the performance of the PCM, specifically whether it would provide sufficient recharge and last the life of the GSHP. Two reviewers noted that GSHP installers may be unfamiliar with the new technology—leading to installation and maintenance issues—recommending that the team constrain the installation design, or use both experienced and inexperienced installers to investigate the technology's sensitivity to installation mistakes. One reviewer highlighted the project team's strong modeling capabilities and extensive experience with ground heat exchangers, but another flagged that the project was highly dependent on the ability of computational fluid dynamics models to accurately capture physical conditions, which could limit the project's success.

Overall, most reviewers agreed that, given its early stage, the project was on track and making good progress towards it project-specific goals. One remarked further that all remaining technical challenges appeared solvable, thus keeping the project on track for a timely completion. One reviewer, however, strongly suggested adding a Go/No Go decision after completion of a small-scale field test and preliminary cost assessment. Another expressed that testing a full-scale prototype through both heating and cooling seasons would be beneficial, but did not see this as likely given the project timeline.

Reviewers were split on how well the project was collaborating and coordinating with relevant stakeholders. Half of the reviewers felt that project team had identified a range of partners reflecting a wide area of expertise. The other half, however, noted that many of the identified partners were listed as "potential" partners only, and commented that it was not clear what these potential partners' involvement with the project would be. One reviewer recommended developing a relationship with one potential partner—NYSERDA—as soon as possible, citing the presence of "inertia" among utility research groups.

Weighted Average: 3.18 # of Reviewers: 6
Approach: 3.17 Impact: 3.67 Progress: 3.17 Collaboration/Coordination: 2.83 Remaining Work: 3.00

A. Approach

This project was rated **3.17** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The following issue was not addressed during the presentation: 20-ish feet length – how limited is application of auger drilling due to rock? How many% of US building stock can this be applied to?
- Otherwise this appears to be an excellent project that uses a very systematic approach.

- Approach to evaluating technology makes sense, but the idea of putting a large thermal mass (PCM) inside of an even larger thermal mass (ground) still seems counterintuitive in some cases.

- The approach is solid with a preliminary experimental and modeling effort.

- Approach is quite viable and based on developing reduced-cost high efficiency thermal battery. The cost-reduction potential due to shallow drilling is identified as the major contributor.

- This project focuses on the development and the commercialization of a low cost, high performance heat exchanger for ground-source heat-pump systems applications.

- The approach is acceptable. It is highly dependent on the ability of the CFD models to accurately capture the physical conditions.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Reduction of installation cost of underground thermal storage -30% acc. to presenter

- If the project goals are met, the technology could have an impact, but it's not clear from what was presented that the industry is prepared to accept that impact (i.e. is the boring industry already tooled up for drilling 20ft deep and 10ft diameter holes?)

- The potential impact of this is huge, reducing drilling costs is one very large hurdle for overcoming the issues associated with GSHP technology.

- It is early to assess the project contribution into overall program goals (no preliminary cost estimate was presented for the review). The project team should preliminary estimate the technology cost-effectiveness prior to designing a full-scale prototype. The estimate should be done for major climate zones taking into account the local fuel and electricity prices

- The project impact will be reduced energy use and reduced greenhouse emissions.

- Has the potential to bring GSHP into the mainstream and make it readily available as a residential HVAC source.

C. Progress

Based on current project efforts, the project was rated **3.17** for the degree to which the project has met ***project-specific goals*.**

- Excellent progress based on early stage of this progress. Looking forward to the next peer review!

- Project appears to be on track with the schedule presented

- The progress is good and on schedule.
- It is newly started project so the progress is its early-stage
- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.
- Looks good at this very early stage.

D. Collaboration and Coordination

This project was rated **2.83** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Partners:
  - University Tennessee
  - Insolcorp, LLC.
  - NYSERDA (2nd year)
  - IGSHPA (2nd year)
  - Frontier Energy (2nd year)
- Overall: wide area of expertise in project team
- Very little mention of collaborators and most of them were listed as potential partners
- The collaboration and coordination was unclear from the presentation. The team looks good but it wasn't clear who was doing what work and how the new proposed members were being integrated in the future.
- It would be beneficial for the project to bring Local Distribution Companies for making UTB introduction for the major market players.
- There are a large number of collaborators and partners for this research as listed below:
  - Insolcorp, LLC
  - University of Tennessee
  - NYDERDA (potential)
  - IGSHPA (potential)
  - Frontier Energy, Inc. (potential)
- Good outreach to stakeholders

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- N/A
- Field testing and project completion are both planned for FY2019, but a full scale prototype has not been designed yet. It would seem that a full cooling and heating season would be most beneficial in field testing, but not very likely that this will be accomplished by the end of the project.
- Good project work in the future.
- It should be Go/No Go review point to be incorporated after testing a small-scale prototype and preliminary cost assessment.

- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.

- On track to meet goals.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Buffering of "short term" daily peaks through PCM may allow reduction of overall covered area by boreholes. Very curious how this will work out in field studies.

- Strong modeling capabilities
- Lots of experience with ground heat exchangers
- Good capabilities for lab and field testing

- This is a novel heat exchanger design and it is excellent to see work in this area. The utilization of the combination of natural convection and PCM's is an interesting idea.

- UTB is successfully developed and should a cost-effectiveness with a relatively short payback period be demonstrated - it may be a market winner!

- The project's strength is that the R&D, along with the technology developed, could lower costs while reducing the effects of environmentally harmful working fluids.

- Innovative approach to GSHPs that could break through the cost and site restrictions that currently hamper widespread GSHP adoption. This has the potential for market transformation.

2) **Project Weaknesses**

- Unclear if/how the larger diameter heat exchangers will be thermally connected to the ground. Will these be grouted? What is the sensitivity to "bad" thermal contact if contractor unfamiliar with this technology? Is it more difficult and/or expensive to grout this type of HX?

- Lack of involvement of GSHP installers.

- The organizational part of the presentation could be made clearer.

- Due to early stage of the project there are no solid cost-benefits justifications and lack of credible stakeholders so far

- None

- Lots of technical uncertainties:
    - Will the PCMs provide sufficient recharge?
    - Will PCM performance persist over the life of the GSHP?
    - Will natural convection be maintained in the tube
    - Do the tubes have enough surface area to provide sufficient heat transfer?

3) **Recommendations**

- Conduct field experiments and compare to conventional ground loop heat exchangers. Use both, experienced and inexperienced installers to investigate sensitivity to installation mistakes. Environmental impact of phase change materials, if leaked due to system malfunction? How disposed at end of lifetime? What is the lifetime of encapsulated PCM? Conventional ground loop heat exchangers (HDPE) are considered "infrastructure" with the anticipated lifespan (100+ years) being greater than current lifespan of human beings.

- Work more on the installation side to constrain design better

- A real-world demonstration would be helpful to convincing people this is a useful activity.

- Put more focus in FY2018 on detailed small-scale evaluation and cost justification

- None

- Test in ground at required depth as soon as possible.
- Build relationship with NYSERDA as soon as possible to avoid project lag. Utility research groups can have a lot of inertia.

Project #32226i: HVAC&R Research Collaboration through IEA (and IIR activities)

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

Brief Summary of Reviewer Comments

Reviewers unanimously agreed that this project's approach supports the international exchange of scientific findings, and allows for a continuous robust engagement with industry, academic, and public-sector HVAC and refrigeration peers. Most reviewers found that this project directly aligned with BTO's program goals, in that it allows the U.S. to actively participate on the world stage to achieve energy related goals, and fosters a valuable transfer of technologies and ideas across different international organizations and societies. One reviewer did comment, however, that while this impact is significant, it is difficult to evaluate without appropriate measurements and metrics.

Most reviewers agreed that this project is meeting its project-specific goals in a timely fashion, though one reviewer notes that, given the ongoing nature of this project, it is difficult to comment on progress. Looking forward, reviewers found planned future work to be appropriate and should continue. As previously stated, however, one reviewer found it difficult to comment on the future work of a project without clear milestones.

Reviewers were impressed with the project team's inclusion of high-profile community members and its ability to work, learn, and collaborate with the international community. Additionally, all reviewers found the coordination with partners excellent, and representative of a broad range of cooling technologies. Two reviewers specifically called out the partnerships with the International Energy Agencies Technology Collaboration Programme on Heat Pumping Technologies (IEA-HPT), the U.S. National Committee for the International Institute of Refrigeration (USNC/IIR), academia, and manufacturers. Critically, reviewers agreed that the project's largest issue was its lack of visibility and effective communication to the public, with one reviewer commenting that—as an outsider—it was unclear how to get involved with the high profile groups listed.

Though the project was consistently highly-rated, reviewers none-the-less offered a number of recommendations for the project team. Specifically, reviewers felt that the project team struggled with communicating the success and importance of the project, both to the audience at BTO's Peer Review and to the public at large. For Peer Review, one reviewer suggested presenting the project in a more visual and interesting way to reflect its significance. Two other reviewers recommended that the project be promoted and advertised better, so that other stakeholders can apply to participate in the project, and so the HVAC field as a whole can benefit from the project's successes.

Weighted Average: 3.89 # of Reviewers: 5
Approach: 4.00 Impact: 3.80 Progress: 3.80 Collaboration/Coordination: 4.00 Remaining Work: 3.75[1]

[1] The average reviewer score for Remaining Project Work is based on the individual scores of only 4 of 5 reviewers.

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- This activity supports international exchange of scientific findings and as such allows to integrate the US research community with other countries that in some areas are ahead of the US.
- The approach to strategically participate with international bodies is a great approach.
- N/A
- This project led by ORNL is to promote the competitiveness of US companies by engaging and interacting with various international organizations.
- In this ongoing project, staff appear to maintain continuous, robust engagement with industry, academic, and public-sector HVAC/R peers both in the US and around the globe.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.80** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- International activities widen the horizon of the US research community and as such are critical to the success of DOE and ORNL.
- Actively participating on the world stage with other trying to achieve similar energy related goals should only aid in the DOE/BTO having its desired impact.
- The impact is huge but the metrics for evaluating the impact seem difficult to measure.
- This engagement with international organizations and societies allows for valuable transfer of technology and ideas among all parties and as such has a great impact on HVAC.
- Project efforts contribute to growing US manufacturing jobs, keeping stakeholders up to date on competitive threats from other countries, and making BTO aware of emerging innovative technologies from abroad.

C. Progress

Based on current project efforts, the project was rated **3.75** for the degree to which the project has met ***project-specific goals.***

- This project had led to substantial coordination on IEA events, including some which I was involved in as a student.
- Hard to comment on progress as this is an ongoing and not milestone based project.
- N/A
- The progress is ongoing and steady and hopefully to be continued for years to come.
- FY18 milestones are on schedule to be met in a timely fashion.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- N/A
- It seems that the point of this work is collaboration and it going very well.
- N/A
- The key partners in this ORNL project are organizations that represent a broad range of cooling technologies. Examples are:
  - International Energy Agency Heat Pumping Technologies program (IEA-HPT)
  - US National Team (USNT) for IEA-HPT
  - International Institute of Refrigeration (IIR)
  - US National Committee for IIR (USNC/IIR)
- Excellent collaboration and coordination with IEA-HPT and USNC/IIR as well as academia and manufacturers.

E. Remaining Project Work

This project was rated **3.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- This is an ongoing activity that should not be discontinued.
- There is no clear milestone base work, so difficult to comment on this one.
- N/A
- None
- Project has successfully built and expanded on work from previous and is set to continue as successfully in the future.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Inclusion of high profile HVAC&R community members.
- Working and learning with the technical international community.
- Good to see a program that encourages lots of collaboration and coordination between international/US researchers.
- This project promotes the competitiveness of US companies worldwide.
- Excellent stakeholder engagement with HVAC community as well as international organizations. Joint Annex projects, conference participation and facilitating BTO's activities through the USNT and USNC/IIR all contribute to successfully implementing BTO's MYPP.

2) **Project Weaknesses**

- As with all high profile groups, it is a bit unclear how one can get involved early on in his career. To an outsider this appears to be a little bit of an exclusive club.
- N/A
- N/A
- It needs more visibility.
- The only weakness I see is in communicating the project's value to the public in the Peer Review presentation. The slide presentation is too text heavy and makes it difficult for the audience to assimilate what the project supports, how industry benefits and how successfully the project meets BTO's MYPP.

3) **Recommendations**

- I think it would be outstanding to allow the next generation (post docs, young researchers) to apply to be supported financially to partake in these efforts. In particular, the financial support would make it possible to justify time commitment to university administration. This would allow DOE to unlock access to a lot of talent.
- Continue doing what is being done
- Improve the impact metrics for better evaluation of the program.
- ORNL should promote and advertise this project so that others in HVAC can benefit more from what it does
- Even though you have a BTO template to follow you could start by working with communication staff at ORNL to figure out how to present this information in a more visual and interesting way. Or you could browse through a book like this to get some ideas: The Visual Slide Revolution, https://amzn.to/2JMXEQg.
- A place to start could be to identify some big buckets of success/effectiveness and focus on a visual presentation of these. Use more examples to communicate the success of this project.
- I can envision one slide of a visual tree of projects/annexes and various funders (ORNL, Universities, Foreign organizations, EPRI, etc) so we can get a better (and visual) understanding of the relationships.
- Additional specific (and important) details can be provided in reference slides.
- In this day of communication via social media, visual communication is everything!!!!! You have so much success to shout about - make it easy for your audience to assimilate.

Project #32226j: Novel Solar Absorption Cooling System to Reduce Peak Loads

Presenter: Moonis Raza Ally, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers were generally pleased with this project's approach to developing a cooling system that incorporates a liquid desiccant element, finding it to be an innovative thermal storage approach to reducing peak loads by using the liquid desiccant to store dehumidification capacity. Reviewers also applauded the project's promising method of decoupling latent and sensible loads and regenerating the desiccant with renewable energy. However, while approving of the project's approach, one reviewer questioned why liquid desiccant systems had not already penetrated the market, and noted that the large space requirements could limit commercialization. Another reviewer also raised questions about whether evaporation of the liquid desiccant could affect the system's performance and function, as well as about whether evaporated desiccant could pose any health risks for building occupants.

A majority of reviewers agreed that the project's displacement of high-global warming potential refrigerants, combined with its reduction of peak grid demand by separating latent and sensible loads, would have a significant impact. Two reviewers, however, felt that the project's impact was not clearly expressed during the Peer Review presentation. According to one of these reviewers, "the claim is that the technology can be used to adjust demand side curves, but those claims seem independent of the liquid desiccant technology, and more closely related to any system that separates latent and sensible loads."

Most reviewers commented that they found the project to be on track, and that it was progressing at least satisfactorily. Often, however, these remarks were caveated with remarks about how the project was still early stage. One reviewer also questioned whether the time and funding that were allotted to this project were appropriate, noting that evaluation of liquid desiccants—constituting half of this project's effort—had already been conducted as part of a previous project.

There was no consensus amongst reviewers on the project's remaining work. Two reviewers expressed their expectation that the project would be completed on schedule, but two others felt that bringing the technology to market within three years would be a challenge. In contrast to the latter two, a third reviewer felt that the project's timeline—given its funding level—was not aggressive enough. Reviewers also offered a few recommendations for the project moving forward, including that the project team should consider using a hybrid solar-gas approach as a heat source, as this would function regardless of weather and time of day, minimizing the risk of user complaints.

Most reviewers correctly noted that the project team had not yet collaborated or coordinated with any outside stakeholders. One reviewer commented, however, that they found it difficult to evaluate this project's collaborations, citing the Peer Review presentation's reference to other product development partners that the project team had engaged with on other research efforts; this reviewer was uncertain about if or how these product development partners were linked to the current project.

Weighted Average: 2.86 # of Reviewers: 5
Approach: 3.00 Impact: 3.20 Progress: 2.80 Collaboration/Coordination: 2.40 Remaining Work: 2.80

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Membranes as heat and mass exchangers to capture air moisture. This reduces exposure of desiccant to air. Contractor should clarify on evaporation of liquid desiccant through membrane to air. Good idea to use a hybrid solar-gas approach as heat source. This should reduce the risk of user complaints since it should lead to 100% function independently of time of day and weather.

- The technical approach in general seems well thought out, but is not completely covering a few items:
  - Why have commercialized LD systems not penetrated the market in previous attempt?
  - Additional space requirements seem like a big headwind to commercialization and there's not a big focus on that.

- The approach is ok.

- This ORNL project is innovative in that it was a novel thermal storage approach to reduce peak loads. Specifically, Liquid Desiccants (LDs) are used to store dehumidification capacity, which is equivalent to air-conditioning capacity, and as a result, cooling can take place during periods of high cost power or when the solar absorption system is inoperable.

- Innovative approach – remove the latent heat before it enters the AHU.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.20** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Displacement of GWP refrigerants.

- The presentation did not have a clear explanation of the expected impact. Separating latent and sensible load has significant potential, so I believe the impact could be high if the technology was successfully deployed. It's just not clear from the material presented

- The impact is confusing as the claim is that this technology can be used to adjust demand side curves but those claims seem independent of the liquid desiccant technology and more closely related to any system that separates latent and sensible loads.

- The impact of this technology and approach is that it can solve the age-old question of how to store the energy-producing potential of solar energy, abundant in the daytime, for potential use in those hours without the sun, either because of night-time or clouds.

- The AHU pathway (vs the fabric pathway) reduces technical barriers resulting in quicker commercialization. Utilities with, or considering, significant solar on their grid would benefit from this technology's ability to reduce the slope and peak of the afternoon/evening duck curve.

C. Progress

Based on current project efforts, the project was rated **2.80** for the degree to which the project has met ***project-specific goals*.**

- Project appears to be in early stage. Looking forward to the results.

- Progress seems to be in line with presented schedule/milestones

- It appears that a majority of the effort for evaluating the liquid desiccants was already completed in a separate project which is half the proposed effort on this project. It is unclear why it requires 2 years and $500k to take the results from the previous project and build a prototype system.

- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.

- Early stage progress on track.

D. Collaboration and Coordination

This project was rated **2.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- As far as I could judge, this project does not have a collaboration and coordination aspect.

- The presentation outlines that ORNL has product development projects with Whirlpool, GE, AOSmith, and Lennox, but it's not clear that they are directly related to this research. This makes it hard to comment that collaboration is strong or not.

- There is no stated collaboration but the speaker suggested there were previous partners on a separate study.

- There are a number of strategic collaborations that are helping with technology development and assisting with commercialization.

- In-house team.

E. Remaining Project Work

This project was rated **2.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- It seems challenging to bring the technology to the market place within 3 years. My suspicion is that longer-term field studies are needed first to address potential health risks from evaporating liquid desiccants as well as risks to the built structure from the same source.

- Bringing the technology to the market within 3 years is in the remaining project work and the project ends in 2020. Does not seem that the proposed technology is that close to entering the market, or at least it was not communicated clearly.

- This seems like a 'casual' pace of a project of this dollar-value. The proposed efforts are reflective of a project that may be half the cost of this one.

- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.

- On track.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Good project team, promising method from a thermodynamic approach.

- Decoupling latent and sensible loads efficiently is a major plus
- Regenerating with renewables or with more energy effective means is a great approach

- The liquid desiccant technology is novel technology.

- The project's strength is that the R&D, along with the technology developed, could lower operating costs and reduce the emissions of environmentally harmful GWP gases.

- An innovative approach to solving the energy intensive burden of removing latent heat in the cooling process.

2) **Project Weaknesses**

- Unclear if liquid desiccants pose a health risk. This is both, from an exposure point of view as well as from a flammability point of view – "designer" liquid desiccants are typically based on flammable molecules. Unclear what cost of liquid desiccant is – no answer other than "looks promising" given during the session. This may be a "chicken-egg" problem – cost of the ideal working fluid may be too high without mass production, but no mass production without mass usage. The budget in one of my preproposal in that area consisted mainly of the cost of the needed liquid desiccant and to a lesser extend of team salaries.

- Initial estimates presented on system size could be a major market barrier to technology.

- The proposed progress seems very low given the timeline and budget. I would expect a fully instrumented system and model tool development within 1 year with a follow-on prototype in year 2.

- There are no major project weaknesses.

- Successful development of the fabric with nano-carbon rods pathway is a challenge.

3) **Recommendations**

- The project itself is fine. My recommendation would be to heavily invest into how to address flammability concerns, not only for conventional refrigerants (as already in progress) but also for liquid desiccants. I'd also recommend to address health concerns to increase the publics (and our industry's) acceptance of this technology.

- Focus on optimizing size/complexity of systems while keeping energy savings high
- Clearer presentation of milestones and project participants

- Better presentation of collaboration and partnerships, more detailed explanation of specific project progress outcomes.

- None

- As you get closer to commercialization, suggest comparing the cost performance of LD HVAC system with California's Hot Dry AC standard to see if you will be cost competitive. Here is a link to the original report: Hot Dry Climate Air Conditioner (HDAC) Combined Field Test Report. https://bit.ly/2jqTWRs.
- Reach out to California utilities early on to gauge interest. I suggest Mark Martinez at So Cal Edison, Manager of Emerging Markets and Technology.

Project #32226k: Peel & Stick Sensor for Refrigerant Leak Detection

Presenter: Pooran Joshi, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Most reviewers agreed that the technical approach adopted by this project to develop a low-cost refrigerant sensor—to enable direct and continuous monitoring of refrigerant leakage—was sound. Reviewers highlighted the project team's use of special manufacturing technologies to develop refrigerant sensors at a reduced cost, and identified the project's dual pathways for developing a successful solution as a project strength. However, one reviewer expressed that the project team needed to consider product lifetime in their approach, recommending that the lifetime of the sensor should be comparable to the lifetime of the equipment in which it will be installed. Another reviewer highlighted the difficult technical challenge of characterizing power requirements and achieving low-power options for use in an Internet-of-Things environment, recommending a focus on increasing the power-source life of the sensor or offering a wired solution in addition to wireless.

All reviewers agreed that the project had a significant potential for impact on multiple fronts, including direct emissions, indirect emissions, cost, and minimizing the leakage of flammable refrigerants. One reviewer recommended, however, that the development of these sensors should occur concurrently with the development of an automatic action for affected equipment (e.g. switching on of an evacuation fan, switching off the equipment, alerting staff, etc.).

Though the project was at an early stage, reviewers generally found that it had progressed satisfactorily, and also that it was on track with the presented schedules and milestones that were presented. Reviewers did not agree on their assessment of the project's remaining work, however. While half the reviewer's found the work outlined to be characteristic and appropriate for the project, the other half either could not determine what the specific future work would be or found it insubstantial.

The project team's collaboration and coordination with partners was generally applauded by the reviewers, though one reviewer expressed that the collaboration appeared to be hastily pursued as an afterthought. A reviewer also recommended that the project team consider collaborating with those stakeholder groups that would be applying the sensors in the real world (e.g. original equipment manufacturers and building systems operators).

Weighted Average: 3.09 # of Reviewers: 5
Approach: 3.00 Impact: 3.60 Progress: 3.00 Collaboration/Coordination: 3.00 Remaining Work: 2.80

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The proposed technology should help with reduced cost sensors.
- Technical approach seems good to build off other sensor successes, need to consider product lifetime though (should be comparable to lifetime of equipment it will be installed in)
- The approach was unclear from the material presented. The technologies which enable these technologies was presented but it was not clear how it was proposed to be used in this project.
- The innovativeness of this ORNL project is that it uses special manufacturing technologies to develop refrigerant sensors. This technology is a combination of direct-write printing and pulse thermal photonic processing that then uses roll to roll manufacturing techniques.
- Risk is mitigated by exploring both a direct-write printing and a pulse thermal process.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- It appears that this project is aimed at flammable refrigerants. This may help somewhat with their acceptance but requires additional actions to mitigate the risks of leaks. No point in having sensors if they are not connected to lead to automatic action (e.g. switch on evacuation fan, switch off leaky equipment, alert staff, evacuate people from building through building PA system, if needed).
- Impact could be high on multiple fronts:
    - 1) Direct emissions - catch leaks earlier, fix them earlier, lose less refrigerant
    - 2) Indirect emissions - system perform more efficiently with correct refrigerant charge. The earlier leaks get detected the earlier they get fixed and the longer systems operate at their most efficient charge levels
    - 3) Could be cost effective safety requirement if flammable refrigerants are introduced into common HVAC vapor compression systems
- The potential impact is very important.
- The potential impact of this project is huge in that refrigerant leaks are costly and harmful to the environment so any approach that can reduce these leaks is worthwhile.
- If goals are met, this project should lay the groundwork for widespread use of low cost sensors for monitoring leakage of flammable refrigerants.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- This project is still at an early stage, the shown research is at an appropriate level.
- Appears researchers are on track with presented schedule/milestones
- Progress seems good.

- The project has progressed satisfactorily and appears to be on schedule to meet the project goals..
- Results still early stage

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Well assembled research team.
- Having both Danfoss and AHRI involved in collaboration is a big plus to program. Could be even more beneficial if those applying sensors (i.e. OEMs, building systems operators) were involved with project.
- The collaboration seems like an afterthought.
- ORNL has Danfoss, a leading HVAC company, as a key partner.
- Interest expressed by Danfoss and AHRI.

E. Remaining Project Work

This project was rated **2.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Proposed remaining project work to evaluate sensor characteristics seems appropriate.
- Explanation of remaining work a little light, but schedule seems reasonable
- Similar to the approach, it is unclear what the specific processes used moving forward will be.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- Difficult to ascertain from presentation.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Excellent project team.
- Have a simple, effective, and cheap refrigerant leakage sensor is a huge plus. It seems the technology is not that far off and the researchers have a pretty clear line of sight as well as a good track record in similar work.
- The application is great and the impact will be excellent.
- The project's strength is that the R&D, along with the technology developed, could lower costs while reducing the effects of environmentally harmful working fluids.
- Exploring two enabling pathways increases the opportunity for developing a successful solution.

2) **Project Weaknesses**

- Limited information provided. This is still at an early stage; power requirements of sensors unclear.
- Not enough focus on increased lifetime. Sensor needs to have a lifetime equal to or greater than the equipment it will be installed in as it will likely not be replaced consistently in the field.
- It is unclear what the methodology is.
- None
- Characterizing power requirements and achieving low power operation for use in IoT environment is a difficult technical challenge. And the target of achieving a sensor system that will be an order of magnitude less costly than existing is an ambitious goal.

3) **Recommendations**

- Evaluation of the power requirements appears to be part of the project as mentioned verbally during the presentation. I would also like to see this as part of the Q4 milestone. The entire concept of stick on sensors fails if power requirements are too high. Sensor needs to be able to wirelessly integrate with building management system and chiller controls.
- Increase power source life or offer a wired solution in addition to wireless
- Present more precisely what you plan to do in the future.
- None
- None.

Project #32226l: Design/Optimization of Heat/Mass Exchangers (HMX) using Membrane Technologies

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

Brief Summary of Reviewer Comments

A majority of reviewers felt this project's model development approach was appropriate to overcoming the technical hurdles of a well-defined problem. One reviewer specifically noted that the approach of developing a verified and validated model, and then using this model for design optimization, can mitigate potential sorption issues for heat pump water heater technologies.

Reviewers did not agree on the potential impact of the project, nor the value of this impact. Two reviewers stated that the project's impact would be a reduction of gas and fuel consumption. However, other reviewers either did not have a clear understanding of the project's potential impact based on the presentation, or expected the impact to be a small, incremental step toward fuel consumption reductions. One reviewer specifically noted that the technology developed could lower costs while reducing the effects of harmful working fluids, but another reviewer expressed concern about the cost of ionic liquid desiccants, and recommended consideration of an alternate, non-ionic liquid desiccant as an intermediate step to achieve market penetration.

Given the early stage of the project, reviewers did not have many comments on the project's progress, noting only that it appeared to be on track. Reviewers also generally agreed that the future work laid out is appropriate, though one reviewer commented that details of the future work were too vague to adequately evaluate.

Most reviewers found the collaboration between ORNL and the University of Florida appropriate, given the strong modelling backgrounds, but one reviewer noted the project's lack of qualified manufacturing expertise. One reviewer, however, expressed that the project's stakeholders were not clearly identified in the presentation, and encouraged the project team to define the stakeholders and expand engagement.

Weighted Average: 3.04 # of Reviewers: 6
Approach: 3.33 Impact: 2.83 Progress: 2.83 Collaboration/Coordination: 3.00 Remaining Work: 3.00

A. Approach

This project was rated **3.33** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- This project appears to be focused on modeling. Accurate models will allow further optimization of conceptual designs and feed into future pre-production prototype design.
- Model development plan seems appropriate.
- Very good approach.
- Approach has been proven to overcome the technical hurdles identified in prior years of this challenging effort.
- A potential weakness is sorption HPWH Technology is that verified model are not available for absorbed mechanical components, such as the HMX. This project address this weakness by developing a verified and validated model and then uses this model for design optimization.
- Developing and validating models of absorber components to facilitate system design and optimization used in absorption heat pump systems is a valid approach.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.83** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- Reduction of fuel consumption.
- Development of advanced gas heat pump models should aid in the expected impact, but will be an incremental step toward that impact.
- It is not clear from the presentation how the project addresses the energy market in its entirety presented on the "cheat sheet" slide.
- The impact of the membrane-based HMX strictly depends on the availability of the attractive (efficient and cost-effective) gas-fired heat pump concepts. The reviewed project is targeted to enhance simulation of the membrane dehumidification process. The presented materials are not clearly indicate the direct impact to the program goals.
- The impact of this project is that gas usage can be reduced as new technologies for space and water heating are designed and developed.
- Early stage R&D to facilitate design and optimization of a membrane HPWH system.

C. Progress

Based on current project efforts, the project was rated **2.83** for the degree to which the project has met ***project-specific goals.***

- Early stage
- Project seems to be in line with the presented schedule/milestones
- N/A

- Due to recent start of this project (and accounting the prior work has been done) the progress is fair.
- The project has progressed satisfactorily and appears to be on schedule to meet the project goals..
- Project on track.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- University of Florida – property information and system data for model validation
- ORNL – strong modelling background.
- As this is model development of an emerging technology there is not a high degree of collaboration, but partnering with UFL on the IL properties should be beneficial to the project, addition of a membrane manufacturing partner could further aid the project.
- N/A
- It is not clear who are the project "stakeholders" and what would be the "customers" for the project results.
- ORNL is collaborating with University of Florida, who is a key partner with years of experience with ionic liquids.
- Strong inter-lab team with appropriate skill set to tackle a complex problem.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- No additional comments, this seems well planned out
- Remaining work clearly outlined. Not extremely clear what level of effort the development/testing of the lab prototype membrane HPWH will require. If this level of effort is high, completing this by the end of FY18 may prove difficult
- N/A
- The remaining work scope is described quite vaguely for adequate assessment
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- On track.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Strong modelling project team.
- Building off previous work
- Using researchers strong modelling capabilities

- The modeling outcomes are very good.
- Membrane-based multi-fluid HMX model development and validation is quite useful for the research and preliminary assessments. The actual HMX performance depends on its specific design and application.
- The project's strength is that the R&D, along with the technology developed, could lower costs while reducing the effects of environmentally harmful working fluids.
- Well defined problem and strong in-house team.

2) **Project Weaknesses**

- Ionic liquid desiccants are quite costly; in one of my own previous proposals they made up about ¾ of the total project cost. This may change with mass production, but I'd strongly recommend to at least check into whether or not any data is available on how cost of such fluids drops with produced amounts.
- Focus on model development of a lower TRL technology may only result in incremental development.
- The impact was not well communicated and it isn't quite clear how the project addresses the impact presented? What is the embodiment that this technology can be used for beyond water heater technology?
- Lack of qualified SH/WH/HP/HXR manufacturing expertise on board - at least for the high level overseeing and feedback
- None
- Successfully incorporating HMX model into HPDM model may prove challenging.

3) **Recommendations**

- Consider alternate, non-ionic- liquid desiccants as an intermediate step to achieve market penetration prior to switching to ionic liquid desiccants.
- N/A
- N/A
- Define the stakeholders and expand their engagement
- None
- None.

Project #32226n: Validate Performance of Existing Pre-Commercial Gas-Fired Equipment

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

Brief Summary of Reviewer Comments

All but one reviewer found this project's approach—supporting technology commercialization through third-party testing of a new product—to be appropriate. One reviewer emphasized the value of objectively testing newer technologies to validate performance claims, though a different reviewer questioned if project this was an appropriate use of government funding, as it could demonstrate bias toward a specific company. A majority of the reviewers remarked that this project could open the market for absorption-based heat pumps by providing data independent of manufacturers' performance claims, thereby reducing building energy use intensity by accelerating the commercialization and market-availability of high-performance building technologies. One reviewer, however, highlighted that the selected technology still had a number of technical issues requiring cost-effective resolutions prior to performance evaluation for market introduction and impact assessment.

Most reviewers were satisfied with the project's progress to date, commenting that there was no reason to believe that it was not on track to hit key milestones. One reviewer cautioned that the project was still in an early phase, however, while another expressed confusion about the timeline, acknowledging that this confusion could be a result of typos in the Peer Review presentation. Almost all reviewers found the project's remaining work—consisting primarily of the actual performance testing—to be appropriate. However, one reviewer did note that performance testing was dependent on receipt of a working prototype, which remained uncertain at the time of the Peer Review.

In terms of the project's collaboration and coordination with partners, some reviewers found the project's partnerships to be strategic, serving to efficiently minimize duplicative work. One reviewer, however, commented that project partners were limited to primarily serving as sources of information, and expressed that partners' practical expertise could have been better applied to the preliminary cost-benefit evaluation for technology down-selection. Reviewers also noted that collaborative and down-selection processes did not allow more than one manufacturer or technology to be selected for validation and benchmarking, which could have helped mitigate the risk of one product underperforming. Two reviewers remarked that the project would benefit from stronger strategic partners and more manufacturers and products per data point.

Most reviewers commented that the key project strength was promoting technology commercialization through independent evaluation of the newly developed gas-fired heat pump technology. As the project moves forward, however, reviewers offered a number of recommendations, including identifying other products to test, harmonizing with U.S. testing standards, engaging with more partners and coordinating the evaluation with them, and working with a certification partner to assess performance, safety, and design deficiencies in selected technologies.

Weighted Average: 2.90 # of Reviewers: 6
Approach: 3.00 Impact: 2.83 Progress: 2.50 Collaboration/Coordination: 3.17 Remaining Work: 2.83

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Support commercialization through laboratory evaluation. High TRL level only.
- Pretty straightforward testing to validate claimed performance, not much to comment on with technical approach. But there is definitely value in having objective testing completed to validate performance claims of newer technology
- Good approach to develop third-party testing for a new product.
- 1. The approach was not well-thought upfront. It is not quite clear what the reason was to waste the project resources for selecting and assessment of the commercially available candidates that were excluded afterwards (almost half of the list - 6 out of 13).
- 2. Most of the collaborators/key partners were used just as formal information sources. Higher level of involvement would be more helpful for the project in both informational (wider list of attractive technologies) and assessment capacities (more practical expertise for the preliminary cost-benefit evaluation).
- 3. In some cases <TRL6 candidates may present a certain interest and have a higher potential for fast commercialization as opposed to >TRL6, so every innovative candidate should be evaluated prior to exclusion from further step consideration
- A significant number of gas-fired heat pump technologies are undergoing R&D, meaning they are at the pre-commercialization stage. The project goal is to have ORNL conduct unbiased laboratory performance evaluations to support and promote the commercialization of new gas-fired heat pump technologies.
- Realistic down selection criteria selected.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.83** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Open the US market for absorption technology heat pumps.
- The successful execution of this project should help by giving the market independent data of manufacturer's performance claim for a product that few are familiar with.
- This seems like a poor use of government funding because it can be viewed as biasing toward a specific company. The third-party testing seems like a good service to provide although it would be preferred if the DOE did not pick up the bill for it.
- To achieve the BTO goals on significant reduction in building energy use intensity, the promising technology commercialization must be accelerated for the U.S. market. The government support is essential for the breakthrough technologies and products from all over the world with the maximum possible impact. It seems SaltX is very attractive technology however, it still has many technical issues required cost-effective resolutions prior to performance evaluation for market introduction and impact assessment.
- The impact of this project is that the best of all of the energy saving technologies might be brought to market sooner than what might have otherwise taken place.
- Validating selected project equipment performance will support moving project to commercialization and accelerate equipment market availability.

C. Progress

Based on current project efforts, the project was rated **2.50** for the degree to which the project has met ***project-specific goals*.**

- This project is still at an early phase.
- It would have been better if more than one vendor with one technology could have been tested to do some benchmarking, but down selection process makes sense.
- N/A
- Based on verbal presentation the project is on track, while slides after careful examination are quite confusing. Slide 2 indicates the project timeline from 10-1-2017 to 9-30-2018, while slide 17 shows 2018-2019. Logically assuming, there is a typo on slide 17, so the project will be over prior to the planned field test results will be available. Another concern if there is laboratory-scale prototype will be available for the planned ORNL testing in late Summer 2018. The future steps listed on slide 13 looks promising and should be executing in parallel with main scope.
- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.
- Down selection process identified project for testing. Agreements are being developed.

D. Collaboration and Coordination

This project was rated **3.17** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Close work together with various partners to avoid duplication of work.
- Collaboration seems to have important stakeholders involved, but similar comments as previously, that it would be nice to have more than one manufacturer/technology being benchmarked to help mitigate the risk if one product does not perform as expected.
- N/A
- Strategic collaboration must be established with the relevant stakeholders. What are the relevant stakeholders for the commercialization support? The key stakeholders must be OEMs (that actually bring the technologies to market place) and Utilities (that power those technologies). Since it is the project focused on Gas-Fired Equipment the project team should establish close communication with the LDC (Local Distribution Companies) or their consortia to coordinate the testing and relevant commercialization activities.
- Significant partnerships exist between ORNL and other entities. Such as GTI, AGA and Northwest Energy Efficiency Alliance and SaltX Technology Holding AB.
- Partners assisted in selection of projects for consideration and participated in down selection process.

E. Remaining Project Work

This project was rated **2.83** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Proposed tests – albeit limited detail provided – appear to make sense.

- Very clear that testing is the remaining work
- N/A
- Remaining project work strictly depends on the working prototype availability that seems quite questionable based on the presented materials.
- The project work still to be performed will most likely be completed on schedule as no technical challenges appear to exist.
- Project selected, agreements in progress, performance testing to come.

F. Additional Comments and Recommendations

1) **Project Strengths**

- High TRL level research, goal is to support commercialization through field studies.
- Testing "new" technology to validate claims
- The approach for the project activity is good.
- The major strength of the project is ability to perform the independent evaluation of the newly-developed gas-fired heat pump technology (while selection methodology is quite questionable). Testing resources are available at the ORNL, but the evaluation success strictly depends on the reliable system prototype.
- The project's strength is that it promotes technology commercialization, which will benefit society.
- Providing performance validation support for emerging technologies to remove barriers and speed the tech transfer to commercialization timeline.

2) **Project Weaknesses**

- This is not a project weakness, but it seems odd that the funding climate in the US prevents third party funding from investors to go the last mile to commercialization.
- Lack of more than one data point with respect to manufacturer/product
- The utilization for DOE funding for this activity seems like a poor idea.
- The major weakness of the project is lack of strategic partnership at this time.
- None
- None

3) **Recommendations**

- I think the project itself is fine. I think it may be excellent to harmonize future US testing standards for this type of equipment with international standards to then no longer need performance evaluation of foreign products. The increased competition should help drive innovation in the US itself and make projects like this one entirely unnecessary. DOE could then redirect funds to further develop low TRL level research to improve the efficiency of absorption systems.
- Try to identify other products that could be tested

- N/A
- Establish the relationship with OEM and LDC and coordinate the evaluation with them (test plan/matrix, key performance criteria, etc.) I would also suggest to involve certification partner such as Underwriters Laboratories (UL) into the evaluation to assess performance safety and design deficiency that may shorten a market introduction time in the future.
- None
- If possible, engage more partners so you could enlarge the pool of potential projects.

Project #32291: Adhesive Bonding of Aluminum and Copper in HVAC&R Applications

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

Brief Summary of Reviewer Comments

Reviewers generally found this project's approach to the development of adhesive joints for HVAC&R applications to be very sound, highlighting in particular the project's team innovative use of adhesive bonding to replace traditional brazing, as well as the team's use of neutron imaging to verify surface preparation and bonding. One reviewer also called out the project team's utilization of a test bed facility, which allowed them to test adhesive improvements as they were being developed, thereby promoting an iterative process of improvement throughout the project. Critically, one reviewer raised concerns about potential difficulties using adhesive joints as part of the manufacturing process—though other reviewers felt that manufacturing site visits by the project team addressed this issue—and multiple reviewers voiced concerns about the long-term reliability of joints due to the difference in thermal expansion coefficient between the epoxy and the metals being joined.

All reviewers agreed that the project had made good progress and was on target to reach project milestones. The remaining project work was also well reviewed, though one reviewer questioned how the project team would successfully jump from meeting 75% of joint strength requirements to meeting 100% of requirements in just 11 months.

A majority of reviewers agreed that the project will successfully reduce heat exchanger production costs, improve heat exchanger efficiency by reducing leakage, and cause direct and indirect emission savings. One reviewer did express doubts about the scale of the project's impact, however, citing the concerns noted above about joint long-term reliability, and recommending that a follow-on project be conducted to look specifically at reliability testing.

Reviewers generally approved of the engagement and collaboration with project partners. One reviewer emphasized the benefits of ASHRAE involvement and was buoyed by the interest from braze suppliers and equipment manufacturers. Another recommended formal partnership with a coil manufacturer, however, to ensure that questions about manufacturability are thoroughly and sufficiently considered.

Weighted Average: 3.45 # of Reviewers: 5
Approach: 3.60 Impact: 3.00 Progress: 3.60 Collaboration/Coordination: 3.60 Remaining Work: 3.40

A. Approach

This project was rated **3.60** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Glass beads as spacer to obtain spacing between surfaces to have specific distance between glued surfaces.

- Technical approach of using adhesives addition to enhanced surface treatments in place of brazing seems technically sound. There may be some manufacturability difficulties that will be hard to address in this project (more on this statement in the section on project challenges)

- The utilization of the neutron imaging is novel and a very helpful mechanism to evaluate the coupon bonding. The utilization of the pressure variant test is unclear.

- In this project, innovative approaches are being explored to use adhesive joints to replace traditional brazing as presently used in the HVAC industry. Of special importance, there is a great need to improve bonding so as to reduce leakage and lower costs, especially for bonding diverse materials.

- Removing surface contamination drives towards best geometry – doesn't depend on flow.
- Developing 1K v 2K epoxy path allows for
    - Automated dispensing - minimizing application challenges.
    - Dependable viscosity over time extends shelf life
    - Better shear strengths reduce failure risk
- Neutron imaging mitigates technical risk by identifying coverage.
- Test bed allows testing adhesive improvements as they are developed. Promotes iterative process improvements throughout the project.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Decrease in manufacturing cost, overcoming corrosion issues

- Better joints in refrigerant containing components will lead to both direct and indirect emission savings

- It is unclear that the impact will be that large. The study doesn't really address the long-term reliability of the joints which is a majority of the leakage issues associated with brazed joints. Without a follow-on to this to address reliability of these joints it is unclear that the impact will be realized.

- The impact of this study of adhesive bonding is huge in that it could reduce HX production costs by 30-40%.

- Reducing furnace temp and pass time improves process efficiency; as does ability to finishing curing in ambient conditions.
- 1K epoxy has improved thermal properties
- Well thought out approach maximizes potential to meet joint strength and leak requirements that should persist over life of product.

C. Progress

Based on current project efforts, the project was rated **3.60** for the degree to which the project has met ***project-specific goals*.**

- Good progress on addressing various issues

- Progress is in line with the presented schedule/milestones
- The progress is excellent, ahead of schedule.
- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.
- On target.

D. Collaboration and Coordination

This project was rated **3.60** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders. (NOTE: Projects should be scored appropriate to the current project stage and level of development).
- Integration of various areas to ensure project success. I think the contractor has as good of a team as one could wish for.
- Collaboration is good with current team members, but could be strengthened greatly from an integration/manufacturing point of view by including a major coil producing partner that is familiar with current brazing techniques in place.
- The partnership is very good and the novel program sharing the student is a good utilization of federal dollars.
- There are a number of strategic collaborations that are helping with technology development and assisting with commercialization, including ORNL, 3M and Herrick Laboratories at Purdue University.
- Good collaboration and coordination with 3M.
- Interest from braze suppliers and flaring equipment manufacturers.
- Site visits to manufacturers provides cost comparisons and mitigates future manufacturing risks.
- ASHRAE involvement a plus.

E. Remaining Project Work

This project was rated **3.40** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Good plan for moving this forward!
- Remaining work outlined appears appropriate. What is not immediately clear is what it will actually take to make the jump from meeting 75% of joint strength requirements in month 18 to meeting 100% in month 27.
- The remaining project work is good.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- On target.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Excellent project team, substantial experience in traditional bonding and access to facilities to develop surface pre-treatment using laser pulses. Technology allows bonding of dissimilar materials.
- Good technical capabilities of researchers and partners to develop the technology and test strength of joints.
- The approach and the teams at 3M and ORNL are strong assets to the team. Verification of the neutron imaging to verify the surface preparation and bonding is appropriate will save enormous effort and lead to a better result.
- The project strength is its approach to using adhesive joints to replace traditional brazing, and its talented group of collaborators
- Well thought out approach. Test bed and manufacturer site visits act as reality checks throughout the project to identify potential design/process problems so they can be addressed before they become insurmountable.

2) **Project Weaknesses**

- I am a bit weary of the difference in Young modulus and thermal expansion coefficient between epoxy and metals. This may lead to long-term reliability issues.
- Ability of this joining technology to be implemented in a manufacturing environment. It was not clear what the cure times are for the epoxies being evaluated, but in many continuous line manufacturing facilities, there is very little time to isolate joints and wait for them to cure.
- 30-40% production cost reduction was compared to controlled atmosphere brazing, but most of the geometry presented appeared to be more similar to round tube applications, whereas CAB tends to be a microchannel brazing process, should look at those different types of joints that are not usually hand brazed.
- The team from Purdue, while a very excellent graduate program, has little experience with the modeling and physics of adhesive technologies. The lack of reliability testing is also of concern for the overall impact.
- None
- Will the epoxy maintain its strength and thermal properties over the useful life of the joint?

3) **Recommendations**

- 1K epoxy – long term durability, compatibility with refrigerant and oil? How much experimental data is there to support durability claims? Do we risk increased refrigerant leakage rates for typical equipment lifetimes of 12+ years?
- The addition of a coil manufacturer (preferably one that makes both microchannel and round tube) would go a long way in ensuring that manufacturability was considered in development of the technology
- Ensure there is a follow-on project looking specifically at reliability testing of new joints.
- None
- None

Project #32293: Advanced Serpentine Heat Exchangers

Presenter: Daniel Bacellar, Optimized Thermal Systems, Inc.
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers agreed that this project's approach was solid, as it addresses key problems in heat exchanger (HX) manufacturing and can produce incremental improvements in performance by reducing the number of HX joints. Reviewers did identify several potential issues with the approach, however. One reviewer flagged that there was no risk mitigation strategy for the HX design's split-type joints, while another remarked that further validation was required to demonstrate that the new joint type does not result in higher leakage that offsets the gains of a serpentine design. One reviewer was "suspicious" about the long-term viability of the split-type joints, while another flagged that the project team was not considering internally enhanced tubes, which the reviewer identified as being a significant part of the HVAC industry today. To address some of these issues, reviewers made a number of recommendations, including conducting performance testing earlier in the process to identify potential issues as soon as possible and conducting an analysis of energy savings potential due to reduced leakage versus energy consumption increases due to pressure drop.

Many of the reviewers were unclear on this novel HX design's potential impact, with one commenting that not all brazing joints have the same risk of leaking, and another flagging that the general serpentine joint may help reduce leakage, but it might also cost more energy as a result of the pressure drop. Two reviewers, highlighted the potentially significant impact of the technology if a prototype is validated, commercialized, and adopted widely.

Reviewers agreed that the project had progressed satisfactorily based on the project team's schedule, though one reviewer noted that the project is somewhat behind in its efforts to optimize fin geometry. The team has partnered with several companies along the entire supply chain, which all reviewers applauded, with one reviewer noting in particular how these strategic collaborations would help with technology development and commercialization.

As the project continues, a majority of reviewers found the remaining project work to be on track, though two reviewers voiced concerns. One reviewer noted in particular that a very significant challenge that remains is scaling up the project's approach for manufacturability, commenting further that, at this stage, performance and manufacturing issues will pose the highest risk to the project's success and market adoption. Another reviewer similarly highlighted the potential challenges of transitioning from analysis to prototyping.

Weighted Average: 3.05 # of Reviewers: 6
Approach: 3.00 Impact: 2.83 Progress: 2.83 Collaboration/Coordination: 3.67 Remaining Work: 2.83

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- No risk mitigation strategies for split joints.
- Modelling approach is strong as the researcher has high level of capability. Approach of introducing a new type of joint (split/merge), needs further validation to show that it won't offset some of the gains of going to a serpentine design, as this is a less common braze joint type that may lead to higher leakage.
- Approach is good.
- Solid approach was selected for the incremental improvement of the coils performance by reducing the number of joint. The approach enable the minor intrusion into manufacturing paradigm.
- This project addresses an important problem in HX manufacturing, namely working fluid leakage at bends and high manufacturing costs. Specifically, the innovative approach in this project is to design and optimize a novel “dog-bone” fin concept using a serpentine tube approach that results in better performance compared to current tube-fin heat exchangers.
- Approach addresses tradeoffs needed to achieve a single tube HX with minimum # of joints.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.83** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Unclear if all brazing joints have the same risk of leaking - is the impact overstated by adding that field manufactured joints are more likely to leak and then talking about OEM processes only?
- If the number if joints in heat exchangers can be reduced without any impact on performance the impact to leakage of refrigerant containing systems can be significant, assuming high levels of technology adoption.
- Potential impact seems unclear. Reducing the number of braze joints is a good idea, it is less clear if the outcome of this project will produce that with the modified braze joint. The general serpentine joint may help reduced leakage but also cost more energy due to pressure drop.
- Impact was not adequately presented for review however, based on other presented materials and involved partners the impact is expected to be significant for the A/C market (though it is needed to be quantified based on market demand and penetration)
- There is a huge potential impact from building and testing a prototype and then validating and commercializing this technology.
- Project offers an alternative approach in circuit and fin design to achieve program goals of reduction in refrigerant leakage from HXs.

C. Progress

Based on current project efforts, the project was rated **2.83** for the degree to which the project has met ***project-specific goals*.**

- Acceptable

- Researchers appear to have made good progress, with respect to the schedule that they outlined
- The progress seems on track based on what was presented.
- Based on the presented information and demonstrated samples the project progress is on track.
- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.
- Prototype candidate identified. Optimization in progress but somewhat behind.

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Several companies are involved, but OEM and suppliers
- The researchers appear to have strong collaborators along the entire supply chain, which is a huge benefit to the project
- Excellent team.
- Team is top qualified and well-equipped - no other comments
- There are a number of strategic collaborations that are helping with technology development and assisting with commercialization, including OTS, HTT, and UTRC.
- Demonstrates success so far in analysis/optimization phase.

E. Remaining Project Work

This project was rated **2.83** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Good capture of what tasks are remaining
- The remaining project work will likely be the most difficult as it will focus on how well the approach scales to manufacturable heat exchangers. This will be the portion of the project where performance issues and manufacturing issues will pose the highest risk to project success and ultimate adoption of the evaluated technology
- N/A
- It seems the project team is on track for successful completion of the 3-year effort.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- Project plan makes sense. However, moving out of the analysis phase and into prototyping will bring potential new challenges.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Reduction of joints in HX

- Great modelling capabilities
- Realistic expectations of technical challenges to performance (i.e. pressure drop sensitivity)
- Strong collaboration partners

- The concept is interesting, team and organization is also good.

- Alternate circuiting analysis and design concepts

- The project strength is its innovative approach to reducing the number of HX bends, thus cutting back on leakage and reducing manufacturing costs.

- Key partners and vendors bring strong expertise to entire technical problem set.

2) **Project Weaknesses**

- unclear if actually has mentioned impact since unclear if field and OEM brazes behave similarly
- No risk mitigation strategies for splitter-joiners

- Lack of demonstration that scrap rate won't increase
- Data showing that performance can be met without significant increase in heat exchanger material due to what is essentially increased contact resistance increase.
- Not looking at internally enhanced tube which is a huge part of HVAC industry

- The split-type joints have suspicious long-term viability. Additionally, the added pressure drop due to the flats is not addressed.

- Would be helpful to expand the fin enhancement options

- None

- Potential for any one of those partner/vendor relationships coming off the rails and negatively impacting overall success of project is high. Project management may be a higher hurdle than technical accomplishments.

3) **Recommendations**

- Provide details on how this project actually will affect leakage rates; are AL HX more or less likely to leak than copper heat exchanger?

- Focus on getting earlier performance testing, even if on smaller scale to get an indication of if there is performance issues earlier rather than later.

- An analysis that looks at the energy savings potential due to reduced leakage in contrast to the increased energy consumption due to increased pressure drop is warranted. If the savings due to reduced leakage is eclipsed due to increased pressure drop energy consumption the effort is less useful.
- No comments for current project.

- None

- To the extent possible, be proactive in project management to anticipate and mitigate potential disruptions as project moves into prototyping and mechanical testing phase.

Project #32294: Improved Braze Joint Quality Through use of Enhanced Surface Technologies

Presenter: Brian Westfall, Trane
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers generally found this project's use of enhanced surface braze joints to reduce refrigerant leakage to be innovative. One reviewer described that the approach's focus on improving a specific manufacturing process reduced the project's scope of effort required to achieve its goal, and minimized the variables that could negatively impact project outcomes. In contrast, however, a different reviewer remarked that the approach was actually unclear based on the Peer Review presentation, describing further that the efforts of the project team and its partners appeared to be totally independent, and that it was not clear how the project's modeling and experimental efforts would be utilized in the future.

Across the board, reviewers felt that this project had the potential to positively impact the incidence of refrigeration leaks and brazing issues, as well as reduce the quantity of brazing materials used. Reviewers did note, however, that the project team did not quantify an impact on energy savings, and also that the project could potentially cause a large increase in production costs, which would limit adoption and therefore impact.

Reviewers were split on their appraisal of the progress that the project had made. One noted the project's 6 month delay due to problems with the test apparatus, two others commented that the project had progressed and was on schedule to meet future milestones, and one opined that the Peer Reviewer presentation could have included more precise measure of accomplishments. Reviewers were also split on the remaining project work. Half of the reviewers noted that the project had a very specific project plan that was on schedule, while the other half felt that no details were shared, and that work that would be done in the future was unclear. One reviewer recommended that, as the project moves forward, the project team should consider other technologies for reducing braze materials, including 3D printing as well as polymer and composite materials.

All reviewers agreed on the success of the project's partnerships and collaboration with industry and academia. One reviewer enthusiastically added that a government funded, original equipment manufacturer-led, academia-supported, peer-reviewed project was "the best arrangement for… applied R&D success!"

Reviewers were most pleased with the project's potential impacts, particularly it's potential to reduce leaks and lower manufacturing costs. Another reviewer highlighted the project team's work with Trane's Advanced Manufacturing Engineering group—focused on validating and demonstrating the project's joint strengthening design—as the project's most significant strength. The most common weakness flagged by reviewers was the Peer Review presentation itself, with reviewers recommending that the project team share information on relevant outcomes and proposed impacts more directly.

Weighted Average: 3.18 # of Reviewers: 5
Approach: 3.40 Impact: 3.20 Progress: 2.60 Collaboration/Coordination: 3.40 Remaining Work: 3.00[1]

[1] The average reviewer score for Remaining Project Work is based on the individual scores of only 4 of 5 reviewers.

A. Approach

This project was rated **3.40** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Very interesting approach to move hydrophilic/hydrophobic principles to improve brazing joints
- Most of the approach was unclear from the presentation. The efforts at Trane and UIUC seem completely independent and it wasn't clear how the results from the modeling/experiments will be utilized in future efforts.
- Engineered surface structuring is a popular approach to enhance surface properties for bonding, brazing, phobicity, philicity. Specific structures for this project are confidential.
- This project's use of enhanced surface braze joints to reduce refrigerant leakage is innovative and should result in major breakthroughs.
- Focusing on improvements in a mature manufacturing process reduces the scope of effort required to achieve reduced leakage loss and minimizes the number of variables that could affect a successful project outcome

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.20** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- I think this has the potential to reduce brazing issues
- Provided the outcome of this study does not suggest a large increase in production costs, this could produce some very good impact.
- Presentation materials are not quantify the impact on energy savings. However, the reduction in refrigerant leaks by 25% may provide a significant impact in both energy and environmental aspects. Based on verbal presentation a wide spectrum of surface structures was evaluated and the best performers were selected for moving forward.
- The goals of reducing refrigerant leaks by 25% and brazing materials by 10% if achieved in this project will have major impact on HVAC industries and operations.
- Project has the potential to achieve the goal of reduced refrigerant leakage and move towards market transformation quickly because it is improving an existing manufacturing process rather than the disruption of requiring development of a new manufacturing process.

C. Progress

Based on current project efforts, the project was rated **2.60** for the degree to which the project has met ***project-specific goals.***

- Looking forward to the results; curious on long-term stability
- The work at UIUC seems pretty good but it wasn't terribly precise what was accomplished aside from developing the test setup and running a few isolated tests. What was learned and will be leveraged needed to be presented.
- According to the given Gantt chart the project progress is on milestones schedule

- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.
- Progress was delayed by 6 months due to problems with the test apparatus.

D. Collaboration and Coordination

This project was rated **3.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- No apparent issues
- Good team
- Government is funding, OEM is leading, academia is supporting, multi-disciplinary professionals are reviewing! That is the best arrangement for the applied R&D success!
- Trane and the University of Illinois at Champaign/Urbana have teamed up on this project.
- Project is at mid-point with U of I conducting the research.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- No details shared
- Again, unclear what precisely what was going to be done.
- Very specific plan that corresponds to the project schedule
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- Once the research identifies the optimal surface enhancement Trane will examine manufacturability and costs.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Potential reduction in leaks
- The potential impact and the team is quite good.
- Approach and methodology are bullet-proof, but cost analysis is essential for project ultimate success!
- The project's strength is that the R&D, along with the technology developed, could lower manufacturing costs while reducing the effects of environmentally harmful working fluids being released by leakage.
- Teaming with Trane's Advanced Manufacturing Engineering group brings technical and manufacturing expertise to validate and demonstrate that the project joint strengthening design can be effectively moved to commercialization.

2) **Project Weaknesses**

- Relevant details for leakage rates are not shared
- The coordination between partners was unclear and the efforts at each location were also not clear. The outcomes that suggest the project has learned what is required to address the potential impact was not clear from the presentation, more details should have been provided.
- It seems not much scientific breakthrough such as innovative materials, new physical processes, etc. Just a good and reliable engineering study that may lead to the market success by incremental enhancement of the existing product line.
- None
- Test rig delays may indicate future project management problems in the research efforts.

3) **Recommendations**

- Is it possible to share more details once the project is complete?
- Present more directly the relevant outcomes and how they specifically address the team's ability to address the proposed impacts of the project. This does not mean presenting IP but an effort should be made to inform the public that knowledge has been developed and how that information will be used to address the impacts of the project.
- The best way to reduce refrigerant leakages is to eliminate using the refrigerants. To reduce braze materials - to employ other technologies such as 3D printing, polymer/composite materials, etc.
- None
- None.

Project #32296: Mechanical Dehumidification Using High-Frequency Ultrasonic Vibration

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

Brief Summary of Reviewer Comments

Reviewers were split on their evaluation of this project's approach to developing a proof-of-concept dehumidification system utilizing high-frequency mechanical vibration. For example, two reviewers complimented the project's innovative use of high-frequency ultrasonic vibrations to mechanically dehumidify moist air, calling it a project strength. One reviewer also highlighted the team's approach of investigating three structure paths, noting that it would allow for work to continue should one structure experience failure. Two reviewers agreed, however, that while the approach for some elements of the technology (i.e. actuator) were appropriate, investigation into the technology's capillary action was unfocused, needed to be proven as technically viable, and was a main challenge and a major point of uncertainty for the project. Reviewers also raised some concerns about the mechanical long term stability of the technology, and identified a potential risk of hearing loss to users as a result of the high frequency sound waves.

Overall, reviewers found the potential impact of the technology under development to be significant, especially in regards to its ability to increase efficiency without the use of harmful refrigerants. One reviewer noted that if latent load could be removed without cooling and reheating air, this project's outputs could potentially replace the ubiquitous, inefficient vapor-compression system.

Most reviewers found the project to be progressing well and on schedule, though one reviewer flagged that the project had yet to complete a long-term, usable outcome. Moving forward, however, reviewers disagreed on the project's future direction. While some commented that the project was likely to hit outlined milestones, two reviewers felt that next steps were unclear, and expressed concern about long-term stability of technology components. To address these issues, reviewers recommended that the project team develop and presents metrics of success for evaluating problematic elements of the technology.

Reviewers found that the project had a strong project team of national lab, industry, and academia experts, all of whom were perceived to have clearly defined roles and frequent communications. To even further strengthen the project's collaborative efforts, however, one reviewer recommended coordinating with a group whose specific focus was on dehumidification technology.

Weighted Average: 3.11 # of Reviewers: 5
Approach: 2.80 Impact: 3.60 Progress: 3.00 Collaboration/Coordination: 3.40 Remaining Work: 2.80

A. Approach

This project was rated **2.80** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Several complementary teams are involved in the project.
- The approach of getting removing the water through vibration seems like a sounds approach, what has yet to be proven as technically viable is the how to remove the water from the air. Capillary condensation seems challenging in an airstream and using desiccant would end up with an approach not that different than current desiccant technology
- Approach is good on the actuator technology, the approach to investigate the capillary action is a bit too un-focused.
- The project is innovative in that it uses high frequency ultrasonic vibrations to mechanically dehumidify moist air. There is no evidence of this having been done before.
- Innovative approach:
- Using absorption and mechanical vibration to extract water and bypass the latent heat of evaporation.
- Eliminates need for regeneration of the desiccant materials – increases system efficiency.
- Some technical challenges are mitigated by building on the research and findings of the ultrasonic clothes dryer project.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Grid flexibility due to possibility to adjust power input, reduction of energy consumption for cloth drying applications
- If the latent load can be removed without the need to overcool and reheat air, as is currently the most popular method, there could be significant energy savings
- The potential impact is very large
- The dehumidification technology being developed should have a huge impact with its increase in efficiency without the use of harmful refrigerants.
- This project will contribute another proof-of-concept high-efficiency emerging dehumidification technology to replace the ubiquitous inefficient vapor-compression system.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*****.**

- Project has yet to complete with a long-term usable outcome.
- Project progress seems in line with schedule presented
- Progress is acceptable
- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.

- On track.

D. Collaboration and Coordination

This project was rated **3.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Well defined team of complimentary expertise
- Collaboration on the modelling and development on the piezo front seems very strong. Could be even stronger if there we coordination with a group that had a focus on dehumidification technology
- Good team.
- ORNL has developed collaboration with industry and academics, namely Virginia Tech
- Strong team taking advantage of in-house ORNL expertise combined with industry and academic experts.
- Clearly defined roles for team members along with ongoing bi-weekly communications is a plus.

E. Remaining Project Work

This project was rated **2.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- It seems that long-term stability of the membrane-actuator assembly is not yet a concern. Should it be?
- Remaining work seems to be in line with the amount of time remaining in the project and the milestones that have yet to be achieved
- The remaining work is quite unclear because the approach is not great.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- On track.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Substantial reduction in energy consumption for dehumidification processes, good team.
- Strong modelling team
- Demonstrated capability to make piezo based water shedding successful in previous work
- The potential impact is very good and the team and progress seems good, and the actuator evaluation is strong.
- The strength of this project is in its innovative approach to using high frequency ultrasonic vibrations to mechanically dehumidify moist air.
- Strong team.
- Building on prior research

- Investigating three structure paths allows for work to continue if unanticipated failure of one structure occurs

2) **Project Weaknesses**

- Mechanical long term stability may be an issue that needs to be addressed
- How does lint affect the resonance frequency if it attaches to the ultrasonic actuators during standstill?
- Is there a risk of hearing loss if users are exposed to high sound pressure sound waves? Ultrasound is use for cleaning surfaces, and it may potentially lead to resonances in the spiral organ of the ear that could be large enough to clear out the sensitive hair cells that we use to sense sound, aka lead to deafness. I strongly suggest for the contractor to review literature and wear hearing protection during experiments.

- Condensing water out of the airstream is going to be the main challenge of this project and it seems that most of the emphasis is placed on capillary condensation, which could be risky to implement successfully.

- The focus of the capillary technology is a bit too broad to provide confidence of success.

- None

- Uncertainty around the viability of capillary condensation.

3) **Recommendations**

- I think it would be outstanding publicity to show some high speed videos of the moisture removal process to the public. See my comments on project weaknesses. This project still has a long way to go before being a commercial product.

- Identify other means of condensing water out of air stream or put more effort into how piezo technology would work with desiccants and be substantially different/better than current desiccant technology

- Develop/present metrics of success for evaluating the various capillary devices.

- None

- None.

Project #94150d: CERC: HVAC Energy Savings and IAQ: Integrating Air Cleaning with Smart Ventilation

Presenter: Brett Singer, Lawrence Berkeley National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers generally agreed with this project's approach to developing and demonstrating air cleaning materials and air quality sensor applications, as well as building simulation tools to reduce energy and peak loads and improve indoor air quality (IAQ). Curbing the need for outdoor air for ventilation and IAQ purposes was viewed by reviewers as a primary strength of the project, as it would reduce demand for conditioning and filtering the air, especially when outdoor air is unhealthy. One reviewer also highlighted the project's finding that air cleaning equipment can be made more robust by incorporating volatile organic compound, CO_2, and particle sensors to better capture ultrafine particles. Other ancillary benefits of the project that were identified by reviewers were the development of cost effective and reliable IAQ sensors and sorbent technologies.

Reviewers complimented the project on its collaborations with Chinese researchers and other industry partners, and they saw it as a positive sign that one partner intended to manufacture a product from this project. However, one reviewer expressed a desire to see more engagement with sensor and control manufacturers, such as Johnson Controls, while another questioned China's role in the project.

Reviewers agreed that the project was making progress, although multiple reviewers highlighted the IAQ monitoring sensors as an area of concern. One reviewer compared the situation with IAQ sensors to that of CO_2 sensors—a multiyear iterative process that just then seemed to be on the road to resolution—and recommended that the project team set realistic goals for IAQ sensor progress. A reviewer also identified the need to quantify energy savings, as well as the project's focus on new systems versus existing systems, as risks that could hinder the project's impact on BTO's 2030 goals for energy savings.

Reviewers agreed that the project team should be able to complete its remaining work in line with the project schedule, though they acknowledged that there was still a significant amount of work to be done. One reviewer also recommended that the project team develop a plan for presenting research to end-use customers, utilities, and others to prepare the market for technology introduction.

Weighted Average: 3.58 # of Reviewers: 5
Approach: 3.60 Impact: 3.60 Progress: 3.20 Collaboration/Coordination: 3.80 Remaining Work: 3.60

A. Approach

This project was rated **3.60** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Strong research and technology development and demonstration approach taking advantage of expertise and research strengths in the U.S. and China along with key market actors. Approach addresses important need for energy savings and improved IAQ in both countries by identifying most promising products/applications as well as remaining challenges needing further research and development. Demonstration of the technology's potential along with rigorous testing to document performance is key to addressing barriers and increasing market interest.

- The approach is ranked as "likely" mainly due to the stage of the project and the amount of variables yet to identify and overcome before I feel I can rank it as "highly likely". There are a number of steps remaining in the project that have the potential to disrupt full completion, chief among them being reliable real time data from air quality sensors. Other risk factors include reliable quantification of the energy savings to be realized. It is certainly encouraging that one of the program partners has filed an intent to manufacture a product that would be used in this application. Also, I feel the program's focus is relatively targeted and unless it can be cost effectively implemented in existing systems, might only appear in new systems, which would tend to stunt its impact on achieving BTO program energy savings goals by 2030.

- This project is well positioned to have a measurable impact in improving indoor air quality in buildings. The collaboration with researchers from China and the integration of industry partners is a positive aspect of the approach. Addressing improved air cleaning technologies is important given the conditions stated by the researchers.

- The approach makes sense in that the technology needs to be developed first and then tested. This technology will have wide spread use in countries with poor air quality.

- Approach was well thought-out and straightforward. Good combination of technology development, simulation and demonstration.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Reasonable target impacts based on products and outputs advanced by the project. Significant energy savings and carbon emissions reductions in both the U.S. and China are equitable based on population of each country. Workshop planned for this summer an important part of strategy to ensure cooperation and engagement.

- Assuming project goals are met, I believe this project will contribute to achieving programs goals by potentially significantly reducing the amount of exterior air that is needed to be introduced to conditioned spaces to dilute pollutants and ventilate these spaces.

- It is logical to think that the approaches to sensing contaminants and filtering out those contaminants could have a direct impact on improving IAQ in buildings. Incorporation of smart ventilation will have a measurable impact on reducing energy consumption while meeting goals of IEQ.

- What I wasn't clear on was how this was China's contribution to the project and how this was going to be tested in China once the technology was developed. I think that it is a much needed technology and the development process makes sense but again question China's involvement in the process other than we are developing and manufacturing it and they will use it.

- Cost effective ventilation is critical to integrating building envelope and mechanical systems. This linkage is, in turn, critical to building energy savings.

C. Progress

Based on current project efforts, the project was rated **3.20** for the degree to which the project has met ***project-specific goals.***

- The project is still in the first half of the overall project term. Good progress toward milestones, all of which are still some time in the future. Valuable insights to date include the finding that CO2 capture medium is not sensitive to humidity and the finding that air cleaning equipment can be made more robust by incorporating VOC, CO2, and particle sensor to better capture ultrafine particles.

- Though one significant hurdle remains, that of reliable IAQ monitoring sensors, the project appears to be on track and has already led to pre-production of marketable products to achieve program specific goals.

- There are no concerns regarding progress. The efforts on materials selection appear to be moving well. It is less clear of the progress on the sensors and simulation modeling, but the project is still in its early stages.

- This is a large project with several pieces so you would expect some progress adjustments based funding levels. The progress to date seems reasonable.

- Good start on sensor and sorbent technology.

D. Collaboration and Coordination

This project was rated **3.80** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Project staff is working with a number of industry stakeholders and this work is progressing well with clear benefits that meet industry needs. Key examples include testing and demonstration of BASF air cleaning material, the number of air cleaning equipment manufacturers engaged, and information sharing with private sector sensor and software developers, manufacturers, and others. Collaboration with Chinese research partners progressing well toward joint workshop in China scheduled for Summer 2018.

- Collaboration and coordination with stakeholders is good. One area that could be better is engagement with additional sensor/control manufacturers, e.g. Johnson Controls or other large-ish industry player. Cross-country collaboration and coordination appears excellent at this stage of the project and is expected to continue.

- Excellent team effort working as part of the joint project with China. There is also good collaboration with industry partners, with a good feedback mechanism between the material development by the industrial partners and the lab. It was good to see the inclusion of a sensor development partner, though there was not much time to delve into that partnership to assess the appropriateness of that team.

- The cost share on this project is outstanding with strong collaboration. What I didn't get is how China is involved from a collaboration standpoint.

- Very good stakeholder involvement, especially now bringing in the sensor developer.

E. Remaining Project Work

This project was rated **3.60** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Plans for remaining project work are clearly directed toward meeting near-term milestones and long-term project goals. Expanding the industry team to enhance work on sensors, BASF filing pre-manufacture notice, preparing for work on building demonstrations is slated for project year 4.

- The project plan demonstrates a firm grasp of the needed tools, metrics, and analysis to be successful and a strong team and industry partners to achieve the project objectives. In addition, the project is progressing on schedule. Though significant, the project team has a firm grasp on remaining work to be completed and a rational plan for achieving the objectives.

- There are many components to this project, and it is somewhat challenging to make a conclusion on this question based on the limited time for discussion. The team does appear to be on its way, though, towards meeting the project goals. It is not clear what the end goal of the sensor will be, as this reviewer imagines an iterative effort that will take many years to complete. Just as the presenter mentioned challenges with CO2 sensors that seem to just now be on the road to resolution, one would imagine that these types of sensors will undergo similar growing pains.

- The schedule and work plan laid out to accomplish the project look reasonable.

- Clear path to achieve program goals.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Well-defined goals and activities with comprehensive approach to developing solutions.
- Coordination with large number of stakeholders representing the industries and perspectives required for success.

- The main project strength lies in its potential to curb the need for outdoor air for ventilation and IAQ purposes, thereby greatly reducing the demand for conditioning and filtering that air, especially at times when the outdoor air is unhealthy or would drive the energy demand for conditioning that air far above the energy needed to recycle and condition air already in the conditioned space. Ancillary benefits include fostering development of cost effective and reliable IAQ sensors and sorbent technologies, and identification surrogates to fine particulates that can lead to efficient capture of those particulates without needing to develop sensors specifically to monitor such fine particulates.

- This project appears to be tackling critical problems that are certainly an issue in China and can be an issue in the US as demonstrated by the presenter. There is a logical plan that involves a cross-disciplinary team. The collaboration with a leading material company and the national lab should result in a product that can be used in the market; the fact that this company has already started the regulatory process to start getting this product in the market is promising.

- Cost contribution was great and it is good to see industry investing in this type of technology.
- Technology will be very useful in parts for the world with air quality issues and also in the US that are prone to forest fires.

- Clear program plan. Excellent stakeholder involvement. International involvement.

2) **Project Weaknesses**

- I did not identify any clear weaknesses.
- As noted in the response to the first question, development of sensor technology is key to the success of the project but I don't feel was shown to sufficiently narrowed down yet to rise to the level of a "sure thing." Also, application to existing buildings or existing equipment will affect how widely the new tools are adopted and whether it will have a significant effect on reducing energy consumption by 2030.
- The role of the simulation tools wasn't entirely clear, but I believe that concern may be due to the limited time for presentation.
- Wasn't completely clear on China's contribution to this development. This isn't necessarily a weakness but would like to see how they were integrated into this work.
- No obvious weaknesses.

3) **Recommendations**

- Develop plan for presenting research to end-use customers, utilities, and others to prepare the market for technology introduction.
- I think the team is on the right track and has the right players involved, though I would like to see Johnson Controls or a similar larger player in the controls space participating.
- Set realistic goals about the progress on the sensors. It is not clear that a viable sensor can be finalized in the limited time of the project, but hopefully clear progress can be made. The idea of a test approach as mentioned in another project is important, and it is expected that the PI will pursue the use of that procedure should it be appropriate since he serves on both teams.
- This may already be the plan but I would to see this tested in buildings in China to see how the product interacts with potentially different building controls, etc.
- More contractor/builder involvement.

Emerging Technologies
HVAC, Water Heating, and Appliances

Appliances and Water Heating

Project #32226a: Magnetocaloric Refrigerator (CRADA – GE)

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

Brief Summary of Reviewer Comments

Reviewers were supportive of the project's approach, calling it reasonable, justified, and solid; one reviewer described magnetocaloric refrigeration as one of the most innovative and promising technologies of the future, and wholeheartedly supported efforts to overcome technical challenges to its development. On the technical side, one reviewer highlighted the project's design that was able to minimize pressure drop—which is one of the biggest losses of energy—while another reviewer commends the project team's consideration of scaling up to production-type technologies. More critically, one reviewer looked specifically at the use of microchannels for heat transfer, and recommended that the project team instead adjust dwell time in the regenerator to adjust heat transfer effectiveness, and thus the COP. Another reviewer recommended that the approach include thermal inertia as a design consideration to limit cycling losses.

Reviewers unanimously agreed that this technology, if adopted in the market place, would be competitive in efficiency to other vapor compression systems, especially if the project team can hit 20-30% energy reduction while eliminating environmentally damaging working fluids. One reviewer does criticize a claim made by the project team that this technology would add 6,000 new jobs to the U.S. market, commenting that it is doubtful refrigerator demand would grow that significantly. Two other reviewers noted that the cost of materials may be an insurmountable hurdle for successful market adoption.

Most reviewers found the project to be meeting projects goals and be progressing in a timely manner, though one reviewer noted that it was too early to adequately judge the progress. One reviewer flagged that the technology's COP was still low, but acknowledged that the project team will continue to improve upon this over time. Two reviewers noted that the process being developed will reduce manufacturing costs and will benefit the state of the art in heat exchangers, but generally reviewers recommended a greater focus on system-level issues and providing clarity on the cost of materials.

Regarding the projects collaborations, three reviewers noted the benefits of having a major appliance manufacturer like General Electric (GE) partnered at an early stage. One reviewer commented that manufacturing techniques will allow unique heat exchangers to be optimized around design constraints of unique systems. Another reviewer described their perception that GE's involvement at this point was limited to overseeing project development and providing industrial and market feedback, but expected that GE would become more involved at later stages of the project. Given the project's relationship with ORNL, one reviewer suggested utilizing ORNL's Advanced Manufacturing Demo Facility to consider more sophisticated designs of heat exchangers than those presented.

Weighted Average: 3.18 # of Reviewers: 5
Approach: 3.20 Impact: 3.20 Progress: 3.40 Collaboration/Coordination: 3.40 Remaining Work: 2.60

A. Approach

This project was rated **3.20** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Good approach with considering upscale to production type technologies.
- Excellent work on coming up with designs that minimize pressure drop, which is one of the biggest losses in this system. Also great work in using additive manufacturing to come up with novel heat exchanger concepts. It would be good to add thermal inertial as another design consideration to limit cycling losses.
- The approach is solid.
- The approach sounds reasonable and justified.
- Magnetocaloric Refrigeration is one of the most innovative and promising technologies for the future, which should be supported in an effort to address the remaining technical challenges.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.20** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- Elimination of VC technology, acc. to researchers promise to be competitive in efficiency to VC systems.
- If technology is adopted the energy savings seems very likely as a higher efficiency would lead to this directly. The one impact claim I struggle with is the addition of 6,000 new jobs. I doubt there is an expectation that the demand for refrigerators in the US market would grow, so wouldn't any volume of this technology just cannibalize existing market share (and associated jobs) demanded by the incumbent technology?
- The potential impact is good.
- If successful in both technical and economic aspects, the MCR would make a significant impact to the marketplace by introducing another energy saving and non-vapor compression technology.
- The impact of commercializing MCE is tremendous. Specifically, using the MCE for cooling has the potential to reduce energy consumption by 20-30% compared to vapor compression while eliminating the harmful effect to the atmosphere caused by existing working fluids.

C. Progress

Based on current project efforts, the project was rated **3.40** for the degree to which the project has met ***project-specific goals.***

- MCM magnetic stabilization process seems to be a promising technology to reduce manufacturing cost compared to 3D printing.
- Team has made great progress in heat exchanger development and additive manufacturing that should benefit this project and the state of the art in heat exchangers in general.
- It’s too early to be certain, but so far, so good.
- Based on presented materials the project progress builds upon the early development of the magnetic stabilization process at ORNL.

- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.

D. Collaboration and Coordination

This project was rated **3.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- This was a bit unclear from the presentation.
- Having a major appliance manufacturer involved in the project should be a great benefit to development of a final product
- Pretty good team.
- Project team has a strong collaboration partner (GEA). At this early stage of project GEA's role seems to oversee the project development, review the outcomes and provide industrial and market feedback to the project team. It is anticipated higher involvement of GEA into this challenging development at later stage of the project (subject to future BTO reviews)
- General Electric, who is a world leader in MCE, is helping ORNL with technology development and assisting with commercialization.

E. Remaining Project Work

This project was rated **2.60** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Not quite 100% clear from presentation or I missed that point
- Remaining project work seems in line with the task necessary for system integration of heat exchangers
- Would be beneficial to total energy use to look at control strategies
- The necessity of the remaining work is questionable.
- Slide 16 well defines the remaining project work. Since the project has started a few months prior to current review it is too early to make a valid assessment on success of the future milestones.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Still low COP, but the project team seems to move things into the right direction to catch up with VC technology.
- Advanced manufacturing techniques allow unique heat exchangers that allow them to be optimized around the unique design constraints of this kind of system
- Collaboration with a major appliance manufacturer
- The potential impact of MCR is pretty high.
- The project strength is in large energy savings potential of MCR due to very extensive market share.

- The project's strength is that the R&D, along with the technology developed, could lower costs while reducing the effects of environmentally harmful working fluids.

2) **Project Weaknesses**

- COP is still low. Cost of materials is unclear. I think this could be a major hurdle for actual use.

- Lack of system level focus, specifically around controls and entire system thermal inertia (which is important in a piece of equipment that is known for cycling losses)

- The use of microchannels and by extension using 3D printing is of questionable need. It is not clear why a microchannel is needed in this device, the device is intrinsically batched. Therefore, to improve heat transfer why not just adjust dwell time in the regenerator to adjust heat transfer effectiveness and thus COP?

- The project weakness at this point is in lack of reasonable justification of MCR cost-effectiveness for successful market adoption.

- There are no major project weaknesses.

3) **Recommendations**

- Be open about the cost of the materials--Are there any thoughts of moving to lower cost manufacturing techniques that could be used for large scale manufacturing?
    - MCM magnetic stabilization process as potential process mentioned, what is the actual potential on this?
- Cost of raw materials?
    - Not the issue; main cost is the magnet acc. to contractor. How costly?

- A bit more focus on system level issues.

- Explore other parameters such as cycling/dwell in addition to the materials and manufacturing techniques.

- Given the availability of the Advanced Manufacturing Demo Facility at ORNL project team to consider more sophisticated designs of heat exchangers than presented

- None

Project #32226o: Thermoelectric Clothes Dryer (CRADA- SAMSUNG America)

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

Brief Summary of Reviewer Comments

All reviewers found this project's approach viable and innovative in its use of thermoelectric technology to make a heat pump clothes dryer that is cost-competitive with electric resistance dryers and offers a competitive dry cycle time. One reviewer specifically called out the project's novel approach to taking advantage of the temperature "glide" of air on both sides of the modules to deal with the shortcomings of thermoelectric modules. However, reviewers also expressed major concerns around technical barriers to short dry times, the dryer's lint tolerance, and the complexities and cost of manufacturing.

A majority of reviewers found that the progress being made was on schedule and in-line with objectives, citing that the technology was within the target drying time range and was meeting Go/No Go criteria for retail price premium. Concerns noted by reviewers regarding progress were the complexity of secondary loops over conventional electric resistance, as well as cost once the technology was commercialized. One reviewer expressed concern that the thermoelectric modules may not be cost-effective enough to be adopted, and multiple reviewers commented that the technology may experience limited market penetration once commercialized due to its price point. Most reviewers agreed that the project team appeared optimistic in its projections for energy savings potential because of this possibility that the technology will have limited market impact.

Many reviewers were pleased with the project's level of partnership with the clothes dryer manufacturer—Samsung Electronics America Inc.—noting that this collaboration demonstrated the project's teams intention to move the technology to market. Generally, reviewers highlighted this partnership as a project strength.

Given the potentially small market, one reviewer recommended that dedicated humidifiers were another potential application for this technology, while another reviewer recommended that the team considers using an advanced heat exchanger to further improve the thermal performance and reduce costs. On a larger scale, one reviewer noted that if more stringent energy efficiency standards for dryers were ever promulgated, consumers would be forced to adapt to longer drying times, thus removing that as a concern for R&D teams.

Weighted Average: 3.38 # of Reviewers: 6
Approach: 3.33 Impact: 3.50 Progress: 3.17 Collaboration/Coordination: 3.50 Remaining Work: 3.33

A. Approach

This project was rated **3.33** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Use of series of modules to take advantage of "temperature glide" of airstream on both sides.
- Approach seems sound as the researchers have achieved EF and dry time in between the Eco mode and normal mode. This seems to indicate that optimization in the direction of either of those modes would lead to successfully achieving the target efficiency and dry times
- The approach is very good.
- Approach looks viable. The only concern is a cost-effectiveness of TE modules
- The R&D of a solid state thermoelectric heat pump clothes driver technology is innovative in that there is no evidence of this having been done before.
- Innovative approach to use TE technology to make a HP clothes dryer that is cost competitive w/ electric resistance and has a dry cycle time that begins to approach the incumbent technology.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Non-vapor compression technology for cloth driers to replace electric driers without then need for GWP refrigerants
- Based on initial results, it appears that this technology is on pace to hit the target efficiency levels, which would lead to the energy savings impact desired. Not entirely clear that the price point would lead to market penetration necessary to actually achieve significant grid wide energy savings, but having a major manufacturer involved is encouraging that this is being evaluated
- The energy market is very small <1% total energy use with a potential product that will be definition be a premium product and therefore even best case the impact will be low.
- The project impact looks very optimistic with 40% energy savings and <$565 retail price. If the low-cost approach that is targeted by the project team will be successful - the tremendous commercial impact is anticipated.
- The impact of this project is immense in that it may be possible to reduce conventional dryer energy consumption by 50% with an installed cost of less than $565.
- Project is nearly 90% of the way to meeting the Program Goal of HP clothes dryer with a 6.1 EF.

C. Progress

Based on current project efforts, the project was rated **3.17** for the degree to which the project has met ***project-specific goals*.**

- Project makes good progress; only concern I have is complexity of secondary loops over conventional electric resistance.

- Progress seems well in line with project schedule and objectives.
- The progress is good.
- Reviewing the global development since 2015 - there is a significant progress observed. Technical performance looks achievable as predicted. The concern is in cost component. Minor engineering issues can be successfully resolved by commercialization partner during the manufacturing review and TTA.
- Progress is on schedule.
- Is within the target drying time range.
- Has met its go-no go criteria for retail price premium.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Project makes good progress; only concern I have is complexity of secondary loops over conventional electric resistance
- Progress seems well in line with project schedule and objectives
- The progress is good.
- Reviewing the global development since 2015 - there is a significant progress observed. Technical performance looks achievable as predicted. The concern is in cost component. Minor engineering issues can be successfully resolved by commercialization partner during the manufacturing review and TTA.
- Progress is on schedule.
- Is within the target drying time range.
- Has met its go-no go criteria for retail price premium

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Plans look promising.
- Clear target that needs to be achieved in the next steps of the project. Somewhat vague description of next steps required to get there, however, current results are a good indication that they will likely be successful in achieving the required performance
- Excellent plan to move forward.
- The remaining steps are mostly focused on the design enhancements and control variations that makes a strong confidence in the project success.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- Nearing achievement of technical goals and focusing on improving system performance.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Unique approach for dealing with the shortcomings of thermoelectric modules, essentially taking advantage of the temperature "glide" of the air on both sides of the modules.

- Strong partnership
- Demonstration that technology is already on the way to achieving performance targets

- The novelty is excellent and, the approach is very good, with good team, and good organization.

- The major project strength is knowledge base developed in the past projects along with the expertise and active involvement of the strategical partner such as SEA.

- The project's strength is that the R&D, along with the technology developed that could lower operating costs and energy consumption by 50%, which reduces environmentally harmful CO2.

- Focus on achieving high efficiency at a price point that will be competitive and encourage market transformation.

2) **Project Weaknesses**

- How large is the market for this? It seems that this is limited to a premium segment that may not be very large. Total cost of operating the cloth driers is relatively low ($1 or so per month). Will this technology ever be cheap enough to be worth it from a cost perspective?
- Current electric driers have evolved to be quite lint tolerant. How do thermoelectrics compare to this? To me it seems like the cost and maintenance requirements (is simply cleaning a lint sieve still sufficient) may be higher to allow to deal with the lint.

- Lack of clarity on manufacturing complexity and cost, which could both be headwinds in market penetration
- No focus on fouling of heat exchangers

- The potential impact is very low due to a small energy market and a premium product

- As usual for the TE developments a cost-component is a major concern.

- None

- Technical barriers that preclude shortening the drying time. Consumers have shown reluctance in the past to longer drying times.

3) **Recommendations**

- To me it seems that this project – while being an excellent idea – may not have a large market. I am wondering if the technology is maybe better used in other applications, such as in dedicated dehumidifiers.

- More work on fouling to ensure that efficiencies are maintainable over the life of the equipment

- N/A

- Consider employment of the advanced heat exchanger (in lieu of conventional) to further improve the thermal performance and reduce cost. It would also be helpful to involve the certification agency such as UL to the project in order to get their feedback that may accelerate certification and save resources (redesign, testing, etc.) in the future.

- None

- If BTO is working on implementing a more stringent energy efficiency standard for dryers then consumers will have no choice but to adapt to longer drying times.

Project #32226p: Radiation Defrosting Technique

Presenter: Kashif Nawaz, Oak Ridge National Laboratory
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Reviewers were conflicted about this project's approach to developing a novel, radiation-based defrosting process for cold climate heat pumps and commercial refrigeration systems. Several reviewers noted the project's innovative approach to controlling frost, and one highlighted the project's effort to target treatment on those areas of a heat exchanger with the most frost as a project strength. Two reviewers raised concerns with the project's approach, however—one commented on the difficulty of getting radiation between the fins of the heat exchanger, which could lead to issues if defrost water runs off to the rear; another reviewer commented that the plan for characterizing the impact of radiation on frost growth was not well thought out.

Reviewers were split on the potential impact of this technology. Three reviewers commented that the technology could have a huge impact on the cost of removing frost—which can cause system inefficiencies and increase energy consumption—potentially removing a perceived barrier to cold climate heat pump adoption. Another reviewer commented that, even if the project's technology was not commercialized, its characterization of frost growth and defrost patterns would be useful information for the field. One reviewer was less positive, however, remarking that even if project goals were met, this project might not have the expected energy impact. Another reviewer was critical that the project team was not addressing the "penalty" that comes with the use of radiation, which could also limit the project's impact.

Most reviewers agreed that the project was progressing satisfactorily and on schedule, with one reviewer explicitly highlighting that the project was still early stage, and another expressing their expectation that the project's progress would score higher in one year's time because of its low technology readiness level. As project work moves forward, however, some reviewers were pleased with its direction, but two reviewers commented that the planned future work required additional thought, while another questioned the acceptability of using microwave radiation. To address these issues, reviewers recommend that the project team develop a more concrete plan to test the influence of radiation on frost growth, and also consider alternative sources of radiation.

Despite the early stage of the project, reviewers were pleased with the project's collaboration with external partners, with one reviewer applauding the inclusion of academic experts as well as heat exchanger and equipment manufacturers.

Weighted Average: 3.09 # of Reviewers: 5
Approach: 3.00 Impact: 2.80 Progress: 3.00 Collaboration/Coordination: 3.80 Remaining Work: 2.80

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Low TRL level. I expect that this project will score higher at the next review. My main concern is that it is difficult to get radiation between fins, which may lead to issues if the defrost water does not run off straight down but backwards past the frost to the rear of the heat exchanger.
- This technology is at a pretty low TRL level, but this project seems likely to bring it to a higher TRL level and begin to explore/identify some of the hurdles to bringing it to market
- The approach is ok, but it was not that clear how the PI plans to characterize the frost growth with radiation applied.
- The project takes an innovative approach to frost control by using radiation.
- Solid experimental approach investigating existing technology and techniques before digging into specifics of surface morphology, air conditions, fin geometry, etc.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.80** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- My expectation is that this should be substantially help to reduce heat pump power (or freezer) energy consumption.
- It's not clear that, even if this project is successful in raising the TRL level of this technology to the goal, that it will have the energy impact expected from DOE
- This is unclear because the defrosting using radiation comes with a penalty and that penalty was not addressed in the current state of the work.
- Performing R&D on a new energy-efficient approach for defrosting cold climate heat pumps and commercial refrigeration systems can have a huge impact on the cost of removing frost growth on heat exchanger surfaces, which causes system inefficiencies and increases energy consumption.
- If this defrosting approach can be commercialized it will contribute to improving the efficiency of cold climate heat pumps and remove a perceived barrier to their uptake in cold climates.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- Early stage low TRL level. I expect this to score higher at the next review. The current results look very promising.
- Researchers have done a great job in adding to the understanding of frost growth and initial investigations of radiative frost removal
- Good progress
- The project has progressed satisfactorily and appears to be on schedule to meet the project goals.

- Project is early stage. Modeling and experimental tasks underway.

D. Collaboration and Coordination

This project was rated **3.80** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Good project team, including external partners.
- Good team which included academic experts in the field all the way to heat exchanger and systems manufacturers
- Very good team.
- A large group of collaborators and partners have been assembled by ORNL for this project, including Johnson Controls Inc. Hillphoenix, University of Illinois at Urbana Champaign, and Isotherm Inc.
- Project in early stage.

E. Remaining Project Work

This project was rated **2.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- I think the contractor has a decent plan on how to move this forward. Looking forward to it!
- Most of the next step make sense, but I wonder about the acceptability of microwave radiation.
- The remaining work does not seem well thought out.
- The project work still to be performed will most likely be completed on schedule as the remaining technical challenges appear to be solvable.
- Early stage. Bulk of analysis and model development yet to come.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Targeted treatment of the area of the heat exchanger that has the most frost. This should substantially decrease defrosting energy costs.
- Strong team with great understanding of topic
- The topic is interesting, technology shows some promise and the impact could be large.
- The project's strength is that it is doing R&D on a innovative energy-efficient approach for defrosting cold climate heat pumps and commercial refrigeration systems, which can in turn reduce the cost of removing frost growth on heat exchanger surfaces.
- Characterizing frost growth/defrost on various surfaces and analyzing the effectiveness of various radiation sources for defrosting will provide useful information even it this technology/technique doesn’t move to commercialization.

2) **Project Weaknesses**

- The proposed method requires costly modifications. At this point it is unclear if any other issues, e.g. with refreezing of water further into the coil, during the defrost process itself. I expect this to only come out during repetitive frost/defrost cycles, and the contractor should ensure to draft his test matrix to reflect long term operation.

- Not clear which form of radiation would be best
- A focus on microwaves seems one of the least likely paths forward

- The impact of the radiation on the characterization of frost growth plan is not well thought out.

- None

- The challenge of having numerous parameters that affect the process and identifying interactive effects between these parameters.

3) **Recommendations**

- Relocate defrost heaters of conventional technology to where they are actually needed instead of using infrared lights?!

- N/A

- Develop a more concrete plan moving forward to test the influence of radiation on frost growth.

- None

- None.

Project #30007: SBIR: Advanced Hybrid Water Heater using Electrochemical Compressor

Presenter: Bamdad Bahar, Xergy
DOE Manager: Antonio Bouza

Brief Summary of Reviewer Comments

Most reviewers appeared to find the approach taken by this project—to develop a prototype hybrid hot water heater using a proprietary electrochemical compressor—to be at least appropriate. One reviewer highlighted the project team's efforts to solve problems as they occurred, while another lauded the benefits of this project's approach for overcoming potential flammability problems and enabling the use of "safe" refrigerants. Critically, one reviewer described the project's approach as "shotgun" style, which they felt was generally less effective than a more targeted approach. Reviewers also identified weaknesses in certain technical aspects of the project, including the complicated nature of the system being developed and skepticism that the technology could hit its targeted efficiencies.

Reviewers commented that the potential impact of this project was potentially far reaching, both in terms of achieving significant energy savings and assisting in the phase out of harmful working fluids, thereby reducing global warming potential (GWP) emissions. Reviewers noted that, if successful, the project could improve hybrid water heating performances for cooling and dehumidification, as well as contribute to a safe environment by promoting the use of zero GWP working fluids. One reviewer cautioned, however, that the impact would be limited by the type of fluids capable of being pumped while using electrochemical compression, none of which were considered by this reviewer to be good replacements for conventional refrigerants. Other reviewers also questioned the technology's marketability and large-scale manufacturability.

Reviewers generally approved of the progress being made on this project. Two reviewers were pleased with how the size of the compressor was being substantially reduced, as well as with how the project team was using this technology platform in other applications. One reviewer noted that an extension had been requested, however, while another remarked that it was clear that the project performer was making progress on its product development, but that it was not clear how this progress was being influenced by DOE's funding.

Reviewers unanimously agreed that the project team had solid partners in industry and academia, who worked well together and could support the technology's movement toward commercialization once development was complete. Reviewers also found the remaining project work to be promising, on track, and in line with the current project progress. Despite these expectations, however, reviewers still offered a number of recommendations for the project team to consider moving forward, including that they should investigate another working fluid that did not cause embrittlement of the components or long-term leakage (e.g. CO_2), and that they should focus on non-technical barriers to market infiltration once temperature lift and efficiency had been achieved.

Weighted Average: 3.13 # of Reviewers: 4
Approach: 2.75 Impact: 3.00 Progress: 3.00 Collaboration/Coordination: 4.00 Remaining Work: 3.00

A. Approach

This project was rated **2.75** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Good portfolio of companies assembled; problems were solved as they occurred, including manufacturing of membranes.
- Good approach to technology.
- The project approach feels like a 'shotgun' approach which is generally less effective.
- The approach of replacing a conventional compressor with an electrochemical compressor (ECC) will allow for the use of “safe” refrigerants, thus overcoming potential flammability problems.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Electrochemical compressors allow compression of fluids that are impractical or inefficient with traditional mechanical compressors, thus allowing to use lower GWP fluids.
- If COP's are achieved this could be a technology that has significant energy savings.
- The impact is potentially good but is limited by the types of fluids capable of being pumped using ECC technology, none of which are good replacements for conventional refrigerants.
- The impact of the ECC technology and associated systems are far reaching in that it will not only improve performances for cooling, and dehumidification, but also contribute to a safe environment by promoting the use of zero GWP working fluids.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*****.**

- Size of compressor was substantially reduced throughout several iterations.
- It appears that the researchers are meeting the project specific goals but also taking this opportunity to use the technology platform in other applications (i.e. oxygen removal in food storage).
- The company itself has made some good progress, it was difficult to discern what was influenced by the current DOE project, though.
- The project progress is good and it appears to be on schedule; however, an extension is being requested.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Total of 4 partners, including a major appliance manufacturer for roll-out of the technology, once development complete.

- Collaboration with project participants appears to be going well.
- Good team.
- The collaboration efforts for the project are outstanding in that industries and a university are all working together.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Looks quite promising. Looking forward to seeing this move into products as done at previous stages of this "membrane track."
- Presentation appeared to show that work is on track and remaining tasks are in line with current project progress.
- N/A
- The only work remaining is to deliver the hybrid hot water heater to ORNL along with providing a commercially viable ECC/MHHX/ILD system.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Excellent team that moves this project forward.
- Developing a technology platform that can be used in multiple applications outside of the scope of the current project.
- Technology with out of the box thinking that appears to have efficiency that would result in substantially energy savings if adopted.
- The novelty and range of the projects/applications is excellent.
- The strength of the project is its innovativeness and the fact that it will assist with the phase-out of harmful working fluids.

2) **Project Weaknesses**

- New technology that leads to skepticism by people with mechanical background. It is unclear to me if such skepticism is justified.
- Not entirely clear that this technology can hit the efficiency claims at the temperature lifts specifically required in water heating applications, if it doesn't, still may be applicable in other applications
- Not clear that system size would allow for a highly marketable product as the water heating market as specific expectations on product size.
- Large scale manufacturability still a big question.
- The project approach is too un-focused. It would be nice to see a more focused approach on a particular application and/or working fluid to maximize opportunity for success.
- There are few weaknesses, but the complicated nature of the system compared to more simple existing technologies could be a challenge.

3) **Recommendations**

- Hydrogen embrittlement of components and long term leakage by migration of the hydrogen molecules through metal pipes to the ambient seem to be a valid concern for the current working fluid. I would recommend to investigate other working fluids that do not have this issue. CO2, as proposed by the contractor, may be a potential option.

- Once temperature lift and efficiency are demonstrated begin to narrow design focus on non-technical barriers to this technology being introduced into the water heating market place (i.e. size and, cost, and manufacturability).

- Focus the technology efforts.

- None.

Emerging Technologies
Building Envelope

Project #31395: Ultra-High R/Inch VIP with Polymeric Fibrous Core Material

Presenter: Kaushik Biswas, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

The reviewers found the project's approach to the development of thinner, higher-performing insulation materials to be strong, and likely to overcome barriers and technical challenges. One reviewer complemented the vacuum insulated panels (VIPs) as having good targets for thermal performance and cost, but another reviewer cautioned that the performance of the future-looking core-based insulation dropped off significantly with any pressure loss. One reviewer identified this project as a "high risk, high reward" project, and others commented that, if this project were to meet its potential, it would significant contribute to the state of the art. One reviewer warned, however, that market acceptance would be a problem for the technology, which they encouraged the project team to more fully address.

Reviewers found the project to be on target to reach its goals, despite its early stage, and described the project's future plans as logical and well aligned to reaching the project team's R80/inch insulation performance target. Reviewers generally felt that the project team's collaboration with industry, especially NanoPore and Firestone, to be strong, though one reviewer recommended engaging with additional market stakeholders to ensure market adoption.

Reviewers applauded the project's experienced team and their sound technical approach to the VIP technology, particularly the continued development of modified atmosphere insulation (MAI). However, reviewers found weaknesses in the insulations installation challenges and longevity potential. Another reviewers flagged the sensitivity to pressure for new cores as a potential issue in the future, and recommended an increased focus on barrier development. Other reviewer recommendations included developing greater market connections, direct engagement with installers, and more varied demonstrations to illustrate the technology's impact.

Weighted Average: 3.40 # of Reviewers: 4
Approach: 3.00 Impact: 3.50 Progress: 3.75 Collaboration/Coordination: 3.75 Remaining Work: 3.25

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach taken and proposed will assess viability in an application. The VIPs described do meet good targets for thermal performance and cost.

- The project seems very likely to overcome all the technical barriers of production, but have to face the more challenging hurdles of contractor installation.

- MAI in demonstration mode so N/A.
- Core development and barriers identified as key for new core.
- Expected more focus on barrier as new cores are 1000x lower in pressure and R will fall off quickly with any pressure loss.
- Not sure what the backup plan is here.

- Although the project is in the early stages, its approach is very likely to contribute to overcoming barriers, technical challenges, and mitigating project risk. The project will perform full-scale installation of the R25 composite insulation or R12/inch composites on a low-slope roof of an occupied commercial building. R25 composite contains low-cost VIPs called Modified Atmosphere Insulation (MAI) with fumed silica core. Long-term performance via natural and accelerated aging will be evaluated. Contractor feedback will enable further technology development/optimization that will include developing higher R/inch VIPs at lower cost than MAI.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The performance and cost targets for the VIPs do align with BTO roadmap priorities. However, a big obstacle to having such an impact is market acceptance. While the team acknowledges this is a barrier, more can be done to explore how to overcome this barrier and have greater impact.

- The VIP have already achieved the ambitious R 12/inch goals, so their even higher R-value targets will further advance the program goals

- Project would significantly contribute to the current state of the art.
- New core at such a low pressure is high risk but also high reward.

- If the project-specific goals are met, the project is very likely to contribute to the program goal(s). Based on the analysis done so far, it is projected to lower costs. The same performance is expected to be achieved with thinner panels which will lower material and shipping costs and also, reduce installation thickness. The applications of the technology include low-slope commercial roof and residential walls.

C. Progress

Based on current project efforts, the project was rated **3.75** for the degree to which the project has met ***project-specific goals***.

- The project has made good progress to-date to achieve their goals.

- The project has met its immediate R-value goals and scaled up production of panels for testing.

- Relatively new project. Some barrier work and new core development. Project appears on track.

- When combined with previous related research done by the project team on MAI and R25 composite insulation development, the project has demonstrated significant contribution to the project-specific goals. On the installation and long term performance of R25 composite insulation, the project team has scaled up and manufactured R25 composite insulation boards containing fumed silica-based MAI panels. The team has developed vacuum pump system for the development of new core to achieve R80/inch to rapidly make VIPs with internal pressures of 0.1 mbar; and has identified and evaluated barrier films that can maintain low internal pressure and their impacts on thermal bridging/edge effects. The building selected is located in Caribou, ME. Approximately, 5500 ft2 section of the roof will be retrofitted with gravel-covered built up with slope 2:12. Natural-aging test is being done in Charleston, SC. Based on the measured heat flux data, no degradation in thermal performance has been found during the one and half years of testing. A high vacuum chamber that can rapidly achieve VIP low pressures of less than 0.001 mbar is under construction. New core is yet to be optimized to reduce radiation heat transfer.

D. Collaboration and Coordination

This project was rated **3.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The collaboration with Firestone and NanoPore is key. Additional market stakeholders should be engaged to help ensure market adoption.

- The research team has developed strong collaborators in the VIP and foam industries, and the active support of both bodes well for the project.

- Strong core team (research through manufacturing & commercialization).

- The project team has demonstrated very good strategic collaboration/coordination with relevant stakeholders. There is collaboration between government (DOE), research organization (ORNL) and industry (NanoPore and Firestone). ORNL has access to test beds for evaluations of prototypes of VIP-based insulation systems. Firestone has access to roofing contractors and commercial buildings that can act as test beds for installation evaluations. Based on the work done so far, there is a journal paper submission in April 2018 to Applied Energy, demonstrating that publications and presentations at technical meetings/conferences is being pursued as part of enabling dissemination of information to relevant stakeholders.

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The development and testing proposed are appropriate to achieving the overall goals of the project.

- The team seems on track to meet the goals of their first focus area, and the R80 goal of their second focus area seems within reach.

- Logical plan and list of activities.
- Few details on alternative barrier/sealing technologies if metalized films are not successful.

- The project plans shown for the remaining project work are likely to meet the project-specific goals. The remaining project work includes completion of roof installation of the R25 composite boards, design of an accelerated aging protocol for laboratory aging of silica-based MAI panels and the R25 composite, testing the efficacy of barrier films to maintain low internal pressure in the new core-based VIPs, optimizing the new core material with respect to gas and solid conduction and radiation heat transfer, developing and evaluating the full-scale composite insulation boards with the new R80/inch VIPs, evaluation of the impact of metallized films on overall R-value and evaluation of the long-term performance of the R80/inch VIPs.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Sound technical approach and material development. The technical approach is considering issues such as edge effects, which are critical to ensure performance once installed.
- Great team.

- Strength of the project is the VIP technology, and the composite panel approach as a method for delivering/installing VIP panels. The real innovation won't be the development of the R80 VIP, but of developing a successful method of using it and of guaranteeing the longevity.

- Continued development of MAIs.
- Novel approach for new cores.

- Previous experience of the project team is an asset to this project. Previously, the team has successfully developed foam-VIP composites that can achieve R25 at 2 inch thickness, or R12/inch. The project's approach is very likely to contribute to meeting the project-specific goals. Based on the analysis, it is projected to lower costs. If successful, the same performance will be achieved with thinner panels which will lower material and shipping costs and also, reduce installation thickness. Results from the project will be applicable to low-slope commercial roof and residential walls.

2) **Project Weaknesses**

- Need greater market connections to help ensure market penetration.

- The weaknesses of the project are the inherent weaknesses of VIP: installation and longevity. They are addressing the installation issue fundamentally with the project, and the development and testing of stronger barriers may work for the longevity. The ability of the fumed silica core to maintain its R value while it loses vacuum could be real plus for longevity and durability if the self-sealing works.

- R-value sensitivity to pressure for new cores necessitating exceptional barriers.

- The project team stated that the new core-based VIPs are projected to cost $0.02/ft2/R-value (assuming R80/inch). The low cost is based on this assumption. What happens if this R-value is not achieved? Will the objective of lower costs be achieved?

3) **Recommendations**

- If possible, consider other demonstrations that could further illustrate the impact and applicability of the new VIPs.

- Direct engagement with installers (which is planned) will the key to making it succeed.

- Expand / detailed focus on barrier development.

- Since there are still a lot of tasks to be completed to meet the project goals, the project team should hasten progress to enable the project's specific goals to be met. The team should explore pathways for easy integration into existing buildings since the ratio of new to existing buildings is 1:100 as well as introduction to the market.

Project #313108: Robust Super Insulation at a Competitive Price

Presenter: Ravi Prasher, Lawrence Berkeley National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers found this project's approach to be novel yet ambitious for developing nanoscale insulation with a high R/inch value. Reviewers noted that if the project were successful, it would have a significant impact by providing low-cost durable insulation. However, they also noted significant challenges with the material development, and doubted the feasibility of achieving an R-12 materials for actual applications.

Reviewers were somewhat split on the project's progress, with several observing the project to be on target for achieving its technical goals—though with some factors like cost yet to be addressed—but one expressing that the project's technical achievements were modest for a project at its halfway point. Reviewers found the remaining work to be logically planned out, though they noted that there was substantial work left to do. One reviewer reiterated their concern that the R-12 goal was not actually achievable, while another was more concerned about the insulations' mechanical strength than its R-value. To address some of these issues, reviewers recommend adding more Go/No Go checkpoints to the project plan, and encouraged the project team to more clearly identify and mitigate project risks.

Although reviewers observed that the project team had strong technical qualifications, they found that the project lacked adequate collaboration and expressed concern that industry or manufacturing partners might not want to take on the risk of such an early stage technology.

Weighted Average: 2.93 # of Reviewers: 4
Approach: 3.00 Impact: 3.25 Progress: 3.00 Collaboration/Coordination: 2.75 Remaining Work: 2.50

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach being used depends significantly on the underlying theoretical calculation of the target R-value. That calculation was not presented to validate. Nonetheless, new insulation materials with high R-value can have a significant impact on building energy efficiency.

- An ambitious project of fundamental research; more risky, but seems worth pursuing.

- Novel approach.
- Thorough understanding of heat transfer modes.
- Didn't see mechanical properties addressed.
- Might need some type of binder to contain nanoparticles in the application.

- If successful, the project's approach is very likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. The project aims at manipulating heat transport at the interfaces at the nanoscale to achieve high R/inch value. With this it will develop insulation that is 2 to 4 times more efficient than conventional materials and at a comparable installed cost. Compared to emerging technologies of aerogel and vacuum insulated panels, the new insulation will have significantly higher mechanical robustness and considerably higher flexibility. It is also expected that the insulation will be cost-effective and can easily be retrofitted into existing buildings.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- If the R-value is achieved, the project will be on a good path toward the development of new insulation materials. However, significant challenges remain with respect to material development.

- The immediate goal of a low-cost and durable (even flexible) High R insulation aligns well with program goals.

- If successful would be a significant change to the state of the art.

- It is anticipated that if successful, the new insulation technology from this project could be a potential replacement for insulations used in walls of residential and commercial buildings. It could provide cost-effectively, variable very high thermal insulation that will fit within the space limitations of existing buildings. Using this technology on the interior side of a wall could open up the retrofit market making it appealing for both renovations and new building construction as it will minimize energy consumption and cut energy bills.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals***.

- The project is on track to meet their very early stage technical goals.

- The progression of refinements is approaching the project goal of R12, but still have some hurdles to overcome. It doesn't (can't) yet address the question of cost.

- Unclear of significant progress to date. Few quantitative details.

- Q1 through Q3 progress in presentation were very modest for 1.5 yrs. into a 3 yr. project.

- Although the project is halfway on its timeline, it has demonstrated very good contribution to the project specific goals. Progress made includes (a) procurement, characterization and selection of nanoparticles, (b) completed studies to identify thermal and mechanical metrology impact on particle and acoustic mismatch, (c) surface modification of nanoparticle for lower surface energy, and (d) optimization of parameters to achieve R/inch of 6 in sample area of 1 cm^2. A provisional patent has been filed and a journal paper showing the effect of pressure on Van Der Waals contact has been published in *Nano and Microscale Thermophysical Engineering*.

D. Collaboration and Coordination

This project was rated **2.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- There have been other scientific groups that have explored the development of similar material systems. Their work should be consulted and leveraged.

- The team has a good advisory board, but little evidence of real industry interest at this stage, partly because of the risky nature of the research and early stage of results.

- Strong technical team.
- Needs a manufacturing partner.
- Industry advisory board won't be sufficient for manufacturing challenges.

- The project team demonstrated significant strategic collaboration or coordination with relevant stakeholders. The team has constituted an industrial advisory board of people from insulation and energy efficiency industries and academia to advice on potential funding opportunities and early stage application and market. They have presented their work to an expert who has over twenty years' experience of leadership in research, policy and technology development in the Department of Defense (DOD) who expressed satisfaction with their work presented to him. A provisional patent has been filed and a journal paper showing the effect of pressure on Van Der Waals contact has been published in *Nano and Microscale Thermophysical Engineering*, demonstrating that "publications" is being pursued as part of enabling dissemination of information to relevant stakeholders.

E. Remaining Project Work

This project was rated **2.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The project has clear steps in place to meet the remaining project goals. However, I question whether an R-12 is even achievable.

- The plan seems good, though the risks also seem substantial. they should be able to achieve the Rvalue target, but the mechanical strength remains to be seen

- Process optimization and R2R spray processes are activities that a manufacturing partner would add significant value (dollars, speed and process knowledge).

- Although substantial work remains to be done, the project plans are likely to meet the project-specific goals if all the associated risks are articulated and mitigated. Process optimization for the right combination of nanoparticle size, surface chemistry and acoustic mismatch to achieve final goal of R/inch = 12 and development of a spray process for making flexible insulation are among the tasks remaining. Also, a final insulation product that can be attached easily to wall surfaces is expected to be developed.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Good theoretical understanding of underpinning phenomena.

- Strength is returning to first principles and seeking a novel approach at the nano scale.

- Strong technical team.
- Very good knowledge of key components to be optimized.
- Novel approach.

- The project's strengths are more dependent on the results. The project aims to develop a cost-effective insulation that is 2 to 4 times more efficient than conventional materials and at a comparable installed cost. Compared to emerging technologies of aerogel and vacuum insulated panels, the new insulation is expected to have significantly higher mechanical robustness and considerably higher flexibility. The new insulation can be retrofitted easily into existing buildings since the ratio of new to existing buildings is 1:100.

2) **Project Weaknesses**

- There are numerous questions related to this project:
    - 1. What is the underlying theoretical evidence that an R-12 is achievable? What assumptions were used in that analysis?
    - 2. How could such a material even be developed for actual applications? Is it even possible or is this simply a theoretical endeavor?
    - 3. Others in the scientific community have already explored such materials - why are they not being referenced to demonstrate how the team is developing these materials differently?

- Weakness is perhaps the scope of the ambition, but also the potential toxicity of nano particles of silica.

- Lack of a manufacturing partner.
- Lack of demonstrated technical progress to date.

- The project's weaknesses are partly dependent on the results of some of the associated research (including manipulation of heat transport at the interfaces at the nanoscale to achieve the desired R/inch value). The project will not be very successful if the results from the research do not meet the required anticipation.

3) **Recommendations**

- I would add in more Go/No Gos to the project related to the material development.

- The team has a confident path of exploration, but the initial proposition made me wonder if there couldn't be some greater reduction in conductivity by layering dissimilar materials, rather than focusing only on the contact between similar particles.

- Get a manufacturing partner.
- More progress to date detail in presentation.

- All the risks associated with the project and the methods for mitigation should be adequately articulated and addressed.

Project #313110: Stationary Concentrator Daylighting System

Presenter: Chris Gladden, Glint Photonics, Inc.
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project's approach—developing a prototype daylighting roof-mounted concentrator to transmit light into the building interior—could help overcome some market barriers and technical challenges to the achievement of greater reductions in lighting energy demand as a result of daylighting. Unfortunately, reviewers also agreed that while the project team did a good job of identifying potentials risks and challenges to the project's technology, actual solutions to the risks and challenges were not adequately identified or elucidated. On the technical side, reviewers applauded the project's innovative daylighting optical design, which avoided the use of fiberglass and could provide considerable cost and performance improvements compared to existing designs, but they critiqued both the technology's reliance on direct sunlight, which would limit its effectiveness on cloudy days, and the effort that would be required to maintain the system's internal mechanism and keep it calibrated.

If successful, reviewers expected that the project would contribute to BTO's program goal of increasing the provision of sunlight to the interior of buildings, and would likely increase daylighting market penetration. However, though one reviewer did note that the project team had met a significant milestone of producing a working prototype, multiple reviewers expressed concerns with the project's progress, noting the presence of delays in optical molding and the fact that two-thirds of funding had been spent at the project's half-way point. Given these concerns, two reviewers suggested that the project team accelerate its pace, and recommended that additional resources be considered for the remaining project work. Moving forward, reviewers also recommended the project team consider marketing the project's technology as a window extension—which would be easier to explain to consumers—and explore ways to integrate the technology into the large existing-buildings market.

Reviewers were split on the project's collaborative efforts. While one reviewer positively commented that the project team had met with a variety of downstream stakeholders, and had developed the project according to the feedback received, another reviewer was critical of the fact that no up-stream collaboration had occurred to de-risk the research effort.

Weighted Average: 2.82 # of Reviewers: 3
Approach: 2.67 Impact: 3.67 Progress: 2.33 Collaboration/Coordination: 2.67 Remaining Work: 2.67

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A. Approach

This project was rated **2.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- They clearly listed the risks the project faces, but were less clear about their approach to overcoming them. Two areas seem important to address. One is the robustness of the mechanical movements inside the concentrator and the other is the architectural insertion – both how it is explained and how it is integrated with the construction.

- Novel optical design to improve daylighting.
- Key risks were identified but sub-bullets were not mitigations but looked like primary activities.
- No clearly identified backup plan.
- Little to no technical data so unclear of technical challenges or progress (durability, sealing, theoretical performance, etc.)

- This project aims to develop a prototype daylighting roof-mounted concentrator to transmit light into the building interior with the aim of reducing energy use for electric lighting in buildings. The system will include the actuation mechanisms, light delivery system and building interface and then, evaluate the system's performance in a field installation. The approach presented, if successful, will contribute to overcoming some barriers and technical challenges. Key risks include: mechanical actuation system accuracy, solar position algorithm, panel sealing, environmental durability, building interface and market acceptance. Measures to be adopted to mitigate these risks were highlighted. The presenter however, forgot to include a key slide that would have helped reviewers to better evaluate the approach to the solution of the problem.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- It is a clever and thoughtful project aimed at an important aspect of existing buildings, which is the large areas that can't be reached by daylight from openings. If they can overcome the hurdles, it is able to capture significant daylight on the outside of the building but deliver it through a very small duct.

- If successful, would add a new daylighting option which would increase daylighting market penetration.

- If the program specific goals are met, the project is highly likely to contribute to the program goal of provision of sufficient sunlight in the interior of buildings. Compared to present technology, more light will be delivered through a smaller roof penetration. Building Technologies Office (BTO) has a target to reduce lighting energy by 50% for a 50-foot floor plate. This daylighting technology will advance towards realizing this objective.

C. Progress

Based on current project efforts, the project was rated **2.33** for the degree to which the project has met ***project-specific goals***.

- They have met the key goal of producing a working prototype ready for installation in a trial location.

- Project progress OK to this point although mainly design work.
- Already with a 6-month, no-cost extension due to delays in optical molding.
- Two-thirds of dollars spent at halfway point in project, so funding to completion might become an issue.

- Vendor delays and quality issues have delayed progress on the work, hence the project has demonstrated modest contributions to the project-specific goals.

D. Collaboration and Coordination

This project was rated **2.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- They have met with a variety of stakeholders and developed the project according to feedback they have received, but their challenge is that there isn't really an existing market for this kind of modification, so hard to really target specific classes of stakeholders beyond designers and building owners.

- Many downstream interviews were made.
- No true project collaboration or coordination. Appears to be a go-it-alone project.
- Project needs partners to de-risk effort and enhance go-to-market attractiveness.

- The project has demonstrated significant collaboration and coordination with relevant stakeholders. So far, the project has worked with molded optics vendor to develop molding process. It also showed significant market interaction with lighting and daylighting experts and designers to validate some outcomes. The project has also secured field installation opportunity. The presentation showed that a number of key decisions were directed by industry engagement.

E. Remaining Project Work

This project was rated **2.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- They seem likely to meet the 75% of theoretical efficiency goal and the field test seems to be proceeding.

- Future planning looks OK but project deliverables are backend loaded.
- Risk with dollars spent already.
- Should consider project acceleration or augmented financing.

- The project is currently at the mid-point. If the project workers hasten progress from this stage on, the project is likely to meet the specific goals. There are some key risks that are remaining to be dealt with. These include (a) extended environmental testing of the panel sealing and environmental durability, (b) development of mounting hardware for the building interface system and (c) techno-economic analysis for market acceptance of the project. Details on how to mitigate these risks were not given.

F. Additional Comments and Recommendations

1) **Project Strengths**

- It is an innovative approach with some very original work to get the optics to work with no exterior movement and to avoid using glass fiber optics. This allows them to dramatically amplify the amount of light they can push into the ducts or light tubes.

- Novel daylighting optical design.

- This daylight concentrator hopes to provide considerable cost and performance compared to existing technology. More light is expected to be delivered through a smaller roof penetration. There will also be reduced installation and operational costs, and routing flexibility. The system does not require an external power or wiring.

2) **Project Weaknesses**

- One is that it only works with direct sunlight, so even though they show results in cloudier climates, it is unlikely to make sense there.
- Two is the challenge of keeping the internal mechanism working and calibrated over the long-term.

- Lack of collaborators to de-risk the project.
- Lack of detailed results in presentation (mechanical durability, optical performance, etc.)

- There have been extended vendor delays and quality issues that have led to delayed progress on the work. Key risks include: mechanical actuation system accuracy, solar position algorithm, panel sealing, environmental durability, building interface and market acceptance.

3) **Recommendations**

- I think they will learn a lot from the field installation and might consider testing (or developing) a less efficient version without the moving parts (if possible? didn't show the optics).
- Biggest recommendation would to design and market it as an amplification or extension of a window. Installed about a window, it increases the depth of penetration of useful daylight dramatically, but will be easier to explain and sell as part of thinking about windows and daylight.

- Should consider project acceleration or augmented financing.

- The project is currently at the mid-point. Since there are still a lot of tasks to be completed to meet the project goals, the project team should work to improve progress from this stage on to enable the project to meet the specific goals. Serious effort should be made to address the key risks associated with the project. The team should explore pathways for easy integration into existing buildings since the ratio of new to existing buildings is 1:100.

Project #313112: Development of Low-Cost Isocyanurate-Based Super Insulation

Presenter: Jan Kośny, Fraunhofer Center for Sustainable Energy Systems
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers found the project's approach to developing open-cell nanofoam insulation to be appropriate, well formulated, and well-positioned to overcome manufacturing barriers. Most reviewers commented that the team had set themselves up to address technical challenges and mitigate project risks, but one cautioned that the project's strategy for overcoming its cost barrier relied on a project component—its freeze drying method—which had not yet been demonstrated. On the technical side, reviewers highlighted several project strengths, including the thermal conductivity values being achieved, as well as the technology's elimination of problematic elements of foam insulation and blowing agents. Reviewers did warn about potential challenges to transitioning the project's freeze-drying equipment to scale, and they also remarked on the lack of early-stage durability testing and repeatedly noted that the technology's health and environmental impacts were not clear. Overall, however, reviewers felt that if the project goals are met, the project would likely contribute to BTO's program goals, as there was high commercial interest in this field and the end product would be low-cost and highly durable.

Generally, reviewers were pleased with the progress the project team had made, particularly highlighting the material development and characterization and the identification of commercialization partners. Reviewers also found the project team to be engaging well with industry partners and scientists, though one reviewer recommended finalizing key partnerships as soon as possible. Moving forward, reviewers found the remaining work to be well planned and achievable, though they did recommend acquiring a freeze-drying partner immediately, and to be flexible with the process to allow for scale-up.

Weighted Average: 3.41 # of Reviewers: 4
Approach: 3.50 Impact: 3.50 Progress: 3.50 Collaboration/Coordination: 3.25 Remaining Work: 3.25

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project steps taken and proposed to develop the nanofoam are systematic and appropriate. The insulating material could have an impact on the market.

- The team has a very sensible and well formulated approach, and a strong team, they seem well positioned to overcome the inevitable manufacturing barriers.

- High risk (and potentially high reward) early stage project.
- Open cell nanofoam design eliminating blowing agents would overcome many of the current performance barriers.
- Cost barrier relies on cost effective freeze drying method, which has not been demonstrated.

- The project's approach is very likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. This project intends to develop a new type of aerogel-based super insulation at atmospheric pressure by employing a low-cost freeze drying method for pore solvent removal instead of the cost-prohibitive supercritical drying method. The insulation (a) can attain an R-12 hr·ft2·ºF/Btu·in (λ = 12 mW/m·K), (b) is mechanically robust, and (c) is cost-competitive compared to conventional rigid foam boards. It is expected to be mechanically stronger, more elastic, significantly less expensive, and dust free.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- There is commercial interest in these materials, making their potential impact in the marketplace high. Properties align with the needs of the market and energy efficiency goals.

- It is very early in the project, but they seem well on the way to meeting their Y1 goal.

- A successful SIAP product with low cost and durability would be a significant improvement to the current state of the art.

- If the project-specific goals are met, the project is likely to contribute to the program goals. Insulation produced by this method will have the ability to improve the overall R-value of building envelopes without changing the dimensions of the structural components or insulating sheathing. The chemistry of the new technology is less expensive and could allow for quick adoption by industry. The proposed PIR SIAP, with a target of R-12.0 hr·ft2·°F/Btu·in, which will have almost double R-value, compared to the "in-service R-value" of today's PIR foams (which is only R-5.7). It could also significantly lower environmental impact than today's plastic foam insulations.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals***.

- The team has made nice progress on material development and characterization. They have identified commercial manufacturing processes, which is critical for development.

- In Q2 the team has nearly met the R value goal with batch sample goals, and their formulation removes many of the other impediments. The critical factor seems to be the scale of the freeze-drying equipment.

- Project progress on nanofoam looked good.
- Would liked to have seen some early durability testing.
- No quantitative details on Preliminary Cost-Performance Model.
- No preliminary cost data presented so challenging to assess progress.

- The project has demonstrated some contribution to the project-specific goals. The project team is starting to explore agreement to formalize the company's role in commercializing possible IP developed from the project. The team has made progress towards identifying the manufacturing process and the necessary materials and equipment for producing the freeze-dried PIR-SIAP. It is not clear yet if a secondary solvent is needed, so only a single solvent (t-butanol) has been used for the calculations in the analysis. The apparent thermal conductivity of the first series of nanofoam samples fabricated as measured by the HFMA is around 0.027 W/m-K, which is equivalent to thermal resistivity of about R-5.35 hr·ft2·°F/Btu·in. Although the target goal is still high, this is a good step towards the goal.

D. Collaboration and Coordination

This project was rated **3.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The team appears to be coordinating well with scientists and industry.

- An experienced and well-formulated team with good industry collaboration and feedback.

- Strong technical team. Manufacturing partner discussions occurring.
- Need to lock in this key partner.
- Would like to have seen them on the project at the start.

- The degree to which the project staff has demonstrate strategic collaboration or coordination with relevant stakeholders is not very good. The reason for this, is probably because this is relatively the early-stage of the project. The team indicated that there is crucial need for close cooperation with industry and academia. Two key manufactures of the PIR foam and manufacturers' association have been approached, and NDAs have been signed. The project team is expecting in future to discuss details of the technology with industry partners, patent developments and eventual IP licensing options and scale-up stage that will include industrial lab experiments and small scale field demonstrations. Only, a university and a consultant were named in terms of industry partners, collaborators and coordinators.

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The remaining project work seems achievable, and the approach is sound.

- They seem well on their way to meeting the immediate project goals for Y1 and Y2

- Early in project Q2 of 2 yr.
- Project logically planned out.
- Would like to have seen manufacturing partner as part of team so technical and production paths could be developed concurrently.

- This is the early stage of the two-year project. The project team is currently finishing the second quarter. There are indications that the project team has logically planned the remaining work to meet the project specific goals. Key risks connected with the health and environmental impacts of the new technology were not addressed.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Focus on material development is at the forefront, which is critical. Thermal conductivity values are in the targeted range.

- The strength is in the formulation, how to eliminate most of the problem elements in the foam, eliminating blowing agents and closed cell is key. The use of a less expensive method of curing with freeze-drying will be critical.

- Strong technical team.
- Solid approach.

- If successful, the proposed PIR-based SIAP will have about twice the low apparent thermal conductivity compared to conventional foams. The method adopted will make it not to exhibit thermal aging. Also, compared to currently-produced, non-reinforced silica aerogel products, the new technology will be mechanically stronger, more elastic, and less expensive.

2) **Project Weaknesses**

- While the team is also focused on mechanical properties, there are concerns regarding these properties once materials are scaled up. Scale up could lead to additional problems that limit applicability or reduce thermal performance.

- The scaling-up of the freeze-drying batch process to handle a continuous production situation.

- Relies on large-scale, high-volume freeze drying manufacturing with uncertain cost.
- Lack of freeze drying or insulation commercial partner.

- Information given on the relevant stakeholders for strategic collaboration and coordination were not given in details. The health and environmental impacts of the new technology are not clear.

3) **Recommendations**

- Continue to systematically measure thermal properties with different iterations of the material and through scale-up. Consider changes to processing, as needed, to ensure thermal performance.

- Hard to add anything to their plan.

- Get a freeze drying and/or insulation commercial partner now.
- Provide preliminary cost data at scale.

- The project team should work on demonstrating significant collaboration and coordination with relevant stakeholders. They should also hasten progress from this stage on to enable the project to meet the specific goals. Key risks regarding health and environmental impacts of the new technology should be articulated and addressed.

Project #94153a: CERC: Integrated Design, Construction, and Industrialized Buildings

Presenter: Diana Hun, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Overall, reviewers were pleased with this project's approach to innovating and validating next-generation building envelope technologies, with three separate focus areas. Three reviewers specifically and positively called out the project's efforts to develop new precast insulated concrete walls, with one applauding the project team's focus on air sealing and thermal bridging in addition to the precast design and weight issues. One reviewer, however, questioned the innovation and value of the project's data collection efforts around commercial building envelope retrofits.

If implemented in the marketplace, reviewers expected this project to have significant impact on energy savings in both China and the U.S. However, one reviewer expressed that the lack of data and information about the work being conducted in China made it difficult to assess the project's full potential impact; several reviewers pointed to the project's lack of an intellectual property (IP) exchange system as a potential culprit for this deficit, encouraging that such an IP exchange system be established as soon as possible. Unanimously, reviewers agreed the project was making impressive progress, surpassing goals to date with quick research and development followed by large-scale trials. Further, reviewers remarked that the remaining project work was focused, on track, and had clear pathways towards completion. One reviewer, however, questioned the significance of China's contribution to the project. Generally, reviewers were pleased with the level of collaboration with industry in both the U.S. and China, though one reviewer recommended establishing stronger connections with installers and private companies.

Weighted Average: 3.49 # of Reviewers: 4
Approach: 3.50 Impact: 3.00 Progress: 4.00 Collaboration/Coordination: 3.75 Remaining Work: 3.25

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Good approach to product development and demonstration. Great focus on meeting performance targets.
- Really three projects, of which precast panels and air sealing seemed very likely to meet goals, while it was not clear where the innovation was in the second project for commercial renovation.
- Very good cross functional team. Attacking not just precast design and weight but also sealing and thermal bridging.
- The overall goal of this program is to build on the foundation of knowledge, technologies, human capabilities, and relationships and accelerate and scale up the development and deployment of very low energy and NZEB in the U.S. and China. It does this through: technology innovation, field validation and commercialization. In this project, researchers are developing technologies and evaluating techniques to improve the performance of new and existing building envelopes that includes developing a precast wall system and envelope retrofits that reduce heating, ventilation, and air conditioning (HVAC) loads through the panel and decreases the weight of the panel without increasing the installed cost. The project's approach to passive envelope advancement is very likely to contribute to overcoming barriers, technical challenges, and mitigating project risks.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- If implemented in the marketplace, the new system could have significant impact on energy savings. However, there are various market barriers that will impede adoption. The use of the various demonstrations will help.
- The first and third projects seemed well aligned with program goals, as did the second, but not clear that gathering data on a few more commercial energy efficiency improvements would advance much
- Very good technical progress on US side. Unsure about Chinese progress.
- Maybe hampered by IP transfer so countries may only benefit relatively equally.
- The CERC-BEE program has identified relevant bidirectional outcomes. There are definitely clear, beneficial outcomes for both countries as a result of leveraging bilateral strengths. Both countries stand to benefit equally from the next generation of precast insulated concrete walls and envelope retrofits under passive envelope advancement. However, not enough accurate information on the present state of the project on the China side was available to give the rating of "outstanding" in this category. The impact of the precast walls under the passive envelope advancement includes (a) higher thermal performance, (b) improved air and water tightness and (c) reduced thermal bridging.

C. Progress

Based on current project efforts, the project was rated **4.00** for the degree to which the project has met ***project-specific goals***.

- Nice progress made to-date. Quick R&D followed by large-scale trials.
- Project 1 seems to have surpassed its project goals with the installation in a large commercial project.

- Still can't tell what the goals of project 2 were, and project 3 seemed more like a field test of a manufacturers product.

- Very good progress on many fronts: New compositions, inserts, 3D molds, sealants, lighter better performing precasts, etc.

- After 22 months of research and development, the project on precast walls has shown (a) successful large-scale trial of 1 ½"-thick wythes, (b) that non-corroding inserts meet target loads, (c) shorter production time and (d) primer-less self-healing sealant as the prototype has been seen to recover elastic properties in 2 hours. The project on envelope retrofits has shown a completed retrofit with the benefits demonstrated as well as 3 on-going retrofits. The overall CERC-BEE program has so far launched 19 new products; filed 15 patent applications; influenced nearly 30 specifications; and developed 21 new software tools to advance performance of buildings.

D. Collaboration and Coordination

This project was rated **3.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Good collaboration with Gate Precast. Reference to advisory board. Need stronger connections to more installers/companies.

- Though we didn't hear much about it, it seems that the real strength of the project is its array of serious collaborations in the US and China

- The energy performance improvements, precast mold versatility with a lighter cost competitive product has clear benefit for increased precast demand in the US.

- Clear benefits to U.S. industry are demonstrated by the CERC-BEE program and there is a clearly demonstrated need for this project by the U.S. industry. A wide range of industries such as Johnson Controls, Dow, United Technologies, Citibank, etc. are active participants or supporters of the program. There are other U.S. benefits indicated for the taxpayer, infrastructure and domestic and foreign policy. For the passive envelope advancement project, there is an advisory board that guides the project based on industry needs. In terms of knowledge dissemination, more than 15 precast companies have visited the Precast/Pre-stressed Concrete Institute (PCI) organized by the project team. The team expects to share findings with building owners and managers, building energy consultants and energy service companies

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- Great varied focus on: further design optimization and product development as well as demonstrations.

- 1 and 3 seem very much on track; 2 is less clear

- Major technical hurdles either completed or with a clear pathway for completions. Demonstrations in new construction and retrofit in place.
- Only question is with regard to China's contribution. What are they expected to deliver?

- The project plans are somewhat likely to meet the project-specific goals. The passive envelopment advancement project has completed 2 of the 5 year duration. The indicated remaining work include (a) completing 3 ongoing retrofits in the U.S. and 1 ongoing retrofit in China, undertaken by the Chinese partner and (b) performing new retrofits which is likely to be 2. Information on the remaining project work on the overall CERC-BEE program was not provided in detail.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Comprehensive project that examines design, product development, and demonstration.
- Good partnership with Gate Precast.
- Methodical analysis pre- and post-installation (although I am not sure E+ plus simulations are necessary).

- 1 and 3 have clearly and narrowly defined goals, guaranteeing strong outcomes, while 2's strengths are less clear.

- Very good cross functional team. Very good technical progress and integration of key envelope improvements. Very good engagement with industry.

- The project strengths include the fact that the overall program is an initiative to support leading scientists from United States and China in collaborative research to accelerate the research, development, and deployment of advanced building technologies for the benefit of both countries. The overall goal is to build on the foundation of knowledge, technologies, human capabilities, and relationships and accelerate and scale up development and deployment of very low energy and NZEB in the U.S. and China.

2) **Project Weaknesses**

- Need stronger connection to others in industry (e.g. installers).

- Weakness of 2 seems to be repeating commercial energy efficiency work of the past few decades.

- Unclear Chinese participation/commitment.
- U.S. IP issues on tech transfer?

- Not much information was available on what has been done on the China side of this project. The understanding is that this is due to the fact that the IP exchange process is yet to be set up.

3) **Recommendations**

- Forge additional relationships with industry/installers.

- Clarify the goals of project 2

- Better overlap between US and China teams.

- The project team should develop a way of reviewing, evaluating and keeping abreast with the execution of the project on the China side. The IP exchange process should be set up as soon as possible to enable the benefits of the program to be realized. Although it is complicated, it is a critical and important part of the project.

Emerging Technologies
Solid-State Lighting

Project #33111d: Stable and Efficient White OLEDS Based on a Single Emissive Material

Presenter: Jian Li, Arizona State University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both reviewers credited the project's approach – simplifying the WOLED's structure using stable blue emitters – with producing a highly efficient and stable WOLED. Each reviewer's remarks about the project's expected impact suggests they expect the project to achieve its goal of producing a stable WOLED more cost-effectively by following the project team's stated approach. One reviewer commented that such an achievement would have a "transformative" effect in the marketplace.

The lowest scores reviewers gave this project were for its progress, particularly as it related to remaining work. One reviewer said it was unclear if the remaining tasks could be finished by the project's end date, while the other suggested that a one-year extension might be necessary to accomplish the project's finals tasks. Both reviewers were satisfied with the project's collaboration and coordination efforts, with one highlighting the project team's plans to collaborate with industry partners to finish the optimization of the WOLED's efficiency.

Weighted Average: 3.50 # of Reviewers: 2
Approach: 4.00 Impact: 3.50 Progress: 3.00 Collaboration/Coordination: 3.50 Remaining Work: 3.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The team has been able to develop a high efficiency stable WOLED.
- Simplification of the structure of OLED in order to reduce cost of fabrication via the use of the high efficiency and stable blue-emitters.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- The development of cost-effective WOLED is indeed a great challenge. The steps taken by the team would enable the reduction in fabrication cost of WOLED.
- Significant energy saving due to improved efficacy of WOLED can have a transformative effect on the market.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals.***

- Even though the team has completed important tasks, it is unclear if the team will finish by June 30, 2018.
- The team is planning to collaborate with industry partners to optimize the efficiency of WOLED before the planned end date of 6/30/2018.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The level of coordination with all the team members seems to be adequate.
- Collaboration with Universal Display Corporation will take place for the remaining work until the end date of 6/30/2018.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The team has a good understanding on the nature of the tasks required to complete the project; however, it is unclear if the remaining project outcomes may be achieved before the project end date.
- It seems to me that the team will need a one-year no-cost extension.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team has been able to develop Pt-based WOLED and other single-doped WOLED, which should be able to make a significant impact on the market.
- This concept has the potential of significantly reducing the cost of WOLED.

2) **Project Weaknesses**

- The team could have made more progress up to this point.
- None.

3) **Recommendations**

- Engage others in the WOLED community to ensure greater dissemination of the findings.
- No-cost extension.

Project #33111e: Identification and Mitigation of Droop Mechanism in GaN-Based Light Emitting Diodes (LEDs)

Presenter: James Speck, University of California, Santa Barbara
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both reviewers expressed their confidence in the project's approach to identifying the root cause(s) of droop, with one reviewer describing the approach as unique and noticeably different from the rest DOE's solid-state lighting research portfolio. The reviewers agreed that the project's search to discover the underlying mechanisms of droop would advance the industry's efforts to solve the problem, as well as increase the efficacy of LEDs without substantially increasing fabrication costs. Both reviewers were satisfied with the project's progress to date, but imagined that an extension may be necessary to complete the project's remaining work.

Weighted Average: 3.70 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 3.00 Collaboration/Coordination: 4.00 Remaining Work: 3.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The team has followed a good approach to understand the root causes of droop.
- Finding and understanding the reason(s) for inefficiency should help inform the efforts to solve the problem. The approach of identifying the dominant non-radiative recombination mechanisms is unique and different from other approaches within the track of solid-state lighting.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- By understanding the root causes of droop, the underlying mechanisms could be mitigated and improve LEDs as a result.
- Similar to some other funded projects, this project has the potential of increasing efficacy with minimum increase or no increase of cost of fabrication.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*****.**

- The project is more or less on track, all depends on what the team will achieve in the remaining months of it.
- Some milestones are expected to be reached at the end date of July 31, 2018. A no-cost extension may make it possible to achieve all project goals.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- It appears that there has been good coordination among all the team members.
- Collaboration with Cree, Inc. May need to continue past the planned end date.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*****.**

- The team still has few things to complete in the remaining months. It remains to be seen if the planned milestone will be achieved as planned.
- Remaining work may require time extension past the planned end date.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team has a good understanding of the fundamental nature of droop.
- Deep understanding of the team of the issues in play.

2) **Project Weaknesses**

- No major weakness have been observed.
- None.

3) **Recommendations**

- Disseminate the recent findings with the LED community.
- Again, no-cost extension.

Project #33111i: Combining Fluorescence and Phosphorescence to Achieve Very Long Lifetime and Efficient White OLEDs

Presenter: Mark Thompson, University of Southern California
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Each reviewer remarked that the project's approach to overcoming barriers and technical challenges was sound, and that the project would, by their estimation, ultimately produce a more efficient WOLED. One reviewer noted that they withheld top marks on the project's impact because they could not, with the information available, estimate the magnitude of the project's performance and cost improvements over today's conventional WOLEDs. Each reviewer expressed confidence in the project's progress to date and remaining work ahead, while acknowledging that the project was still in its early stages.

Weighted Average: 3.77 # of Reviewers: 3
Approach: 4.00 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 3.67 Remaining Work: 3.67

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach presented by the team is sound.
- Team has identified barriers to this technology and appears to be very focused on overcoming them.
- The approach of combining fluorescence and phosphorescence white from OLED sources seems to be successful, subject to the end result by September 30, 2019.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The development of WOLED with higher efficiency is necessary to be able to compete with existing products.
- The only reason I did not rate this as a "4" is that the material did not present any information that compared WOLED potential cost/life to current (and potential future) LED cost and life. Without that data, it is hard for me to ascertain if this project will make a contribution. My rating of "3" gives them the benefit of the doubt on this point.
- The OLED under development is likely to reach higher efficacy and last longer.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals*.**

- The project is more or less on track.
- Early progress has met goals ahead of schedule.
- Project is still in the beginning. However, the milestones met show that the project is on track to achieve relevant OBT-set goals.

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The multidisciplinary team and current relationship with Universal Display Corp would be beneficial during the execution of the project.
- I feel that it is a bit early to rate this higher than "3". So far the collaboration looks good both with the manufacturer and between campuses.
- Collaboration with Universal Display Corp.

E. Remaining Project Work

This project was rated **3.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The team has a good plan of action which they are implementing as scheduled.
- I do not have the technical expertise to comment on the engineering efficacy of the plan. It does, however, look good from a program management perspective.
- Testing and optimization are planned for.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team has a good understanding of the fl-dopants that should be used to achieve the stated goals.
- Strong team
- Logical approach
- Has met first batch of milestones early.
- Using fewer layers in producing this new OLED will most likely make it less expensive too.

2) **Project Weaknesses**

- None to report at this time.
- None that I can see. Please note that I do not have the expertise to comment on the technology or scientific approach.
- None.

3) **Recommendations**

- Engage industry partner on a frequent basis.
- None at this point.
- The team is doing a great job.

Project #33111j: Enhanced Light Extraction from Low Cost White OLEDs (WOLEDs) Fabricated on Novel Patterned Substrate

Presenter: Ruth Shinar, Iowa State University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers agreed that—aided by the project team's close collaboration and integration with manufacturing partners—the project's approach of using a low-cost corrugated substrate has helped discover and overcome some of the barriers to mass-producing efficient WOLEDs. By developing an optimized substrate for enhanced WOLEDs, reviewers remarked that this project would likely contribute to BTO's goal of reducing building energy use intensity by 2030, which one reviewer noted would "obviously" increase the technology's market penetration and yield significant energy savings. However, another reviewer noted that the magnitude of these efficiency gains were not clear from the presentation. While all three reviewers agreed that the project team had made significant progress so far, delays and unexpected problems raised concerns among a few that the project team may not achieve its goals within the project's current timeframe.

Weighted Average: 3.47 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.00 Collaboration/Coordination: 3.67 Remaining Work: 3.00

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is sound, which leads to mass production of low cost WOLED.
- Project team has identified specific barriers to developing more efficient OLEDs and has made progress in overcoming them. They have also encountered some difficulties (both technical and schedule) that they are working to overcome.
- The use of low-cost corrugated integrated substrate to increase efficacy of OLED.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The team has been able to develop an optimized substrate for enhanced WOLED.
- The project appears likely to contribute to the goal of achieving a reduction in EUI by 2030. What is not clear is potential impact of an OLED product versus standard LEDs.
- Obviously, an increase of OLED efficacy will increase its use, resulting in significant energy savings.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals.***

- As per the project plan, the team has been able to make significant progress.
- It was not clear from the presentation where the team stands with respect to meeting their goals. There has certainly been progress, but there have also been problems and some schedule slippage.
- According to the remaining work (slide 16), the project will need one-year no-cost extension.

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The multidisciplinary team has been able to work together in different aspects of the project.
- Team appears to have great coordination and is well integrated with their manufacturing partners.
- Collaboration with MicroContinuum, Inc. and Trovato Manufacturing.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- It appears that the main tasks have been completed as per the work plan. Also, it appears that milestone 4.1 still needs to be completed.

- Remaining work appears to be well planned. Note that I have no technical background in this area, so it is difficult for me to truly comment on the remaining work.

- Will need extension.

F. Additional Comments and Recommendations

1) **Project Strengths**

- It's a multidisciplinary team with in-depth knowledge of the science of WOLED.

- Strong team
- Well integrated
- They are making progress towards the goal.

- Collaboration with the two companies giving the research group access to their facilities.

2) **Project Weaknesses**

- None to report.

- Team appears to have encountered some technical and schedule challenges. It is not clear to me where they stand in overcoming them.

- None.

3) **Recommendations**

- Please ensure the widest dissemination possible of all project findings.

- None at this time. Note however that this project is well outside my field of expertise.

- Simplification of the shape of the substrate should reduce cost of fabrication.

Project #33111k: Eliminating Plasmon Losses in High Efficiency White Organic Light Emitting Devices for Lighting Applications

Presenter: Stephen Forrest, University of Michigan
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers gave perfect marks for the project's passive "no photon's left behind" approach, which they credited with yielding significant early advances that are already "meeting or even exceeding" program goals. Reviewers agreed that the elimination of plasmon losses in WOLEDs, through passive means without consuming additional resources, would have significant impact on the LED marketplace. Most reviewers were in agreement that much of the project's work was complete and that its remaining tasks would be accomplished within the remaining timeframe. One reviewer, however, noted that demonstrating the scalability of this novel WOLED would be challenging to complete on time.

Weighted Average: 3.70 # of Reviewers: 3
Approach: 4.00 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 3.33 Remaining Work: 3.67

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The team approach is sound and viable.
- This is certainly not my field, but the project appears to have already hit the 70% out coupling goal and exceed it.
- Maximizing the emitted light that makes it to outside of the source has the highest potential of increasing efficiency. I like the "No Photons Left Behind" concept. It make perfect sense.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Elimination of plasmon losses in WOLED would certainly make a difference in the LED market.
- The project appears to be meeting or perhaps even exceeding its goals and therefore should contribute to the programmatic goals. What is not clear to me is the potential cost reduction and/or energy reduction of OLEDs versus LEDs.
- Maximizing efficacy by passive means without consuming additional resources is a significant improvement to industry standards.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals*.**

- Team still need to demonstrate potential of scalability of the developed WOLED within the time frame of the project.
- If I understood the presentation and deck correctly this team has already met one of their major goals and may ultimately exceed their goals.
- The project is almost ready for the final submission on August 31, 2018. Minor work is left to be done.

D. Collaboration and Coordination

This project was rated **3.33** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Lead PI has been able to share results with Universal Display Corp.
- Stakeholder engagement appears to be appropriate to the project.
- Collaboration with Universal Display Inc.

E. Remaining Project Work

This project was rated **3.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- It seems the project is more or less on track.
- The project has already met one major goal and has a logical plan to complete the work. Note that this project is well afield of my personal expertise so I cannot comment on the technical approach or remaining work per-se.
- Not too much work left. Should be done by the end of the summer.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Being able to file patents.
- Have already met a major goal
- Appear well placed to successfully complete their work.
- Strong team
- Increasing efficiency by three fold is market-transforming – assuming the new technology is not expensive.

2) **Project Weaknesses**

- None to report.
- None that I can see.
- I suggest to address the cost of this improved technology.

3) **Recommendations**

- Engage other LED manufacturers in the research discussion but keeping in mind existing NDA.
- None
- Compare technologies based on the cost of fabrication as well.

Project #33111l: Stable White Organic Light-Emitting Diodes Enabled by New Materials with Reduced Excited-State Lifetimes

Presenter: Bernard Kippelen, Georgia Tech
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Each of this project's reviewers stated that this project's approach to addressing organic light-emitting diode (OLED) material degradation – particularly if achieving 100% internal efficiency were possible – was rooted in science, would overcome barriers, and would advance BTO's technical goals. If successful, reviewers were confident that the project's scientific advancements could make OLEDs more cost-effective in the near future, but one reviewer noted that BTO would likely need to address market deployment in a separate project.

Though the project had just begun, reviewers agreed that the project was on track according to the project team's schedule. They expressed confidence in the project's remaining work, which, however significant, was clearly, logically, and reasonably planned by the project team. Two reviewers described the project's collaboration and coordination efforts as excellent, while one reviewer commented that no industry engagement was present, though without indicating whether this was a positive or negative arrangement.

Weighted Average: 3.57 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.33 Collaboration/Coordination: 3.67 Remaining Work: 3.33

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is solid and based on a fundamental understanding of the science of OLED.
- Approach appears to contribute to overcoming barriers. My only reason for not rating the project a "4" is that this area is far outside my field of technical expertise, so I do not know the importance of overcoming the problems that were described.
- Avoiding OLED material degradation and possibly achieving 100% internal efficiency should help achieving BTO technical goals.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- If all the stated goals are achieved satisfactorily, the developed concept could make OLED cost effective in the near future.
- Once again this project is difficult for me to score. The issue for me is that the information presented did not explain in clear enough terms the importance of solving these issues. I could not answer the question: "If this project succeeds, what does that mean in terms of practical new energy reduction products and how might they compare to existing solutions?"
- Scientific impact is highly likely. However, dissemination to the industry has to follow in a follow-up project.

C. Progress

Based on current project efforts, the project was rated **3.33** for the degree to which the project has met ***project-specific goals***.

- The project progress has been good at this point in the project. The team has a clear plan of action in place to meet all the stated goals.
- Project appears to be on schedule however that is a bit difficult for me to ascertain because this area is too far outside my expertise and the information presented was not entirely clear.
- This two-year project is still in its early stages, with a planned end date of August 31, 2019. The team made the planned progress in tasks 1 & 2, so the project is on track.

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The level of coordination and collaboration has been excellent up to this point.
- Project team has demonstrated excellent collaboration both internally and externally.
- No industry partnership found. So far, it is an interdisciplinary collaboration.

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- Significant project activities lie ahead; however, the team has a clear plan of action to meet all the project goals.
- Remaining plan is logical and well organized.
- The plan is reasonable as presented.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The interdisciplinary nature of the research team and the level of expertise of all the team members.
- Strong team
- Excellent collaboration
- Well-structured and tied to goals
- A strong interdisciplinary team of scientists.

2) **Project Weaknesses**

- None at this moment.
- Noe that I can see. However, I cannot comment on the technical approach or likelihood of success.
- No industry partnership.

3) **Recommendations**

- Ensure to engage industry partners early in the development of the improved WOLED.
- None
- Cost of this new technology is unknown.

Project #33111m: Low Cost Corrugated Substrates for High Efficiency OLEDs

Presenter: Xiangyu Fu, NC State University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Reviewers expressed confidence in this project's approach of using a buffer layer at the corrugated substrate interface to achieve a higher light diffraction efficiency in organic light-emitting diodes (OLED's), calling it an "excellent idea." Reviewers credited the project's concept for making "excellent progress" on achieving BTO's OLED quantum efficiency goals—the impact of which one reviewer said could "move OLED [technology] one step further." Every reviewer expressed similar confidence in the project's progress to date, either by saying that the project was on track, or that it had nearly achieved its primary objective. Reviewers did not comment significantly on the project's collaboration and coordination efforts aside from acknowledging their existence and adequacy. However, one reviewer claimed to not have heard of any collaborators from the Peer Review presentation. While reviewers seemed all but assured of the project's progress and future promise, two reviewers noted that the project's final performance assessment step would determine its eventual impact. Even all reviewers expressed confidence in the team's ability and plans to accomplish this final task, one reviewer questioned if the selected material's durability would persist long-term.

Weighted Average: 3.58 # of Reviewers: 3
Approach: 4.00 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 3.00 Remaining Work: 3.33

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The use of corrugated substrates for extraction of trapped light is an excellent idea. The approach of the team is sound.
- This project appears to have made excellent progress towards meeting its goal of improving OLED quantum efficiency. A word of caution on this assessment: This field is far outside my realm of technical expertise.
- The approach is to insert a low index buffer layer at the interface (at the corrugated substrate) to achieve higher diffraction efficiency.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The potential impact of the developed concept is significant. Greater efficiencies may be reached in the foreseeable future by using the developed concept.
- The project is doing very well in meeting its goals. The only reason I did not rate it a "4" is that there was no information presented to indicate the extent to which moving from LED to OLED would contribute to the goal of improving EUI 45% by 2030.
- Depending on the final results of performance testing, this technology would move OLED one step further. Future improvement is still necessary.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals***.

- It appears that most critical milestones have been reached.
- Looks to me like the project either has already met or is very close to meeting its primary goal.
- Project is on track.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Coordination with MicroContinuum has been good. That should facilitate market adoption of the technology.
- No information was presented on this topic. Therefore, the only conclusion I can draw is that this team is not collaborating with any one.
- Collaboration with two companies, SBA Materials and MicroContinuum.

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The team still has to complete important tasks to complete the project satisfactorily. The team has clearly identified the remaining tasks.
- Appears to be well planned. Based on progress to date, I believe the plan will be achieved.
- The project is almost complete. Next step (assessment of performance) should determine how successful the project is.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The developed concept is novel and cost effective. It is based on a fundamental knowledge of the science of the problem at hand.
- Excellent progress so far.
- Corrugated substrates is a promising technology.

2) **Project Weaknesses**

- The durability of the selected materials could be a concern in the long term.
- There appears to be no external collaboration
- None.

3) **Recommendations**

- Proper dissemination of the projects findings should be pursued.
- Develop and implement a plan for external collaboration.
- May test a variety of proportions of the corrugation.

Project #33111n: Mask-Free OLED Fabrication Process for Non-Tunable and Tunable White OLED Panels

Presenter: Jeff Spindler, OLEDWorks
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both of this project's reviewers made supportive comments about the project's approach of eliminating shadowmasks to reduce OLED fabrication costs, with one reviewer citing this potential improvement as a significant project strength. Both reviewers seemed confident that this project, if successful, could significantly reduce the manufacturing costs of OLEDs in general; one reviewer said it could even transform the marketplace from being dominated by LEDs to OLEDs in the future. Even though this project had just begun, reviewers noted that they were encouraged by the project's progress to date, as well as the project team's plans for the work ahead. Both reviewers were supportive of the project's collaborators, whom one reviewer described as "necessary to the success of the project." One reviewer, however, expressed that the project team could benefit from the expertise of academic researchers in industrial engineering, to "help with the theoretical aspects of fabrication."

Weighted Average: 3.83 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 3.50 Collaboration/Coordination: 3.50 Remaining Work: 4.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The developed approach is adequate and sound for meeting the objectives of the project.
- Eliminating the use of shadowmasks in order to reduce cost of OLED production, by possible use of roll-to-roll technology.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- If successful in the remaining time of the project, the developed concept could reduce the capital cost associated with OLED.
- Significant reduction in the cost of fabrication of OLED have the potential of transforming the market from LED to OLED due to its higher efficacy.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals***.

- The level of progress is adequate given the fact the project started recently.
- Project is in its early stages. On track.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The level of collaboration and engagement has been good at this point in the project.
- OLED Works LLC is working with three other key partners, all of which seem to be necessary to the success of the project.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The team has a good plan of action to meet the stated project goals in a timely manner.
- Majority of the work is to be done. However, it is encouraging to see what was done in the few months since the start of the project.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project's strength lies on the ability to lower fabrication cost of OLED without compromising quality.

- Close collaboration with other necessary industry partners.

2) **Project Weaknesses**

- None at this moment in the project; however, they should make an effort and disseminate new know-how at the appropriate time.

- The team may need the help form academic researchers in Industrial Engineering who may help with the theoretical aspects of fabrication.

3) **Recommendations**

- Consider all the material aspects of OLED including durability and reliability when developing any new fabrication process.

- Does the proposed fabrication process need to be in a clean room?

Project #33111o: Understanding, Predicting, and Mitigating Catastrophic Shorts for Improved OLED Lighting Panel Reliability

Presenter: Chris Geibink, Penn State University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Each of this project's three reviewers were strongly supportive of the project's approach to identifying the source of OLED shorts and preventing them in the future. Reviewers called the research sufficiently "rigorous and scientific" to address the problem of shorts "comprehensively," and one reviewer expressed that they had little doubt about the project's ability to eventually "solve the problem of catastrophic damage" in OLEDs. One reviewer agreed that the ultimate impact of understanding the development and evolution of shorts was "extremely important and valuable" to OLED manufacturing, while a second reviewer noted that—in their estimation—the project's suggestion of adding a Teflon layer to mitigate or even eliminate shorts would likely achieve BTO's 0.01% panel failure goal.

Every reviewer noted the project's strong progress, though two remarked that three significant tasks remained to be completed within the project's final months. None-the-less, all reviewers were encouraged enough by the project's progress to date that they were confident in the project team's plans and ability to complete these remaining tasks. Reviewers also credited OLEDWorks with being a strong project collaborator.

One reviewer did caution that it remained to be seen if the developed solutions would continue to mitigate the risk of shorts long-term, while another reviewer expressed that the team would do well to test other solutions, such as partitioning the OLED panel.

Weighted Average: 3.77 # of Reviewers: 3
Approach: 4.00 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 3.67 Remaining Work: 3.67

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach presented by the team is rigorous and scientific to tackle the stated problem comprehensively.
- Project team has identified the initiator of a short, understands how and why they grow and is now testing mitigation strategies.
- Tracing the cause of early shorts in the OLED by visually looking at the geometry of the affected area is highly likely to help solving the problem of catastrophic damage.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- Having a good understanding and formulating viable solutions to mitigate the risks of shorts are extremely important and valuable in the fabrication of OLED.
- I wanted to rate this a "4" but was unable to do so because I do not understand (and information was not presented) on the extent to which OLEDs are a superior solution to LEDs.
- The program goal of 0.01% OLED panel failure is likely to be achieved due to the proposed solution (adding the Teflon layer). Partitioning the panel may be a worthy solution to test as well.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals***.

- The progress has been good; however, critical milestones still remain to be fulfilled.
- Making great progress and, based on the information presented, they are highly likely to meet their goals.
- The project has successfully identified the cause of the problem.

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The industry partner, OLEDWorks, has been a strong collaborator in the project.
- Team has a strong plan and is executing on it.
- Collaboration with OLED-Works.

E. Remaining Project Work

This project was rated **3.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The scope of the remaining work has been clearly stated; however, three significant tasks remain to be completed in the last few months of the project.
- Based on results to date they are highly likely to succeed.
- The research team is considering a promising solution to the problem.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team has been able to identify how shorts form and how they could be avoided.
- Great results so far.
- Strong team
- Good collaboration
- Imaging of the OLED on such small scale allowed accurate understanding of the problem.

2) **Project Weaknesses**

- It remains to be seen if the developed solutions will mitigate the risks of shorts in the long term.
- None that are apparent.
- None.

3) **Recommendations**

- Seek IP protection as soon as possible for the developed technology.
- No recommendations. They are doing a great job.
- The team may consider testing more than one potential solution of the problem.

Project #33111p: High Performance Green LEDs for Solid State Lighting

Presenter: James Speck, University of California, Santa Barbara
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both of this project's reviewers were supportive of the project's approach to increasing the efficacy of green LEDs (i.e., the "green gap"). One reviewer said that the project team had a good understanding of the technical challenges associated with enhancing green LED performance, while the other described the approach as interesting from a materials perspective. Both reviewers also agreed that the project, if successful, could significantly advance the LED field, which one reviewer said would transform the market. Neither reviewer, however, addressed the project's potential impact as it related to BTO's goals. Both reviewers expressed their satisfaction with the project's progress to date, as well as with the team's ability to complete its remaining tasks ahead—both with respect to project's plans and the amount of time remaining. The only concerns raised by reviewers focused on the project's lack of industry partners, but neither reviewer made any recommendation about how industry partners could be incorporated into the project to assist.

Weighted Average: 3.73 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 4.00 Collaboration/Coordination: 3.00 Remaining Work: 3.50

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The team has a good approach and understanding of the technical challenges for enhancing the performance of green LEDs.
- An interesting materials approach to increase the efficiency of Green LED in order to fill the Green Gap, which should result in overall increase of White LED.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The potential impact of the developed concept could be significant in the LED field.
- Similar to the rest of projects, significant increase in LED efficiency would transform the market.

C. Progress

Based on current project efforts, the project was rated **4.00** for the degree to which the project has met ***project-specific goals***.

- Significant progress has been reached already.
- The project is on track.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The level of collaboration has been fine up to this point.
- No industrial partners.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- There are several tasks that still need to be completed. The team has a clear plan of action for fulfilling the project's goals.
- The team has enough time to complete the project by the planned end date of September 30, 2019.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team consists of experts who complement each other in terms of capabilities.
- Filing the Green Gap is a unique idea that may increase efficacy to 400 lm/Watt.

2) **Project Weaknesses**

- None at this point; however, involvement of industry partners should be pursued soon.
- No industrial partners.

3) **Recommendations**

- Involvement of industry partners should be pursued as soon as possible.
- Cost of production should be a factor to consider later.

Project #33111q: Improved Radiative Recombination in AlGaInP LEDs

Presenter: Theodore Chung, Lumileds
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Comments made by both of this project's reviewers suggested that they were largely satisfied with this project overall. Both reviewers agreed that the project's approach was "suitable" or sufficiently "unique" to increase the efficiency of red and amber LEDs. Each reviewer also agreed that the project's potential impact could be a significant advancement over today's conventional technology. Reviewers noted that the project's progress had been satisfactory, or possibly even ahead of schedule, and neither reviewer expressed concern about the project team's ability to complete its remaining work. Both reviewers pointed to the project's collaborations as a notable strength, commenting that the level of team-member collaboration was "considerable" and appropriately chosen to meet the tasks at hand.

Weighted Average: 3.75 # of Reviewers: 2
Approach: 4.00 Impact: 3.50 Progress: 3.50 Collaboration/Coordination: 4.00 Remaining Work: 3.50

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach presented by the team is suitable for the project.
- A unique approach that is to increase efficiency of Red and Amber LED without sacrificing reliability.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The impact of the developed concept could be significant in the near future.
- Color-mixing LED technology has the potential to reach close to 350 lm/W. That would be a great improvement of what we have today.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals***.

- The level of effort or progress has been satisfactory.
- Project is ahead of schedule.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The level of collaboration among team members has been considerable up to this point.
- Collaboration is planned with MIT & Stony Brook University.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The team has identified clearly the remaining tasks and challenges.
- Project is still in the beginning. It has enough time to deliver results.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Its multidisciplinary nature. In a nutshell, the team has the right mixed of experts for the tasks and challenges at hand.
- Collaboration with the academic sphere.

2) **Project Weaknesses**

- All the key tasks that have been accomplished should be stated more clearly.
- None.

3) **Recommendations**

- Ensure proper dissemination of project findings.
- None.

Project #33111r: Narrow Emitting Red Phosphors for Improving pcLED Efficacy

Presenter: Daniel Bugaris, Lumenari Inc.
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Both this project's reviewers expressed confidence in the project's approach, calling it sound, well-established, and capable of producing outcomes that could achieve BTO's higher efficiency goals. One reviewer was convinced that the project's use of Eu3+-activated narrow band red phosphor for pcLEDs could save a "considerable" amount of energy in the future, while the other reviewer remarked that this pathway to achieving greater efficiencies was, in fact, already proven. While one reviewer said the project had already made significant progress, and that any remaining work would likely be accomplished, the other reviewer twice remarked that a no-cost extension might be necessary to complete the project's tasks. Both reviewers cited the project's collaboration and coordination efforts as a key project strength, describing the project's "many" partners as being "quite comprehensive," and commenting that the diversity of collaborators had brought a broad range of talent and perspectives to the project from across the scientific and industrial communities.

Weighted Average: 3.70 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 3.00 Collaboration/Coordination: 4.00 Remaining Work: 3.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The developed approach is sound and well-established. The team has already benefited from well-planned activities.
- The approach of shifting the majority of (or all of) emitted energy to be within the boundaries of visible electromagnetic waves should yield higher efficacy.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- With the use of Eu3+-activated narrow band red phosphor for pcLED, the developed concept should be able to save considerable amount of energy in the future.
- Proven energy efficiency due to the higher efficacy.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals***.

- The team has been able to make significant progress. Also, the team should be able to complete the remaining tasks before the project's end date.
- May need no-cost extension.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The team is quite comprehensive and the team members have been able to support each as per the project's milestones.
- Collaboration with many key partners as listed on slide 2 of the presentation.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The team should be able to complete the remaining task within the specified time frame.
- May need no-cost extension.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team composition has been a big plus for the project. The results and data to date show that the project has been a success.
- Research team brings diversity of talent across the scientific and industrial spheres.

2) **Project Weaknesses**

- They should engage the broader LED community through publications.
- None.

3) **Recommendations**

- Publish your results as soon as possible.
- None.

Project #33111s: Graded Alloy Quantum Dots for Energy Efficient Solid State Lighting

Presenter: Jonathan Owen, Columbia University
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

All three of this project's reviewers expressed confidence in the project team's approach to the development of red emitting quantum dots (QD) that have sufficient stability on LED chips to withstand the operational and reliability requirements of high-power LEDs. One reviewer called the project's QD screening and synthesis approaches "novel," commenting that they directly addressed a key technological challenge with the potential for a high payoff. Despite reviewers' general collective assessment that the project had accomplished a significant portion of its tasks, however, reviewers unanimously held reservations about the project's remaining work ahead.

Specifically, reviewers said that several significant technical hurdles still needed to be overcome, notably the QDs' durability. One reviewer called this hurdle "formidable," while another remarked that overcoming the obstacle seemed feasible, but also that "time was of the essence." The third reviewer suggested that a no-cost extension might be needed. One reviewer expressed enough concern that they recommended that the project team halt other elements of the project plan, including its works on green graded alloy QDs and indium phosphide QDs, until more progress could be made on the cadmium sulfide QD durability issue. This reviewer also suggested a few potential remedies to "either optimize the [zinc sulfide] shell or look for other shell materials that might better protect the QD from oxidation."

Despite these concerns, all three reviewers agreed that this project's outcomes, if successful, could produce further energy savings down the road and, according to one reviewer, potentially "change the industry." One reviewer also noted that the project's impact would align with the BTO's program performance goals for solid-state lighting, though another remained skeptical about the achievability of the project's impact, calling the project's technical goal "hard to reach."

Reviewers described the project's collaborative efforts as strong, "rigorously formulated," and well-coordinated among academics, industry representatives, and the national labs. One reviewer even credited the project's collaborative efforts with the majority of the project's success to date.

Weighted Average: 3.48 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 2.67 Collaboration/Coordination: 4.00 Remaining Work: 3.00

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The team's approach has been sound and pertinent for the challenges at hand.
- Increase both of the efficacy and color rendering of LED (90 CRI).
- Many good aspects to the project: novel method to reproducibly make QDs, logical chemistry, quick screening, etc.
- Would have been rated outstanding if the durability results were closer to state of the art and project goal.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The team of the project, through rigorous formulation and characterization has been excellent. The findings of the project should result in energy savings in the long run.
- Seems the technical goal is hard to reach.
- Stable and durable red QDs on an LED package aligns with SSL performance goals and would significantly change the industry (cost, manufacturing simplicity, etc.).

C. Progress

Based on current project efforts, the project was rated **2.67** for the degree to which the project has met ***project-specific goals***.

- Even though the team has been able to make significant progress, there are several tasks that still need to be completed.
- According to the project plan and schedule (page 19&20 of the presentation), several technical goals have not been achieved to date.
- All performance properties met other than durability, which appears to have a significant hurdle to overcome.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The level of coordination has been good as the recent results have shown.
- Collaboration with LBNL and Osram Opto Semiconductors.
- Very good coordinated effort between academic (Colombia), national labs (LBNL) and industry (Osram).
- Each partner has clear roles and responsibilities with all actively participating in the project.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The remaining work is feasible but time management is of the essence.
- May need no-cost extension.
- Go forward project plan is fine.
- Technical challenges for this high risk/high reward project are still formidable.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Comprehensive team composition is in place, which has led to significant advances in the project.
- Collaboration with LBNL.
- Novel screening and synthesis approach to QDs. Attacking a critical QD structure and application with high payoff if successful. Excellent team and division of roles. Very good understanding of the critical issues.

2) **Project Weaknesses**

- There are still several key technical milestones that need to be completed. Team is encouraged to complete satisfactorily the remaining tasks before the end of the project.
- None.
- Still a ways to go to meet the durability hurdle.

3) **Recommendations**

- Continue to publish the results of your work and engage the lighting community to ensure adoption of the developed concept.
- None.
- May be worth devoting more effort to either optimizing the ZnS shell or looking for other shell materials that might better protect the QD from oxidation. This was presented in the action plan, but it wasn't clear of the emphasis w.r.t. further improving the QDs - i.e. is the anisotropic shell growth affecting durability? If not, and it is performance focused it appears less important than improving durability.
- Other aspects of project plan (green GA-QDs, and InP QDs) should be put on hold until CdS durability issue makes more progress.

Project #33111t: Highly Integrated Modular LED Luminaire

Presenter: Ramanujam Ramabhadran, GE Global Research
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Two of this project's reviewers made supportive comments about the project's approach to building scalable, efficient, modular outdoor luminaires, calling the approach sound and sufficiently comprehensive to optimize LED elements downstream to reduce costs and improve efficiency. These reviewers noted that resulting improvements in the performance of luminaire components would improve the luminaire's overall performance, and that expected cost reductions could even increase the share of U.S. manufacturers that produce outdoor luminaires. One reviewer continually expressed skepticism about the project team's ability to achieve its 200 lm/W LED efficacy goal, however, commenting that it could only be achieved through investigations beyond the project's scope.

Reviewers made positive remarks about the project's progress to date—particularly the improvement in luminaire efficiency from 74% to 90%, which one reviewer labelled a "significant achievement." Reviewers were also mostly pleased with the project's collaboration and coordination efforts, saying that key partners were able to give necessary feedback. One reviewer, however, wished for a partner that would eventually be tasked with manufacturing fixture cores, though a different reviewer described the manufacturing team as "strong." Two reviewers expressed some concern that Stanford's part in the project was behind schedule, but the other reviewer disagreed, expressing confidence in the project team's ability to complete all remaining tasks.

Weighted Average: 3.35 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.00 Collaboration/Coordination: 3.33 Remaining Work: 2.67

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The developed approach is sound and quite comprehensive. The team has taken a hard look at all the subsystems to reduce total cost and improve efficiency.

- Lower manufacturing coast will surely result in increased US share of manufacturing outdoor LED luminaires.

- Very good progress on many elements of the project.
- Stanford work appears behind and could be project limiting if a cost effective solution is not found.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The impact of improving driver technology and optics should result in enhanced system performance. The projected enhancement is in line with DOE goals.

- Will help realize the goal of producing an efficient long-life outdoor luminaires with the extended warranty demanded by US cities and municipalities.

- Optimization of elements downstream of the LED is important to improving overall efficiency of the luminaire.
- To attain the 200 lm/W goal, LED efficacy, which is outside the scope of this project, has to improve dramatically.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals***.

- Considerable progress has been accomplished to date. The enhancement of the overall system has been attained by using improved driver.

- The project has been granted no-cost extension already.

- Corrected overall efficiency improvement from 74 to 90% with cost parity to imported units is a significant accomplishment.
- Although this efficiency gain can be applied to any LED efficacy improvement, achieving the 200 lm/W goal will not be achieved without significant LED improvements.

D. Collaboration and Coordination

This project was rated **3.33** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The collaboration among team members has been good. Key members have been able to provide the necessary feedback, as planned.

- Collaboration with Current (owned by GE) and Stanford University.

- Good overlap with internal GE stakeholders.
- Overlap with LED supply chain was discussed, but only in general terms. No indication of the extent of the LED improvement was stated.
- Would like to have seen some team member who was going to manufacture the cores to be involved in the project.

E. Remaining Project Work

This project was rated **2.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The remaining work have been described and should be completed before the end of the project.
- Currently, awaiting Stanford University partner to complete work on transformer.
- Unfortunately the 200 lm/W luminaire milestone will not be met without LED improvements outside the scope of the project. Not a team issue, but a poor choice of milestone. Otherwise score would have been higher.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The system-level approach has been effective in attaining the project's milestone.
- Very practical goal that may yield instantaneous results.
- Strong manufacturing team. Good coordination. Significant improvements in efficiency in the elements that were under their control.
- Although not fully presented in the review, appears to be a significant cost-out in manufacturing cost.

2) **Project Weaknesses**

- The project's findings should be disseminated more broadly, if appropriate.
- None.
- Efficiency milestone that strongly depended on improvements outside the scope of the project.
- Core design behind schedule and reliant on an academic institution. Project needed a core manufacturing partner that could bring added skills to the effort.

3) **Recommendations**

- Project's findings should be disseminated through publications and/or in conferences.
- None.
- Look for an outside core manufacturer. If a sufficient core that can be robotically placed on the board, many of the efficiency and cost improvements will be lost with manual assembly.

Project #33111u: Novel Lighting Strategies for Circadian and Sleep Health in Shift Work Applications

Presenter: Gena Glickman, University of California, San Diego
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

Each of this project's three reviewers made supportive remarks on the project's approach to learning more about human-lighting interactions. Reviewers called the approach both sound and scientific, but they did wonder about how the project team was planning to control various confounding variables (e.g. coffee, naps, melanopic lux levels) that could operate independently of the tested lighting conditions to influence hospital workers' alertness and performance.

Despite this lack of clarity, reviewers still thought that the project explored "a new territory of science," and that its potential impact could be significant in the medical field. One reviewer also commented that this research would demonstrate the versatility of LED lighting to maximize human performance.

Each reviewer said that the project team's progress to date was on-track—though qualifying this assessment by noting that the research was still in its early stages—and they expressed no concerns with the project team's plans for remaining project work. Each reviewer also made supportive remarks about the project's collaboration and coordination across a uniquely wide array of stakeholders, whom reviewers referred to as a well-coordinated and "excellent cross-functional group," as well as a highlight of the project.

Weighted Average: 3.78 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 4.00 Remaining Work: 4.00

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project's approach is sound and should lead to the generation of important knowledge in the area of human-lighting interactions.
- Monitoring the behavior of employees and compare to the results of urine and blood is a very scientific approach which should yield proven results.
- Nice complete consideration of baselining.
- Although caffeine & EtOH are not controlled (but are recorded) some bias may be in data if a non-representative population of users is chosen.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The impact of the project will be significant in the medical field, and others where the well-being of the employees has a direct effect on others.
- This is a new territory of science that is so closely related to light and illumination. The impact here is on the body of knowledge. Thank you to BTO for funding such research.
- Project should provide good insight on how various LED lighting characteristics affect human performance.
- Should show the versatility of LED light to maximize performance.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals***.

- The project's progress has been good to date. All key activities have been planned and/or accomplished in a timely manner.
- On track.
- Well-designed project.
- Good use of both circadian phase resetting and alerting.
- Early in project and on track.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Given the nature of the project, the level of coordination has been good.
- Collaboration with NIH, a hospital, flux, and BIOS.
- Excellent cross functional group (researchers, institutions and industry partners).

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The remaining activities have been planned appropriately.

- Enough time to complete the project.
- Early in project, but well designed and on track.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team composition and planned activities should certainly lead to the generation of interesting and valuable findings.
- Collaboration with all meaningful stakeholders.
- Well-designed study, targeted to important human behavior questions, breath of cross functional team, good use of LED components (not just LED vs. conventional lighting).

2) **Project Weaknesses**

- None at this moment.
- I only wished they somehow address the effect of taking naps or drinking coffee. What if all employees in the night shift drink coffee before going to work?
- Might want to note or control for how long nurses are actually at nursing stations and melanopic lux levels. Are there portable recording light meters they could wear?

3) **Recommendations**

- Team members should consider other human factors (i.e. sleep deprivation, etc.) when conducting the study.
- Refer to the comment on the previous question.
- Screen & possibly cluster for caffeine/EtOH use.

Project #33111v: Investigating the Health Impacts of Outdoor Lighting

Presenter: Ronald Gibbons, Virginia Tech
DOE Manager: Jim Brodrick

Brief Summary of Reviewer Comments

All three reviewers described this project's approach as one of its core strengths, calling it a "well-controlled" experimental design to isolate the effects of LEDs from other variables in "complex environments." One reviewer said the project had access to the right equipment and was conducting their research in the right environments, but another had some criticisms, commenting that measurements of outdoor illuminance should distinguish between vertical and horizontal illuminance. Another reviewer recommended that the project team should also account for "the emotional-fatigue of the study's participants," and that the project's sample size might be a bit small.

One reviewer opined that this project would have "a considerable" impact on the design and use of roadway lighting systems, a contention that other reviewers echoed. Another reviewer remarked further that the project's results would add knowledge to "a currently open question." One reviewer expressed their preference for a less general description of the project's goals, however, describing that this would enable them to make clearer a judgement on the project's eventual impact.

Reviewers were satisfied with the project's progress to date, as well as with the team's plans for completing its remaining tasks. Each reviewer was also supportive of the project's collaborations, though one reviewer did note that—given the current disagreement between the American Medical Association and the lighting industry—"it would have been nice to have some health professionals or institutions involved to reduce any skepticism that might result from the study."

Weighted Average: 3.60 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 3.33 Remaining Work: 3.67

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project's approach is solid and should lead to the generation of new knowledge in the area of driver-lighting interactions.
- Measuring the impact of different lighting types on melatonin in the blood of users. Makes perfect sense.
- Well controlled study isolating LED light effects in a variety of complex environments.
- Study considers not only delivers but also other affected individuals (peds & sleepers).
- Only criticism is the small number of subjects and attempting to gather loss of data for a few subjects.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)***.

- The impact of the study will be considerable, specifically in the design and use of lighting systems on roads.
- Should help design outdoor lighting with no negative impact on health.
- If successful, information will help isolate LED light and health affects during high melatonin periods.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals***.

- Progress to date has been good. The team members should be able to complete all the tasks as planned.
- Actually, one year is a tight time for such research project. The project is on track.
- Project efforts support overall DOE LED penetration goals.
- The overall project goals are quite general (execute study). Maybe should have looked at more specific goals.
- Early in project. Overall on track.

D. Collaboration and Coordination

This project was rated **3.33** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- In general, collaboration with team members has been good so far.
- Collaboration with Thomas Jefferson University and Philips Lighting.
- Good technical team supporting measurements.
- As there is disagreement between AMA and industry, it would have been nice to have some health professionals or institutions involved to reduce any skepticism that might result from the study.

E. Remaining Project Work

This project was rated **3.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals***.

- The remaining activities have been well-planned.
- Project is on track.
- Early in project, overall on track.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project's experimental design is solid which should lead to the generation of important knowledge.
- Access to equipment and the correct setting to perform the experiment.
- Well-designed study (outside of maybe subject size).
- Critical inputs identified and controlled.
- Results, one way or another, add critical data to an important open question.

2) **Project Weaknesses**

- None at the moment.
- None.
- Would like to have seen health pros on team.

3) **Recommendations**

- The team members should consider the emotional-fatigue of the study's participants.
- Technically speaking, measurements of outdoor illuminance (and research conclusions) should make a distinction between measured vertical illuminance vs. measured horizontal illuminance.
- Rewrite Project goals to be more specific.
- Confirm sample size.
- Consider medical professionals on team.

Emerging Technologies
Building Energy Modeling

Project #24293: BayREN Integrated Commercial Retrofits

Presenter: Barry Hooper, Association of Bay Area Governments and Tianzhen Hong, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Most reviewers agreed with this project's approach to enabling local-government energy efficiency programs by modifying and enhancing open-source tools to perform large-scale building energy modeling analysis on commercial buildings. Multiple reviewers highlighted that this project's open-source BayREN Integrated Commercial Retrofits (BRICR) tool leveraged existing DOE tools to allow the Association of Bay Area Governments (ABAG) and other entities to identify energy efficiency potential of a hard-to-reach sector—small and medium businesses (SMBs)—and deliver technical assistance at reduced cost and potentially large scale. One reviewer commented that the BRICR tool was focused on a reasonable number of use cases, while another remarked that the project appeared to have a well thought out approach for mass assessment and recruitment of program participants. One reviewer, however, was very critical that the approach did not appear to have a well thought out solution for workflow management, which this reviewer believed would be crucial if ABAG wanted to effectively integrate data on program assessments, recruitment, project scope development, and monitoring and verification activities.

Reviewers generally agreed on the project's potential impact. One reviewer noted that if the BRICR tool was successful in identifying the energy efficiency potential in region-wide SMBs, this could add up to significant regional savings in a sector that was not widely served by efficiency service providers. Another reviewer flagged that the project had already modeled 17,000 buildings in the Bay Area, and that simulation results from 29 energy conservation measures applied to 1,699 SMBs found preliminary energy savings potentials of up to 25%. Conversely, while a third reviewer highlighted that this project was focused on the building stock in California but could be replicated across the country, another questioned whether the project would be replicable or scalable given its lack of a workflow manager. One reviewer also questioned whether the project team's effort would translate into actual energy savings, noting that immediate project impact was reliant on building owners taking action based on recommendations, and that long-term impact was dependent on the project successfully convincing other cities to mimic the approach.

Outside of an unexpected staffing issue that resulted in a 6-month project delay—which some reviewers were critical of—assessments of this project's progress were generally positive. Taking into account the project's revised schedule, for example, one reviewer remarked that the project was on target and on budget, while another expressed that the project was well on its way to delivering the required tool functionality. One reviewer similarly commented that the project appeared to be progressing as expected and was resourced sufficiently to meet the "minimum requirements" of remaining deliverables, while another described the planned future work as logical and building on past phases to expand functionality. One reviewer warned that it appeared as if only half of the software development was complete, and also that a significant portion of work remained in setting up the analysis infrastructure and completing the analysis. However, and in contrast, a different reviewer observed that BRICR development had made significant process, that the buildings for retrofit had been identified, and that—with its 6-month extension—the project had significant time to complete its work.

Reviewers positively observed the project's "impressive" list of collaborators representing government stakeholders, financial and risk management institutions, and others. One reviewer was also encouraged by the inter-national lab cooperation that was present, though a different reviewer was confused about the specific roles played by—and the level of engagement of—service providers and contractors that were engaged in the project as partners.

Weighted Average: 3.13 # of Reviewers: 5
Approach: 3.00 Impact: 3.40 Progress: 2.80 Collaboration/Coordination: 3.40 Remaining Work: 3.00

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project appears to have a well thought out approach for mass assessment and recruitment of program participants. The project also demonstrates a well thought out information workflow supporting the creation and presentation of retrofit packages to program participants. The project also has a well thought out approach to the systems involved in performance verification (specifically the use of Caltrack methods accessed through OpenEEMeter services.
- The project does not appear to have a well thought out solution (such as a technology integration platform) for integrating 1) participant assessment (pre-qualification / qualification), 2) participant recruitment (eg a web portal driven enrollment following pre-qualification/qualification), 3) project workscope development, and 4) Project and program M&V related activities related to providing estimates of realized energy savings.

- The open-source BRICR tool builds upon existing DOE tools to allow ABAG and other entities to identify energy efficiency potential of a hard-to-reach sector (SMB) and deliver technical assistance at reduced cost and potentially large scale. The partnership provides the DOE developer context for an important real-world application and supports a partnership with a motivated group invested in the effort.

- This project is making the best use of current modeling tools and techniques available to develop efficiency measures and analyze their impact.

- The project's approach is likely to contribute to overcoming barriers, technical challenges, and mitigating project risk. The project leverages existing tools, has focused on a reasonable number of use cases on which to use the tools.

- Integrated commercial retrofits to take advantage of retrofit programs in the bay area cities that invest into "prospecting," looking for opportunities where they might be. The approach is a nice connection between actual needs and skillsets available in the participating national labs.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.40** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Achieving BTO's Goals for decreasing national energy use intensities will require successful penetration of energy efficiency into both the small and medium commercial building (and multifamily) sectors. This project attempts to demonstrate Energy Efficiency Investment workflows for all (3) of those sectors. If successful at meeting the project's specific goals, the project deliverables, will provide documentation describing a clear roadmap for both local governments and utilities to apply and replicate/improve upon for accessing potential for energy efficiency improvements in their communities. More importantly, this project will also provide a framework for the 'aggregator ' community to replicate and also improve upon, potentially providing a degree of investment confidence that previously was missing.

- The tool builds upon existing DOE tools to identify the EE potential in region-wide SMBs. The initial assessment of the ECMs are reported to save up to 25%. Future versions should also identify operational savings opportunities. This can add up to significant regional savings in a sector that is not widely served by efficiency service providers.

- This project focuses on the building stock in California; however, the process and strategies can be used on all buildings across the country with additional work.

- The project is likely to contribute to the program goal(s) because it targets a large, difficult to influence portion of the market and is providing information that can lead to significant energy consumption reductions. The question is, when provided with the information, will it be acted upon?

- The project already modeled 17,000 buildings that have information from SF public disclosure code. Simulation results from 29 ECMs applied to 1699 SMBs. Initial assessment of ECMs found energy savings potential of up to 25%.

C. Progress

Based on current project efforts, the project was rated **2.80** for the degree to which the project has met ***project-specific goals.***

- The project remains on budget and target, given a revised schedule needed to account for unforeseen and unavoidable circumstances affecting key project delivery staff. The adjusted (revised) project plan and schedule appears to be achievable buy the current team and if executed will lead to achievement of the project's goals. One concern should be raised - given the lack of a technology integration (workflow manager) solution as part of the project, it is unclear to this reviewer that replication of this project will be 'scalable'. Nevertheless, if the project is well documented, significant value will be generated even by studying the 'lessons learned'.

- The Year 1 work focused on the Phase 0 workstream with 2 years of follow on work planned. To complete this phase of the effort, about 75% of the functionality has been put in place. Thus, the project is well on its way to deliver the required tool functionality. No major hurdles are foreseen for successfully completing this potentially high-impact, open-source tool.

- Due to administrative and staff issues, the progress during the past year has not been the same as planned/proposed; but the team is well aware of the need to ramp up the work in the coming year. They seem to have all the personnel and expertise in place to accelerate the work.

- The project has demonstrated **modest** contribution to the project-specific goals because of the 6 month delay from a change in PI. BRICR is not yet completed and the retrofits have not been started. The no-cost extension give me hope that the project will be completed in full.

- The project experienced a 6 month delay due to the PI's retirement, but the team managed to successfully overcome this setback.

D. Collaboration and Coordination

This project was rated **3.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The peer review presentation described an impressive list of key partners and collaborators representing government stakeholders, financial and risk management institutions and others. It was not clear to this reviewer how service providers and/or contractors are engaged in the project (as partners). From a DOE perspective, the project is involves cross-lab participation, with work products from at least (3) different national labs providing technical underpinnings to the solution. This is encouraging to the reviewer, as it promotes an environment where the labs are encouraged to collaborate on solving 'customer' facing problems, as opposed to a lab focus on competing against one another for limited resources, etc.

- With Bayren as a partner, the tool development will be focused and well-aligned with a replicable real-world use case. Also Bayren is motivated to address regional EE opportunities in response to dCA's recent legislation mandating aggressive energy efficiency targets that will be partially achieved through utility pay-for-performance programs. The effort leverages existing DOE tools (OS, EnergyPlus, SEED, and

BEDES) to create a tool to respond to these new policy mandates. All efforts align to support a tool to address a key new use case - with the potential for many other entities to benefit from this effort.

- Two national lab teams are collaborating with the PI and have excellent project planning and coordination among all the team members. LBNL is developing the strategy and analysis methodologies for retrofit identification and analysis of outcome, NREL is developing measures and software implementation to translate the efficiency opportunities as OpenStudio measures. Overall, the team interaction and complementary roles are a bright spot for this project.

- The project staff demonstrates **significant** strategic collaboration or coordination with relevant stakeholders. The project requires coordination across numerous partners and national labs.

- The project experienced a 6 month delay due to the PI's retirement, but the team managed to successfully overcome this setback.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- While the project appears to be progressing as expected and resourced sufficiently to meet the 'minimum requirements' of the remaining deliverables, it does not appear to this reviewer that the project plans will translate directly towards meeting BTO's energy use intensity goals, without further investments in defining and testing the informational workflows 'end-to-end' using a scalable approach.

- The development process is logical and builds on past phases to expand functionality. The team has also partnered with OpenEEMeter to take the results from BRICR and incorporate into an energy savings methodology currently being adopted by PG&E. This completes all analysis needed to receive utility program incentives and document achieved savings.

- Based on the presentations at the Peer Review, it appears that one half of the software development is completed and a significant portion of work remains in setting up the analysis infrastructure and complete analysis of about additional 28 or so efficiency measures to be considered.

- The project plans are **likely** to meet the project-specific goals because the coordination has been completed, BRICR development has made significant process, and the buildings for retrofit have been identified. With the 6 month extension, the project should have significant time to complete the project work.

- Audit template is available for alfa trials in 28 selected building projects.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project can be considered to be groundbreaking in its attempts to congeal a scalable approach for identifying energy efficiency upgrade potential in a manner approaching an ASHRAE LEVEL 2 Audit, while maintaining a 'light touch' approach that will not over-promise on estimated benefits. The technology stack developed by the NREL, LBNL and PNNL teams, leveraging OpenStudio, CBES and Audit Template tools, has already generated leveragable improvements in infrastructure. Successful demonstration of DOE's SEED platform as a data warehouse that can support programmatic models such as BAYRen is a major (potential) force multiplier that may be recognized in future work beyond this project.

- Strengths include:
    - linking DOE and other open source tools in to a new impactful workflow, specifically BEDES, SEED, OS/E+,Audit Template and OpenEEMeter

  - collaboration with BayREN, a motivated client
  - a new use case that supports pay-for-performance programs, which are anticipated to have wide national impact once implementation challenges are addressed
  - an experienced, committed development team

- Technically a very strong team using the latest tools and techniques to calculate energy savings from utility data. This is an ambitious and challenging initiative with the potential to help utilities and incentive program administrators in prioritizing the efficiency measures. The BRICT tool once developed, promises to be an effective strategy to undertake mass building scale analysis and implement retrofit strategies.

- (1) Targets an important portion of the existing building market
- (2) Includes real life implementation of the software to test its applicability
- (3) Has support of the key partners
- (4) Has a well-developed plan for completion

- SEED Platform is in the CENTER of both data collection and analyses results. BRICR software architecture is flexible and streamlines an effective auditing process.

2) **Project Weaknesses**

- The project's major weakness, in this reviewer's opinion, is the lack of an overarching technology integration layer which can provide means and methods for the various IT based components developed as a part of this project to be scalably replicated.

- The project may need to tweak methods in response to real-world applications and market forces. The market driving force - pay-for-performance program implementation - is in its infancy. The need to use SEED not just as a data repository but as a project management tracking tool.

- Given the current delay in project schedule, it may be necessary to extend the performance period for this project extended by one more year. A significant portion of software development and analysis of about 30 measures still remain. With additional staff/resource, the team may be able to complete the planned development work.

- (1) Immediate impact is reliant on building owners taking action based on the recommendations from the software
- (2) Long-term impact will be dependent on the ability to use the demonstrations to convince use in other cities. If the demonstrations do not succeed, that will be difficult.
- (3) A lot of software tools need to be made interoperable, which may turn out to be infeasible.

- The project seems to be slightly behind the schedule.

3) **Recommendations**

- This reviewer would ask the project team to allocate a considerable amount of time and resources to the project team towards the year three deliverable (final report), ensuring not only that the minimum project milestones and deliverables were met, but perhaps more importantly that 'lessons learned' are adequately documented and shared. This project is very ambitious in its attempts to incorporate advanced analysis technologies into energy efficiency workflows, and there will be a need to describe clearly areas of 'future research' where projects replicating the approach should consider additional directing additional resources and investments, as part of defining the effort needed to scale this project's results.

- Be sure to include work scope and continued maintenance of the tool to address fine tuning tool in response to market forces, program manager, and service provider needs. Also, insights to the tool's accuracy and its practical application may slowly unfold since they will stem from making comparisons between savings

estimates and verified savings values. This may be complicated since the latter are based on simplified methods. Is the simulation better than the monthly M&V regression based approach? How will these two analyses be best utilized and rectified?

- Would like to see the team complete the proposed BRICT implementation work using a generic/open source software infrastructure and document the methodology so other utilities/cities can adapt this without additional work.

- None

- Please, involve stakeholders to help with recruiting case studies to improve rate the project progress.

Project #25136: OpenStudio

Presenter: Luigi Gentile Polese, National Renewable Energy Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Nearly every reviewer commended this project's approach to modularizing OpenStudio, refining its user interface, and enhancing its diffusion and user-responsiveness. Several reviewers made supportive comments about the wisdom of reducing the size of the OpenStudio executable, enhancing the server, and putting OpenStudio on GitHub—thus allowing the project team to directly engage with other software developers to improve the tool and increase marketplace awareness. One reviewer said that the project's approach was highly likely to overcome barriers, technical challenges, and mitigate project risks, while several others directly credited the changes and improvements made to OpenStudio for the "rapid onboarding" of new users over the past year.

Several reviewers expressed that the project team could improve its outreach to new users, specifically those who were not advanced programmers who frequented GitHub. According to one reviewer, online tools were in place that provided "a feedback loop from one specific user-community, [but] other OpenStudio users (potential 3rd party tool developers) may not be reached from that method." Another reviewer expressed that the project team could also better communicate the differences between OpenStudio's suite of tools and the underlying OpenStudio software development kit (SDK), calling this distinction something that had historically confused the BEM community.

Reviewers were extremely supportive of this project's potential impact. One reviewer said plainly that "without [OpenStudio], the benefits of taxpayer investments in EnergyPlus would not be realized." Another reviewer said this project had already made a significant impact on the number of users who adopted EnergyPlus, as well as the number of stakeholders who were supporting further development of OpenStudio. A third reviewer credited this project as having a strong influence on the achievement of BTO's goals, citing that OpenStudio had become "one of the key drivers of BEM use."

All reviewers were encouraged by this project's progress. Reviewers highlighted OpenStudio's greatly enhanced download rate and its increasing integration into other customer-facing tools. One reviewer called the introduction of the "lightweight" OpenStudio SDK "a significant milestone," while another noted the addition of new features and capabilities that "expanded functionality to better support the development of practitioner tools." Another reviewer said that the project had met "every milestone to date" and was "accelerating the use of BEM across federal and state agencies and the private sector." With respect to the project's remaining work, reviewers generally expressed confidence in the team's plans and capacity to continue meeting its remaining milestones, with several positively commenting on the project team's ongoing efforts to refactor OpenStudio tools in preparation for eventual integration with the Spawn of EnergyPlus BEM engine.

While reviewers underscored the important role that the project's collaborations played in its success to date, a few reviewers still highlighted that the project team could better engage the broader simulation tool developer community, to enable the development and integration of other tools into the OpenStudio SDK, and by doing so further advance EnergyPlus' adoption goals. Another reviewer expressed their desire for the publication of a software roadmap for the user-facing tools and the SDK, describing that the current lack of such a roadmap "prevent[ed] or significantly delay[ed]" third parties from strategically planning and executing their own transitions to OpenStudio. A different reviewer thought the team's efforts had largely operated without much industry input, which they cited as a weakness the team could improve upon moving forward.

Weighted Average: 3.43 # of Reviewers: 5
Approach: 3.40 Impact: 3.80 Progress: 3.40 Collaboration/Coordination: 3.00 Remaining Work: 3.60

A. Approach

This project was rated **3.40** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- A key technical underpinning to multiple analysis approaches used by DOE (Scout, etc), OpenStudio provides DOE with a set of enabling tools for delivering consistent energy and water analysis using state-of-the-art methods in a cost-effective and scalable manner. While DOE has fully embraced investments in the automation of energy modeling workflows that OpenStudio provides, the traditional software vendors operating in the private sector have been slow to adopt OpenStudio into their workflows. On the contrary, smaller and more agile emerging enterprises (startups, etc.) have embraced the features and functionality that OpenStudio provides to them.
- This reviewer believes strongly that DOE needs to improve communication methods to better differentiate market perceptions of a) OpenStudio Suite of tools and the b) the underlying OpenStudio SDK. Historically, the community of energy modeling professionals has struggled to understand the differences between the "OpenStudio Application" and the OpenStudio SDK, and misunderstandings have, in some cases, led to confusion and adoption resistance.

- The move to modularize OS is a great approach to capitalize on its current capabilities while preparing the tool to be used with other engines - including Spawn. OS support practitioners, industry, and researchers. Through github, the development team has direct engagement with software developers, which allows them to interact, get contributions, and assess their needs on an ongoing basis.

- This project is aimed at breaking the barriers to EnergyPlus adoption by providing a user-interface and features for a wide variety of use cases. The software development and release is somewhat coordinated with EnergyPlus development, but seems largely driven with no industry input to the development priorities or process.

- The project's approach is **highly likely** to contribute to overcoming barriers, technical challenges, and mitigating project risks because project team is responsive to users (e.g. reduction in files/size of download) and unexpected changes (e.g. SketchUp no longer free).

- More than two dozen third party software developers use OpenStudio, EnergyPlus, and potentially in the future Spawn. A total of dozen direct engagement with software developers. Engagement with IBPSA and other industry stake holder groups.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.80** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- The OpenStudio project, when executed successfully, provides its users major leverage points which ease existing barriers of technology evaluation and support market based activities encouraging subsequent downstream adoption (post analysis). From DOE's perspective, maintaining and investing in internal analysis tools which standardize the technical analysis of calculations and projections enable DOE to perform more integrated long term analysis and scenarios. Providing market access to these same capabilities via open-source licensing arrangements encourages further market innovation.

- Without OS, the benefits of taxpayer investments in EnergyPlus would not be realized.

- This project has had a significant impact on the number of users adopting EnergyPlus and stakeholders supporting further development. According to the numbers presented, the number of OpenStudio users is almost equal to the number of EnergyPlus users (based on number of downloads).

- The project is **highly likely** to contribute to the program goal(s) because it is one of the key drivers for BEM use.

- OpenStudio CLI reduced to 124 MB executable, ongoing support for latest EnergyPlus and Radiance. OpenStudio server allows for massive computing via Amazon server for up to 300,000+ simultaneous analyses. GEM creates Std 90.1-2013 Appendix G prototype buildings and baseline automation model. Can now directly make a model for LEED certification.

C. Progress

Based on current project efforts, the project was rated **3.40** for the degree to which the project has met ***project-specific goals.***

- OpenStudio has clearly met the needs of DOE (as in internal customer) quite well. The OpenStudio Application (OS App) has also been downloaded by over 40,000+ users - and activity on the unmet-hours user group indicates OpenStudio use is increasing.
- At the 2017 DOE Peer Review, the DOE Program Manager stressed that DOE wants to use OpenStudio to support 20 application developers, not 20,000 users. OpenStudio continues to see adoption and integration into customer facing tools (Carrier HAP integration is under development as an example), while in parallel, during 2017 a group of traditional software vendor stakeholders has self-organized under IBPSA-USA, with the goal of minimizing the impact of the user-facing OS Application tool in the domestic marketplace.

- Many new features and capabilities have been added to OS, which expand functionality to better support the development of practitioner tools. New features also support DOE efforts around codes and rating systems.

- The release of lightweight SDK during the past year is a very significant milestone completed by the project team. Also the FloorspaceJS and automation of modeling tasks for several prototypes are very useful features for users.

- The project has demonstrated **excellent** contribution to the project-specific goals as it has met every milestone to date and has accelerated the use of BEM across federal and state agencies and the private sector.

- The integration between OpenStudio, EnergyPlus and Spawn is an impressive task that is on track with regular releases.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The OpenStudio team has demonstrated collaboration with other stakeholders (other labs, other software vendors, etc). A criticism from this reviewer would be the lack of transparency of the OpenStudio "roadmap." It is this reviewer's opinion that the lack of a published software roadmap (both for the user-facing tools and the underlying SDK) prevents or significantly delays organizations from strategically planning and executing transitions towards the use of the OpenStudio software (both user-facing tools or the SDK). It is not clear if DOE/NREL simply lacks a method for developing and communicating a software roadmap or if there are more barriers to publishing a roadmap (for example, the need to be very operate reactively to prioritize and support DOE internal analysis or other customer needs, etc.).

- The experienced multi-lab team supports private-sector adoption and industry organizations. There are 9 market facing tools under development or currently available and 5 internal company-specific tools. The two main HVAC firms with equipment sizing software have adopted EnergyPlus as their calculation

engine. One deploys OS as part of their interaction. There is good progress in making OS/EP the foundation for new simulation applications.

- Though a number of stakeholders are involved in the adoption and use of Openstudio SDK and application, there is a need to involve broader simulation tool developer community to enable other tools to integrate with the SDK and focus on the broader EnergyPlus adoption goal rather than the OpenStudio application adoption.

- The project staff demonstrates **excellent** strategic collaboration or coordination with relevant stakeholders as shown by the long list of partners and associated software tools that use OpenStudio for a variety of purposes.

- This project is an impressive collaborative effort.

E. Remaining Project Work

This project was rated **3.60** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- While not explicitly discussed in the Peer Review Session, it is this reviewer's understanding that significant resources may be directed to the OpenStudio team in FY 2019 to ;'decouple' the codebase used for the OpenStudio Application from the underlying SDK codebase. This would allow future OpenStudio improvements to be made to the SDK, while potentially 'freezing' the OpenStudio Application. This would be a major accomplishment for the OpenStudio development team to finish in FY 2019.

- The move towards modularization and refactoring for improving OS standardization to better support application development are important strategies for meeting effort objectives.

- The remaining tasks of separating the application and SDK, and refactoring the tools to prepare for Spawn integration are well aligned with the overall goals for this project.

- The project plans are highly likely to meet the project-specific goals given the project track record, continuing software improvements, and growing number of partners.

- The remaining project work is focused on preparing the transition of controls EnergyPlus simulations to Spawn. Specifically, Modelica needs improvements in runtime, so that the simulations can be deployed to SMB building stock. EnergyPlus needs will try novel ways to include users in prioritization of feature development. OpenStudio is focused on enabling introduction of custom controls schemes.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project enables automation of 'routine' EnergyPlus energy modeling tasks, allowing energy modeling to be used for use-cases that were formerly inaccessible due to cost issues. The Project 'Measures' capability also provides a valuable framework for re-use and sharing of required energy modeling content (both manipulation of model inputs and standardization of customizable output reports).
- The experienced, committed team has proven success with maintaining and expanding OS. They have effective methods in place for tracking and fixing defects, creating new buildings, supporting vendors. The technical manager is forward looking, which causes OS development to be aligned with a long term view to support simulation needs and DOE tool development.

- OpenStudio SDK and measures have enabled rapid on-boarding of users to EnergyPlus. With the large number of stakeholder adoption of SDK and use of OpenStudio application, EnergyPlus use in the US has

increased significantly in the past few years. Further development of SDK is needed to enable software developers to integrate the EnergyPlus engine with more advanced user-interfaces and industry workflows.

- (1) Responsive to users
- (2) Developed with both a short term and long term vision

- The project has an excellent traction with users (40,000+). EnergyPlus provides reliable simulations, Spawn provides excellent new opportunities and OpenStudio makes all of these features accessible.

2) **Project Weaknesses**

- The project lacks a clear feedback mechanism between DOE, the labs and the stakeholder communities (both emerging and existing) who use the OpenStudio tools and SDK. While user-voice provides a feedback loop from one specific user-community, other OpenStudio users (potential 3rd party tool developers) may not be reached from that method.
- DOE would be wise to consider investing in creating new links and improve existing links to OpenStudio user-communities.

- The OS team readily gets input from advanced users engaged with github or private sector developers. However, it doesn't appear that there are effective mechanisms in place to reveal new users needs or efforts to support their transition. The OS team shouldn't neglect this important but disperse group. OS should have the functionality to be a substitute to eQUEST and track progress made in this area. For example, several case studies of successful transitions by a handful of companies could be highlighted. The companies should represent a spectrum of sizes/workflows/modeling replication. For each, the path they followed should be explained. Trainings can be designed to help other companies get up to speed by following the path that best fits their situation. These might include different levels of customization or automation.

- The OpenStudio team may want to follow a process similar to the EnergyPlus development team by including all stakeholders and broader industry participation for prioritizing the features.

- None

- The project should maintain continuity while making the transition from EnergyPlus to Spawn for controls modeling, and this transition creates uncertainty for existing users.

3) **Recommendations**

- The project could be improved by better 'outreach' and by operating in a more transparent fashion - such as publishing software roadmaps, advising and updating them as needed, and a more general attempt at transparency with respect to how input is gathered to support the decision making process for improve OpenStudio software.

- See previous response, e.g. expand the context of trainings to better track different companies' transitional needs, which won't be the same for all companies. Also, existing building modeling will become an increasingly important use case to support dynamic M&V. This will require that real data be incorporated into the model to improve component calibration.

- The OpenStudio project is perceived by the software developers as competing with private sector, and this could be avoided by emphasizing the value of SDK and measures as open source enablers for broader industry adoption of EnergyPlus.

- None

- At the earliest possible time, please, announce a specific timeline and associated steps for the transition of the controls modules.

Project #32488: Empirical Validation and Uncertainty Characterization for Energy Simulation

Presenter: Philip Haves, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers were generally supportive of this project's approach to eventually producing a performance benchmark for ASHRAE's Standard 140. Reviewers disagreed, however, on whether BTO's efforts to increase the accuracy of (and thereby confidence in) BEM results was a necessary endeavor to undertake. While one reviewer mused that it was "unlikely that any single private sector entity would have engaged in the design, construction and commissioning of the test facilities that were required to execute this project," another questioned whether the industry at-large was indeed skeptical of current BEM outputs, or if increased model precision would even improve the marketplace's use of BEM tools.

Several reviewers also raised significant questions about the project team's ability to manage its approach. On one hand, reviewers were united in their agreement that the project team's decision to thoughtfully distribute the project's tasks to particular national labs—those with the appropriate expertise and experimental facilities to conduct the work—was a notable strength of this project. One reviewer, however, was very critical of the project team's ability to manage risk, expressing concern about the challenges that LBNL faced and believing that these challenges could have been anticipated given stronger risk management. Another reviewer similarly expressed that the project may have suffered from scope creep, which negatively impacted the project team's ability to deliver on its goals.

Reviewers reserved some of their strongest criticisms and lowest scores for the project's progress to date. Several reviewers acknowledged that some useful empirical data had been produced for review by ASHRAE, and that these data had met key project milestones. A few reviewers questioned the usefulness of these results, however, citing instrumentation problems at LBNL that could have systematically produced inaccurate results. Another reviewer believed that this data had been generated by what "appear[ed] to be well designed and instrumented test installations," but the reviewer was "disappointed" by the "limited amount of reported results that the project ha[d] generated" from "a very small set of tests under very simple sets of [test] conditions."

All but one reviewer expressed doubt about the team's trajectory with respect to completing its remaining work. Three reviewers agreed that a significant amount of work remained to address the "discrepancies" and "unresolved problems" identified during initial validation, while a fourth noted that no explicit plan for addressing issues had been proposed. One reviewer also said that it was unlikely the project could achieve stated goals because the project team would need to conduct an "exhaustive set of test cases" that were likely beyond the scope of the project to accomplish.

Reviewers assigned the highest scores, and gave the most affirmative remarks, for the project's "broad" and "complementary" set of collaborators, who reviewers believed generally worked well together. One reviewer, however, lamented the lack of an industry voice and proposed a potential follow-on research task to coordinate with specific product manufacturers to support third-party external validation.

Weighted Average: 2.75 # of Reviewers: 5
Approach: 3.00 Impact: 2.60 Progress: 2.40 Collaboration/Coordination: 3.20 Remaining Work: 2.20

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project appears to be successful in delivering empirical data for ASHRAE Standard 140 Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs. The project seems to be lagging in ability to execute an approach which demonstrates an improved characterization of their BEM tool accuracy, via utilization of the FlexLAB apparatus.

- The effort has the potential to provide an absolute performance benchmark for integration into the ASHRAE 140 building simulation test protocol. This will support a more robust support for evaluating simulation program capabilities and their ability to capture actual building performance.

- This project approach of designing experiments, collecting data from full scale models and validating EnergyPlus engine is well thought out and detailed to support Standard 140. Flexlab at LBNL and full scale experimental buildings in ORNL are instrumented for field data collection. In addition to data collection and validation, a methodology has been proposed to account for uncertainty in experimental data and simulation calculations.

- The project's approach is likely to contribute to overcoming barriers, technical challenges, and mitigating project risk. The test bed designs appears to be well designed. Although in one case the equipment did not appear to be correctly calibrated before use.

- The project is to increase accuracy of energy modeling and confidence in simulation results for practitioners and other users. Four labs looking at different aspects of thermal loads, VAV systems, RTUs data collection and then uncertainty characterization. Sources of uncertainty and variability were discussed. The project aim is to determine whether the algorithms are fit for the purpose.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- The project appears to have a large spend of ~ $900K per year, which has led to few actual documented outcomes. The actual documented outcomes appear to be well designed and instrumented test installations which have only been used to conduct a very small set of tests under very simple sets of conditions. This reviewer is disappointed in the limited amount of reported results that the project has generated.

- Making a connection between building performance measured in testing facilities and simulation programs will his will help improve simulation program algorithms and increase their credibility. This supports meeting BTO program goals. In addition, new use cases will be more and more focused on existing building performance where absolute performance is important (versus making performance comparisons).

- The accuracy and reliability of energy simulation results have often been criticized for lack of standard procedures to validate the calculation methodologies in energy simulation engines. Though Standard 140 specifies standard analytical test methods, there are no benchmark results that can be used for validation. This project aims to provide data and methods to verify and validate heating and cooling load calculations in energy simulation software tools, which can be incorporated in Standard 140.

- The project is somewhat likely to contribute to the program goal(s). Even though there is uncertainty within the modeling tools, it is unclear to me that industry is questioning the validity of current BEM tools or that increased precision will lead to greater use of the tools.

- Flexlab testing with idealized heat sources and thermal manikins has been conducted. There was a lot of details to simulate, so the investigators built a cell within cell and can switch from low mass to high mass by covering the floor slab with insulation and did comparison with the BEST test results. The comparison went well.

C. Progress

Based on current project efforts, the project was rated **2.40** for the degree to which the project has met ***project-specific goals.***

- Specifically, the progress of the research conducted at LBNL seems to be lagging far behind in ability to generate progress towards project goals. Other performing labs (ORNL and NREL specifically), appear to be meeting the projected project deliverables, outcomes and milestones.

- While ORNL and NREL testing has proceeded well, there have been unforeseen challenges associated with LBNL test facilities, which has hindered project progress.

- All experiments have been designed and data collection for certain scenarios have been completed. Initial comparison with simulation results have been completed, uncertainty analysis methodology has been developed and further work is in progress to fine tune the data collection for additional validation scenarios.

- The project has demonstrated significant contribution to the project-specific goals. Most milestones have been completed on time.

- For a couple of years developed instrumentation and test procedures, has 17 documented tests, measure spatial average in 200 points (41 air) to do the comparison. This is a significant amount of measured data for uncertainty characterization.

D. Collaboration and Coordination

This project was rated **3.20** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project demonstrates participation by a broad set of lab stakeholders, but did not demonstrate connections and collaborations with other industry stakeholders (product manufacturers, etc.). Perhaps follow on research tasks might coordinate the use of the facilities with the needs of specific product manufacturers, to support 3rd party external validation of reported product performance.

- It is great to see the 3 labs bringing their expertise and ability to contribute in complementary ways to this project. It is unfortunate that the LBNL facility has not performed as hoped. The other labs experience in whole building testing facilities and measurement might have been better leveraged to address the LBNL issues.

- All the national labs involved in the project have collaborated effectively complementing the various aspects of validation and uncertainty analysis. Field data collection and analysis have been coordinated with the ASHRAE Standard 140 project committee. The bi-annual ASHRAE Standard meetings with separate meetings focused on coordinating the efforts of the validation methodology and data collection demonstrate the outstanding efforts of the project team.

- The project staff demonstrates significant strategic collaboration or coordination with relevant stakeholders except in one case. Reviewers appeared to have several potential solutions for one troubled FLEXLAB experiment. By contacting the research community, they may have been able to identify a solution before it was time for the review.

- In addition to the lab investigators, the project included collaborators from Gatech who provided probability distributions for 75 common energy simulation inputs. Measured results compared with simulations that include uncertainties. Used CRPS is to help reduce error on a continuous basis. Will share data with ASHRAE SSPC-140. Data available through TPAX url.

E. Remaining Project Work

This project was rated **2.20** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Given the very limited set of performance data that has been generated and validated as a part of this project, it seems unlikely that the project will achieve the stated goals of delivering improvements to accuracy of BEM engines, providing consistent and validated products and increasing the confidence in all BEM tools. It is this reviewer's opinion that additional support (through DOE or otherwise) to fund a more exhaustive set of test cases (both measured and simulation validated), likely beyond the scope of this project - are necessary.

- An explicit plan for addressing the identified issues were not laid out in detail during the presentation.

- Several experimental challenges have been faced by the team and much work remains to resolve the discrepancies identified during the initial validation process. In addition, the uncertainty analysis aims to improve the quantification using experimental data and develop a validation framework. It is highly uncertain as to how much of this work will be completed for submitting it to the ASHRAE Standard 140 committee for consideration at the 2018 Summer meeting.

- The project plans are likely to meet the project-specific goals. The milestones are on track to be completed by the end of the project.

- The project provides quasi-real-time, component level data, still need to address unresolved problems such as the night time heating requirement that is either overestimated by the software or underestimated by the heat flux measurement system.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project strengths include successful accomplishment of initial (setup and commission) shakedowns of the respective physical test facilities. It is unlikely that any single private sector entity would have engaged in the design, construction and commissioning of the test facilities that were required to execute this project.

- The project strengths are: 1) the multi-lab collaboration that utilizes each lab's test facilities and staff capabilities, 2) the alignment of test characterizations with ASHRAE Standard 140 modeling runs, 3) the incorporation of the test results into the ASHRAE Standard 140 – an industry-accepted procedure for systematically comparing equivalent model results to highlight and troubleshoot shortcomings. The effort will help bring greater credibility to modeling existing buildings.

- Highly reputed researchers and well equipped experimental facilities to accomplish the goals of this project.

- (1) Project targets a clear issue with existing BEM in the uncertainty of the models
- (2) Project provides needed data (from more realistic conditions) to improve BEMs

- The project provides the heat balance analyzer capable to within 15 minutes specify if there is a balance on experimental side (automated discrepancy localization and detection).

2) **Project Weaknesses**

- The project's weakness appears to be an inability to adequately plan and manage "execution" risk. Specifically, the work completed by LBNL (FlexLAB) appears to be poorly managed, and appears to have been fraught with unexpected difficulties that occurred several times throughout the project execution. Many of these difficulties may have been preventable by proper project risk management.

- The project weakness is the lack of robust results from the LBNL testing facility due to thermal bridging and probable measurement instrument errors. It is unfortunate that these issues weren't uncovered as part of previous or early project efforts to demonstrate the proof of concept and this fundamental capability.

- The scope of validation and uncertainty analysis seems to have expanded from the original proposal, and several unexpected experimental data collection challenges have been faced by the team - potentially impacting the schedule and project outcome.

- (1) Difficult to quantify the potential benefits of the work.

- The issues with the heat flux meters currently create a lack of confidence in the heat flux data.

3) **Recommendations**

- This reviewer would recommend the project team apply for additional DOE funding to continue to use the (now commissioned) test stations to explore the respective performance spaces further. It would be a poor use of DOE investment to not consider supporting additional research use-cases for these highly specialized facilities that have been constructed using taxpayer monies.

- The project may benefit from getting support from additional expert technicians regularly involved in setting up and running performance tests and their associated instrumentation

- Would recommend limiting scope from undertaking any new experiments, but focus on the analysis aspects to resolve discrepancies and sanitize the data for consideration by the Standard 140 committee prior to the 2018 ASHRAE summer meetings.

- Identify individuals in the research community that can assist in improving the FLEXLAB experimental testing to find reasons and solutions for the unexpected results.

- The heat flux meters could be tested in the end of the experiments to understand whether the data could be simply cleaned and calibrated or some of the experiments might have to be repeated.

Project #35390: THERMM: Heat & Moisture Modeling Tool

Presenter: Charlie Curcija, Lawrence Berkeley National Laboratory and Diana Hun, Oak Ridge National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed with this project's approach to developing a software tool capable of modeling dynamic heat and moisture transfer in building envelopes, calling the approach strong, well thought out and detailed, and highly likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. One reviewer also highlighted that, if successfully executed, the approach would provide combined moisture and temperature envelope analysis tools to a large community of users. Conversely, while one reviewer commented that this project would provide a service that was greatly needed for analyses of the residential building stock, another remarked that it was not clear whether the building science community had a critical need for this type of tool. One reviewer was also critical of the fact that the completed software would not be fully released as an open-source product.

Reviewers agreed that the project was making good progress, with one reviewer specifically highlighting the significant progress being made in certain key project areas: developing a data input model, integrating the heat transfer and moisture transport models, and completing initial validation of results. Reviewers also agreed that the project's progress was expected to continue, remarking that the project appeared to have a well thought out plan for executing on the remaining project work, and that remaining tasks had been allocated an appropriate amount of time to complete. One reviewer did express concern, however, that certain milestones had not been met on schedule, while another warned that the tasks remaining happened to be where many issues could reveal themselves, potentially affecting budget and/or deliverable dates.

Reviewers lauded the project's collaboration and coordination with a broad range of partners, subcontractors, and collaborators, describing the project team as being "well positioned to leverage input and information from these stakeholders to ensure the project remain[ed] on track for deliverables." One reviewer commented that the project team had demonstrated significant strategic coordination with relevant stakeholders, while other reviewers specifically highlighted the project's collaboration with several industry entities, its technical advisory group, and ASHRAE.

On this project's potential impact, reviewer assessments were somewhat mixed. Several reviewers highlighted that successful completion of the project would improve the capabilities of design professionals to analyze the effects of improved approaches to energy-efficient building envelope and assembly construction, specifically by allowing them to conduct more moisture transfer analyses. However, one reviewer pointed out that project would not actually contribute to DOE's energy saving goals, and another noted that it would be difficult to quantify the non-energy benefits (e.g., health, safety and indoor environmental quality) of improved building envelopes. Several reviewers flagged that THERM—the base tool that this project sought to enhance—already had a user base of over 25,000, but one reviewer expressed concern that further uptake of this project's tool might be slow, citing confounding market conditions like the decreasing costs of PV as well as tendencies to ignore load reductions before making other building improvements.

Weighted Average: 3.22 # of Reviewers: 5
Approach: 3.40 Impact: 2.80 Progress: 3.00 Collaboration/Coordination: 3.40 Remaining Work: 3.40

A. Approach

This project was rated **3.40** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project team appears to have a well thought out and detailed approach for successfully completing the project both on time and under budget. The approach, if successfully executed, will provide a much larger community of users to combined moisture and temperature envelope analysis tools.

- The project development approach is strong. It draws on international efforts, uses open standards, and leverages EnergyPlus for modeling less-dynamic component. It also utilizes OpenStudio. Spawn also addresses limitations of monolithic BEM engines, which will help it scale and evolve over time.

- This project is adapting well established methods and tools for heat and moisture transfer in an integrated software tool for evaluating the thermal and moisture performance of opaque envelope components.

- The project's approach is highly likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. The project has completed all targeted tasks to date, including a version of the software that compares favorably to the existing software. The remaining milestones of verification and validation should be accomplished.

- The project is coupling WUFI software package with EnergyPlus. This coupling is greatly needed for analyses of the residential building stock.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.80** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Successful completion of this project will no doubt improve the capabilities of design professionals to analyze the effects of improved approaches towards energy efficient building envelopes and assemblies. It is difficult to quantify the non-energy benefits (specifically considering health, safety and IEQ) related to improved building envelopes analyzed by this tool. For example, envelope designs that improve their resistance to moisture transport may not deliver direct energy savings but may deliver reductions in mold and mildew occurrences, which have demonstrated effects on health and IEQ.

- Spawn addresses many shortcomings of current BEM engines. It will allow modeling of actual control sequences, support grid flexible buildings, FDD, and allow measured data to be incorporated into component and system models. These are all needed capabilities for addressing new use cases to expand the use and impact of modeling and achieve BTOs efficiency goals.

- THERM is a very well established tool used by over 25,000 professionals primarily for window frames heat transfer modeling. By adding moisture modeling to THERM, this tool can be used for evaluating the thermal and moisture performance of opaque envelope assemblies; and this data can be used for detailed simulation as well. Though this project does not contribute to the department's energy saving goals, it is critical for designing durable envelope construction and provide the data needed for energy simulation tools.

- The project is likely to contribute to the program goal(s) because the capabilities in the new software were not previously available for free. Since THERMM is publicly available, more moisture transfer analysis will be completed during building designs, leading to better building designs that can perform both in terms of energy efficiency and moisture control.

- THERMM is currently used by 25,000 users. GUI to account for time domain, use TMY, and enhanced reporting capabilities.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- The project appears to be relatively early (~ midway) through execution. The project appears to be well staffed and resources, and is achieving the expected progress towards goals.
- Good progress has been made in developing and implementing the Spawn modular architecture, expanding the Modelica buildings component library, reducing computing time, validating the solver, validating a system model, and coupling EnergyPlus and Modelica.
- This project has made significant progress in developing a data input model, integrating the heat transfer and moisture transport models, and initial validation of results.
- The project has demonstrated significant contribution to the project-specific goals, specifically the completion of a model that performs comparably to existing software. Although some milestones have not been met on schedule.
- The alpha version of software is to be completed by 2019 early 2020. It will include dynamic two-dimensional heat transfer and moisture transfer in buildings. Developing an API for use by custom software.

D. Collaboration and Coordination

This project was rated **3.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project team includes an impressive set of technical integrators. In addition to the technical integrators, the project has also incorporated a broad range of partners, subcontractors and collaborators. The project team appears to be well positioned to leverage input and information from these stakeholders to ensure the project remains on track for deliverables.
- The project draws on LBNL's and ORNL's expertise in heat transfer, moisture transport, and building envelope performance modeling. The project builds upon an existing BTO tool – THERMM – to expand its capabilities and potential applications. The effort involves several industry entities, a technical advisory group, and ASHRAE – in addition to many supporting partner organizations.
- The project team is working with all the leading industry organizations and stakeholders; also is coordinating with the WUFI model developers to avoid duplication and use already proven methodologies and software code.
- The project staff demonstrates significant strategic collaboration or coordination with relevant stakeholders, including standards organizations, private companies, and academia.
- The collaboration is well established among researchers from the participating labs, and the team members have complementary expertise.

E. Remaining Project Work

This project was rated **3.40** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The project appears to have a well thought out plan for executing on the remaining project work - however - the remaining project work (GUI development, software development, verification and bug testing) is also

where many issues may reveal themselves, potentially affecting the budget and/or deliverable dates. This reviewer feels it is critical the software development team follow best practices (agile or otherwise) for incorporating automated reviews, regression testing, etc into the core code development process - else the team risks spending unplanned effort (time and money) on bug fixing and manual verification activities.

- The work plan for the remainder of FY18 seems reasonable with complete development and release of a alpha version for testing and verification.

- It is very likely that the team can complete the user-interface implementation and integrating the calculation engines to release the software without any technical risk, based on the information presented at the review.

- The project plans are highly likely to meet the project-specific goals. Most milestones have already been completed. The remaining tasks have been allocated appropriate time to complete.

- Can display heat flux contours, view factors, false IR image. Translated this content to opaque envelopes. Use area weighting for a wall section similar to what is done for windows. This is currently stead-state modeling, but need to develop dynamic modeling to get Cp.

F. Additional Comments and Recommendations

1) **Project Strengths**

- A key project strength will be leveraging the existing THERMM user base, providing them with an additional powerful feature that is integrated into a tool that they are already comfortable using. This can enable creative and innovative THERMM users to expand their list of services, creating multiple 'touch points' into the envelope design and evaluation community that DOE BTO would otherwise struggle to make connections with.

- The project's strengths are its experienced project team, creation of a free and mostly open source tool to address 2-D heat and moisture transfer in envelopes, and market need.

- Well proven software tools and methodologies used for developing this new software; both the LBNL and ORNL team members have a long history and proven track record in envelope performance assessment tools and techniques. Significant progress has already been made in developing the data model and integrated HAM model.

- (1) Provides new, useful capabilities to an existing software with a large existing software package.
- (2) Increases availability of moisture transfer modeling since the software is open source.

- The project has an excellent engagement of stakeholders that consist of existing THERMM users.

2) **Project Weaknesses**

- This reviewer found few weaknesses in the project's presentation. One weakness (although small in nature) might be the inability of the project to be able to fully release the completed software as an open source project, fully hosted on github, etc. If it were possible to refactor the codebase to allow the full software to be released under an open source licensing agreement (DOE's preferred manner), software developers working in the space may be able to leverage DOE's investment, providing the private sector equitable opportunities to generate additional value on top taxpayer sponsored software investments.

- The uptake of the tool may be slow due to market considerations, such as: decreasing PV cost trends and tendencies to ignore load reductions before making other building improvements.

- It is unclear how critical is the need for such a tool in the building science community. Often energy simulation tools have not incorporated moisture performance data or moisture transport analysis.

EnergyPlus and future simulation tools may be able to take advantage of this tool, but at the moment it is highly likely that only special projects might benefit from this tool.

- None
- The project needs a workflow for software developers and users.

3) **Recommendations**

- This reviewer found little to recommend to the project team. The peer review presentation was well done, and if executed well provides for a set of next steps and future plans that this reviewer agrees would be appropriate to request additional DOE funding to assist with completing.
- Challenges for uptake are market issues that are beyond the scope of this project but could be addressed by broader lab efforts.
- None.
- None
- The project could create the workflow as well as explore using existing open source software available at http://champs.syr.edu/

Project #35511: Spawn of EnergyPlus

Presenter: Michael Wetter, Lawrence Berkeley National Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers agreed with this project's approach to developing a next-generation building energy modeling (BEM) engine—Spawn of EnergyPlus (SOEP). Reviewers described the approach as well thought-out, strong, and highly likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. One reviewer highlighted that the approach drew on international efforts, used open standards, and leveraged existing DOE tools, while another noted that the approach allowed for parallel development of SOEP and EnergyPlus—thus ensuring that the transition to SOEP would have minimal impact on users.

One reviewer described this project as representing the "next generation" of performance capabilities for DOE-funded energy analysis tools and simulation workflows, while another commented that the project's impact, if it was successful, would contribute significantly towards DOE's ability to evaluate and measure progress towards its goals. One reviewer noted that the project addressed many shortcomings of current BEM engines, while also adding needed capabilities for new use cases that could expand the use and impact of modeling. Another reviewer cautioned, however, that while the project's use of advanced techniques would improve simulation methods and could help model complex control system strategies, it might not satisfy a "critical need" for the achievement of greater energy savings.

Reviewers commented that the project team had made good progress so far, and that the project work appeared to be on track, with all milestones to date having been met. Reviewers also remarked that the remaining milestones appeared straightforward to accomplish, with one reviewer opining that the project team's highly technical and specialized experience made them "uniquely qualified to develop and implement the [SOEP] simulation engine and successfully complete the remaining project work." One reviewer warned, however, that the project was nearing several "crux points," and that it remained to be seen how efficiently and effectively the project team would be able to deploy resources to accomplish the necessary tasks.

Reviewers described this project as an impressive collaborative effort. One reviewer remarked that the project team was actively engaging a wide group of stakeholders that were appropriate for the current stage of the research, expressing confidence that the project team was sufficiently leveraging collaboration and coordination opportunities. Another reviewer cautioned, however, that SOEP likely required technical knowledge which exceeded that of the typical BEM user, encouraging the project team to undertake additional educational and outreach efforts to prepare industry to embrace the project's advanced modeling approach.

Weighted Average: 3.50 # of Reviewers: 5
Approach: 3.60 Impact: 3.40 Progress: 3.60 Collaboration/Coordination: 3.60 Remaining Work: 3.20

A. Approach

This project was rated **3.60** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project's goals - while ambitious - are defined via a well thought-out approach and include a team with strong capabilities. The approach includes incremental decision points which will provide feedback to the project as to the ability to meet the aggressive timeline.

- The project development approach is strong. It draws on international efforts, uses open standards, and leverages EnergyPlus for modeling less-dynamic component. It also utilizes OpenStudio. Spawn also addresses limitations of monolithic BEM engines, which will help it scale and evolve over time.

- This project is aimed at enabling equation-based energy modeling using industry standard tools and make it available to practitioners through the EnergyPlus/OpenStudio applications. Much of the software technologies are currently available and mostly this project will be transferring the advanced simulation technique to the industry. Using the advanced techniques will improve the simulation methods, but not necessarily accomplish the department goals/targets for energy savings.

- The project's approach is highly likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. The approach allows for parallel development of Spawn and EnergyPlus, ensuring that the transition to Spawn has a minimal impact on users. The approach also provides greater flexibility by using Modelica to address issues that cannot be resolved in EnergyPlus.

- More than two dozen third party software developers use OpenStudio, EnergyPlus, and potentially in the future Spawn. A total of dozen direct engagement with software developers. Engagement with IBPSA and other industry stake holder groups.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.40** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- The project clearly represent the 'next generation' of performance capabilities for DOE funded energy analysis tools and simulation workflows. The project's impact, if successful, will contribute significantly towards DOE's ability to evaluate and measure progress towards goals.

- Spawn addresses many shortcomings of current BEM engines. It will allow modeling of actual control sequences, support grid flexible buildings, FDD, and allow measured data to b incorporated into component and system models. These are all needed capabilities for addressing new use cases to expand the use and impact of modeling and achieve BTOs efficiency goals.

- This project is an advanced research that can help model complex control system strategies, however may not be the critical need for the programmatic impacts of energy savings.

- The project is highly likely to contribute to the program goal(s) because it will provide the ability to model more complex scenarios (e.g. wider array of HVAC systems) while leveraging much of the existing EnergyPlus, leading to more accurate BEM that should increase use.

- OpenStudio CLI reduced to 124 MB executable, ongoing support for latest EnergyPlus and Radiance. OpenStudio server allows for massive computing via Amazon server for up to 300,000+ simultaneous analyses. GEM creates Std 90.1-2013 Appendix G prototype buildings and baseline automation model. Can now directly make a model for LEED certification.

C. Progress

Based on current project efforts, the project was rated **3.60** for the degree to which the project has met ***project-specific goals*.**

- The project is nearing several 'crux points' where fundamental research may be needed to accomplish the performance goals that have been defined. The project is currently meeting projected goals.
- Good progress has been made in developing and implementing the Spawn modular architecture, expanding the Modelica buildings component library, reducing computing time, validating the solver, validating a system model, and coupling EnergyPlus and Modelica.
- The software architecture and Modelica buildings library have been developed and based on the presentations, it seems the early version of Spawn will be available for testing soon.
- The project has demonstrated excellent contribution to the project-specific goals by meeting all milestones to date.
- The integration between OpenStudio, EnergyPlus and Spawn is an impressive task that is on track with regular releases.

D. Collaboration and Coordination

This project was rated **3.60** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project is actively engaging a wide group of stakeholders that are appropriate for the current stage of the research. The project has plans to engage additional stakeholders, as the research plan progresses, and this reviewer has confidence that the project team is sufficiently leveraging collaboration and coordination opportunities.
- Good collaborative effort that draws on international efforts to develop the open source software and the building component library. While currently the methods are only utilized by a specialized group of developers and users, outreach to such users is maintained through industry professional organizations (e.g. IBPSA) and support platforms (UnMetHours.com).
- The team is coordinating with IBPSA and other industry stakeholders to get their involvement and educate the user community. However, the technical knowledge required by average users is beyond typical building energy simulation knowledge. Hence additional effort should be taken to prepare the industry for embracing this new advanced modeling approach.
- The project staff demonstrates excellent strategic collaboration or coordination with relevant stakeholders by initially targeting the simulation research community as well as coordinating the existing BEM software development (E+, OpenStudio).
- This project is an impressive collaborative effort.

E. Remaining Project Work

This project was rated **3.20** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- A significant amount of 'fundamental research' remains, in order for this project to meet the goals and milestones. It remains to be seen how efficient and effective the research team will be able to deploy resources to accomplish the necessary tasks.

- The highly technical and specialized experience of the core project team make them uniquely qualified to develop and implement the Spawn simulation engine and successfully complete the remaining project work.

- The project team has made significant progress during the past year and it appears to be on-track for completing the QSS performance improvements and integration with OpenStudio for public release.

- The project plans are highly likely to meet the project-specific goals given the track record of meeting milestones and the remaining milestone appears straightforward to accomplish.

- The remaining project work is focused on preparing the transition of controls EnergyPlus simulations to Spawn. Specifically, Modelica needs improvements in runtime, so that the simulations can be deployed to SMB building stock. EnergyPlus needs will try novel ways to include users in prioritization of feature development. OpenStudio is focused on enabling introduction of custom controls schemes.

F. Additional Comments and Recommendations

1) **Project Strengths**

- This project represents significant DOE/BTO commitment towards investing in future (2020 and beyond) simulation activities. To remain relevant, DOE needs to explore advancing simulation methods such as SPAWN, and this project represents the first of many future investments that will likely be needed to bring the SPAWN project to a level of completion.

- The core team are highly technical with specialized experience that make them uniquely qualified to develop and implement the Spawn simulation engine. The development approach is forward thinking and taps into a state of the art open-source modeling software, which is supported by international efforts.

- State-of-the-art modeling technique; definitely advancing the future of energy modeling from predefined components and EMS to component-based, adaptive and advanced controls modeling. The project team is well qualified and has adapted industry standard software tools and techniques for developing Spawn.

- (1) Leverages existing software while expanding capabilities not feasible in existing software.
- (2) The project takes a broad view of both short-term and long-term needs in BEM.

- The project has an excellent traction with users (40,000+). EnergyPlus provides reliable simulations, Spawn provides excellent new opportunities and OpenStudio makes all of these features accessible.

2) **Project Weaknesses**

- As with any project involving fundamental research, this project carries a level of performance risk that is difficult to estimate. The project will require close coordination and oversight from DOE ET management, to ensure progress towards goals is maintained.

- Once developed, the education of industry and modelers will be necessary to have it be used effectively and achieve its full impact potential.

- The complexity of equation-based modeling using Modelica and lack of understanding by the broader energy modeling community pose some uncertainty in the successful adoption of Spawn.

- User buy-in will need to be a key focus of the project. Clearly articulating to users how the transition from E+ to Spawn will be vital. It is not yet clear how that will be accomplish.

- The project should maintain continuity while making the transition from EnergyPlus to Spawn for controls modeling, and this transition creates uncertainty for existing users.

3) **Recommendations**

- This reviewer has identified no significant recommendations to improve this project.
- Include direct collaboration as much as possible; integrate Spawn into university engineering classes and curriculums
- It is important to let the user community know the role of Spawn and its value in addressing advanced simulation needs; most modelers are still in the process of adopting EnergyPlus for their workflows and introducing a variation with more complexity may slow the recent progress with EnergyPlus adoption. Broader education sessions, tutorials and example materials need to be developed and distributed through ASHRAE, IBPSA and other industry groups to help them learn and ease into the adoption of Spawn. Also, any performance issues, licensing needs and technical support needs for Spawn should be well thought out and addressed before taking it to primetime.
- Additional outreach to BEM community to ensure buy-in.
- At the earliest possible time, please, announce a specific timeline and associated steps for the transition of the controls modules.

Project #35513: EnergyPlus

Presenter: Edwin Lee, National Renewable Energy Laboratory
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers strongly approved of this project's approach to improving and increasing the adoption of EnergyPlus, commenting that the approach was strong, forward looking, and engaged a wide group of stakeholders. One reviewer highlighted the project team's well established process for identifying new EnergyPlus features and priorities, and then executing them in an open-source mode, while another remarked that the EnergyPlus features being developed during the current period of performance made sense and were addressing important industry needs.

In terms of project impact, one reviewer described EnergyPlus as a key underpinning of DOE's analysis workflows, commenting further that investments in this project paid dividends far beyond DOE's efforts to improve its own activities. Another reviewer similarly commented that this project was making a significant contribution to the development of a common measurement system for predicting and evaluating the performance of buildings. A third reviewer highlighted that EnergyPlus was foundational to BTO's research, private sector applications, and individual BEM users. Another remarked on this project's significant impact on the adoption of EnergyPlus for all stages of high performance building design analysis, pointing to fact that EnergyPlus had become one of the most widely used BEM tools with over 40,000 downloads.

Reviewers described this project's progress as "good" and "significant," with one reviewer highlighting that every milestone had been met to this point. One reviewer noted that this project was "long term," but also that the project team had created systems and processes to ensure that progress towards long-term goals was maintained. Looking forward, one reviewer acknowledged that the project was likely to extend in "some way, shape, or form" for many years, but they also noted that project work envisioned for the immediate future was logically planned and would continue the project team's effort to expand EnergyPlus' capabilities, uptake, and impact. One reviewer noted that planned activities would help improve EnergyPlus compatibility and support new interfaces and workflow, and called EnergyPlus' planned convergence with the Spawn of EnergyPlus software impressive. One reviewer, however, recommended that the project team also look at ways to help users better understand and resolve error messages, which would help increase user confidence and assure the quality of simulation results.

While one reviewer considered the collaboration and coordination activities of this project to be "adequate given the [project's] large scale," another reviewer called the project "an impressive collaborative effort." Other reviewers shared this second assessment, with one highlighting that the EnergyPlus development team included a large number of stakeholders, subcontractors, and national labs all working together effectively. This reviewer continued by describing how the project's robust teaming model had functioned well over several years, and continued to demonstrate improvements by working with ASHRAE, IBPSA, and other industry organizations.

Weighted Average: 3.80 # of Reviewers: 5
Approach: 3.80 Impact: 3.80 Progress: 3.80 Collaboration/Coordination: 3.80 Remaining Work: 3.80

A. Approach

This project was rated **3.80** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- As a key underpinning of DOE's own analysis workflows, investments in this project pay dividends far beyond DOE's supporting DOE's own metrics. The project has a strong approach which engages a wide group of stakeholders.

- The development team's approach is strong and forward looking, which is necessary due to the long development time associated with simulation engine creation and ever-evolving application needs. They focus on improving execution time, keeping the engine up to date with new building and computing technologies and ensuring its compatibility to support private sector applications, research studies, and service use cases. The features highlighted make sense and address important industry needs.

- Well established process followed by the team to identify features, priorities and execute them in an open source model with agile approaches.

- The project's approach is highly likely to contribute to overcoming barriers, technical challenges, and mitigating project risks because the project has met its milestones every time throughout the project.

- More than two dozen third party software developers use OpenStudio, EnergyPlus, and potentially in the future Spawn. A total of dozen direct engagement with software developers. Engagement with IBPSA and other industry stake holder groups.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.80** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The project, if successful, represents a significant contribution towards supporting a common measurement system adopted by DOE, for both predictions and evaluating the performance of actual (measured) activities.

- EnergyPlus is foundational to BTO supporting research, private sector applications, and individual advanced users. Used in conjunction with supporting tools and the OS API, it is part of a powerful platform for evaluating many aspects of sector, state, utility, or individual building performance. It is a very important tool for meeting BTOs performance goals and advancing the use of modeling by the private sector for realizing building efficiency opportunities by the private sector.

- The EnergyPlus team has contributed effectively with periodic software releases addressing user needs and priorities with significant impact in the adoption of EnergyPlus for all stages of high performance building design analysis.

- The project is highly likely to contribute to the program goal(s) because the software has become one of the most used BEM. The user base is over 40,000 downloads now (excluding downloads within OpenStudio) and is the most widely used engine in research. By improving the software, it will improve the modeling of those users, and therefore their building performance.

- OpenStudio CLI reduced to 124 MB executable, ongoing support for latest EnergyPlus and Radiance. OpenStudio server allows for massive computing via Amazon server for up to 300,000+ simultaneous analyses. GEM creates Std 90.1-2013 Appendix G prototype buildings and baseline automation model. Can now directly make a model for LEED certification.

C. Progress

Based on current project efforts, the project was rated **3.80** for the degree to which the project has met ***project-specific goals*.**

- The project is a "long term" project, and the progress towards meeting DOE's goals is significant. The project team has created systems and processes (agile development, etc) to ensure feedback loops towards larger progress goals are maintained.

- The progress reported is good. The team continues to listen to user and developer needs to prioritize and make progress on new features. The team also has added new features in collaboration with others, which leverages outside expertise and insights on new uses to expand its capabilities.

- Significant bug fixes in two releases, support for EPJson input format and refactoring code to improve processing speed and code maintenance are major accomplishments of the team during this year. These are very significant progress made by the team.

- The project has demonstrated excellent contribution to the project-specific goals by meeting every milestone thus far.

- The integration between OpenStudio, EnergyPlus and Spawn is an impressive task that is on track with regular releases.

D. Collaboration and Coordination

This project was rated **3.80** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The E+ team engages a group of stakeholders involving several labs, several private sector contractors, and several 'touch points' where users and other stakeholders can provide feedback. This reviewer considers the collaboration and coordination activities of this project to be adequate, given the large scale.

- The EnergyPlus development team members comprise an inter-lab collaboration with decades of combined experience working with EnergyPlus. Their specialized expertise in buildings and computer science have resulted in the successful completion of past work plans and enabling EnergyPlus to move beyond research applications to be the modern tool of choice within the industry.

- EnergyPlus development team includes a large number of stakeholders, subcontractors and national labs all working together effectively; this is a robust teaming model functioning well over several years and continues to demonstrate improvements by working with ASHRAE, IBPSA and other industry organizations.

- The project staff demonstrates excellent strategic collaboration or coordination with relevant stakeholders by continuing to expand its users as well as the number of software tools developed based on the EnergyPlus engine.

- This project is an impressive collaborative effort.

E. Remaining Project Work

This project was rated **3.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The project is likely to extend (in some way, shape or form) for many years - the remaining work planned for the next three years represent very significant improvements and changes to current E+ based workflows.

- The remaining project work is logically planned and continues the team's effort to expand capabilities, uptake and impact. The scope identified are consistent with project goals. They will help improve EnergyPlus compatibility and support new interfaces and workflow. The vision for the convergence with Spawn is impressive.

- This is an ongoing project with integration of Spawn, Python based EMS and other high priority feature requests from users.

- The project plans are highly likely to meet the project-specific goals because the improvements (new features, bug fixes, etc.) targeted for the next release EnergyPlus are based on user feedback and will continue to enhance the capabilities of the software.

- The remaining project work is focused on preparing the transition of controls EnergyPlus simulations to Spawn. Specifically, Modelica needs improvements in runtime, so that the simulations can be deployed to SMB building stock. EnergyPlus needs will try novel ways to include users in prioritization of feature development. OpenStudio is focused on enabling introduction of custom controls schemes.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project's key strength include the ability to touch such a wide audience of users (simulation professionals, manufacturers, policy wonks, etc.)

- Past successes demonstrate the ability for the team to expedite further development and commercial deployment. The technical manager's background in computer science, forward looking vision, and ability to extract great, collaborative work from a strong team.

- This project addresses a major energy modeling need in the industry by advancing the simulation engine capabilities to address high performance building design needs. The project team includes industry, academic and national lab experts in the field to provide high quality software tool that sets the standard for energy simulation worldwide.

- (1) The project is based on user feedback, leading to a customer driven product.
- (2) Key stakeholders have been engaged throughout the development process.

- The project has an excellent traction with users (40,000+). EnergyPlus provides reliable simulations, Spawn provides excellent new opportunities and OpenStudio makes all of these features accessible.

2) **Project Weaknesses**

- A key weakness of the project appears to be the ability to manage it from a single point of interest, as multiple, competing interests begin clamoring for limited resources and make prioritization efforts difficult.

- The work requires long term commitment for funding and a supportive administration. It seems to be doing okay though under the current administration but does present risk to the efforts.

- EnergyPlus continues to be one of the challenging modeling tools for the industry practitioners - partly because of the myriad of features and technical background needed to understand and use the tool. In addition to refactoring, the team needs to put more emphasis on simplified documentation for helping users understand the technical background. Though the team is moving from User Voice to Git issues for obtaining feedback, it will be worth considering an annual EnergyPlus user group meeting to get feedback and connect with users directly.

- (1) The decision-making process for selecting new features is not well articulated.

- The project should maintain continuity while making the transition from EnergyPlus to Spawn for controls modeling, and this transition creates uncertainty for existing users.

3) **Recommendations**

- Considering the long term nature of this project, this reviewer finds no recommendation to the project.

- None identified

- One of the most challenging aspect of EnergyPlus is the understanding and resolving error messages (warnings, sever and fatal errors). It is often not well understood when and how users should resolve these to gain confidence and assure quality of the simulation results. Anything the team can do to help will improve this situation will be good. In addition, future refactoring may want to consider creating micro services or modularizing the EnergyPlus modules as components/agents that are used on demand based on the complexity of the model (beyond the Spawn approach).

- None

- At the earliest possible time, please, announce a specific timeline and associated steps for the transition of the controls modules.

Project #35591: Improving Data Center Energy Efficiency through End-to-End Cooling Modeling and Optimization

Presenter: Wangda Zou, University of Colorado Boulder
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Reviewers overwhelmingly agreed with this project's approach to developing holistic modeling and optimization software for data center cooling systems. Reviewers called the approach "impressive" and "innovative," commenting that—if successful—the project would provide value to DOE in several related areas of interest, including (1) establishing strong use cases to encourage the adoption of analysis workflows based on DOE's Spawn-of-EnergyPlus tool and (2) providing real world demonstration of the use of Modelica Building Library-based frameworks to solve vexing energy analysis problems.

Reviewers also strongly agreed on the project's impact, noting the project's potential to significantly reduce energy consumption for data center cooling. Other reviewers commented that this project would positively impact progress towards DOE's energy intensity goals, particularly because the project targeted a quickly growing market that was responsible for an "outsized amount of energy relative to their building size." One reviewer called the project "one of the few…that [could] demonstrate measurable energy savings impact," while another highlighted that the inclusion of a strong commercial technology partner increased the likelihood that research results would be commercialized.

On the topic of partners, reviewers commented that the project team had demonstrated excellent strategic collaboration and coordination with relevant stakeholders, and that this collaboration was well organized and highly effective. One reviewer remarked that the project had assembled a strong Technical Advisory Group (TAG) to help refine project scope and review project progress, describing the TAG's membership as cutting across several key disciplines. Another reviewer described this project as an outstanding example of technology transfer from academic researchers and national labs to industry.

Reviewers described the project's progress to-date as "outstanding." One reviewer commented that project had demonstrated excellent contributions to project-specific goals, while another highlighted that the project team had already completed all the model development work along with implementation and testing in two different data centers. One reviewer remarked that, moving forward, the project also appeared well positioned for the next phase of the work plan. Another reviewer similarly described the project as being well managed from both technical and operational performance perspectives, expressing confidence that the project team would be able to deliver the remaining project milestones and deliverables both on time and on budget.

Weighted Average: 3.82 # of Reviewers: 5
Approach: 4.00 Impact: 3.60 Progress: 3.80 Collaboration/Coordination: 3.80 Remaining Work: 3.80

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project demonstrates an innovative approach which, if successfully executed, promises to provide value to DOE in several related areas of interest - specifically in establishing strong use cases for migration / adoption of Spawn based analysis workflows. The project provides necessary component models and the validation of their usage in such a way that it is likely practitioners will 'trust' the outcomes and integrate the project's software deliverables in their own practitioner based analysis workflows.

- The project leverages and contributes to the development of the Modelica Building Component Library to create various data center cooling system component models. The models are linked to an optimization engine to identify optimal control strategies. The approach also incorporates fast fluid dynamic modeling and other techniques to greatly speed up simulation run time. The impressive approach achieves a fast and self-learning model to support optimized airflow management.

- The project team has identified the optimization of air flow management and cooling system operation as critical for improving data center energy efficiency. Modelica models are used to evaluate control optimization scenarios to accomplish the energy efficiency goal.

- The project's approach is highly likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. The project has been designed into independent tasks, identified willing and active partners for data collection and potential implementation of project results.

- The project is developing a toolkit for datacenter energy use optimization. The approach is based on a holistic tool to connect data management, all the way to the datacenter design and operation. Optimize cooling system operation, airflow management operation, link airflow part to the equipment part. Target is 30% energy savings. 21 billion of kWh annual savings. All tools to be open source software to allow improvement of data center operation.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Given the prevalence of electricity consumption related to cooling data center equipment, if the project succeeds it has the capability to positively impact progress towards meeting DOE's energy intensity roadmap goals. The inclusion of a strong commercial technology partner (Schneider Electric) in this project increases the likelihood that the research results will be commercialized.

- Data centers consume 2% of US electricity use with ½ of this use attributed to cooling. The modeled results from the project indicate cooling system savings in the range of 25% to 55% are possible from deployment of the data center air flow management tool.

- The results of this project are likely to save 30% of cooling energy in data centers, with a projected annual energy savings of about $593 million in 2020. This is very significant and is one of the few projects that can demonstrate measurable energy savings impact.

- The project is highly likely to contribute to the program goal(s) because it targets a quickly growing market (data centers) that is responsible for an outsized amount of energy relative to their building size. The project has also made significant progress to date.

- Working with actual datacenter operators, ASHRAE TC, and a broad stakeholder groups. The industrial partner is the largest datacenter infrastructure provider (Schneider), so the project results have ready set of users. The baseline for the project savings is based on measured data, proposed savings based on the model (30%).

C. Progress

Based on current project efforts, the project was rated **3.80** for the degree to which the project has met ***project-specific goals.***

- The project PI provided a strong project management plan and a grasp of potential technical challenges and managerial issues that the project may encounter during the remaining performance periods. This peer reviewer has a strong degree of confidence that the project team is capable of completing the project both on time and on budget.

- In project year 2, the team has created the system, CFD, optimization modeling components necessary analyze the savings potential for two data centers based on actual performance data. The range of savings exceeds the project target. Also in completing the project, the research team has made noteworthy contributions to Modelica – including creating ~ 80 new system model templates, providing graphic models, and enabling users to build their own systems. Also, the PI resolved administrative hurdles involving delay of payment, which kept the project moving forward.

- Though the Principal Investigator moved to a new academic institution, he was able to continue to make significant progress and complete all the model development work along with implementation and testing in two different data centers.

- The project has demonstrated excellent contribution to the project-specific goals to date. Stakeholders have been identified and engaged successfully. 81 Modelica models have been developed, demonstration projects have been identified and initial results have been created.

- The progress is outstanding, especially considering that the PI change the university during the second year of project execution.

D. Collaboration and Coordination

This project was rated **3.80** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- This reviewer believes that the project team does include sufficient partners and resources for project feedback to be provided and for the overall project goals to be met. The project has assembled a strong Technical Advisory Group, whose membership cuts across several key disciplines and who meet actively to provide feedback on refining project scope and reviewing project progress. This reviewer feels that the project is well positioned to leverage the collaboration and coordination efforts that have been initiated by the project team.

- The project's collaboration and coordination plan includes working with a TAG of key stakeholders, engaging with data center operators, designers, and consultants as well as conferring with experts from government and ASHRAE.

- This project is a collaboration between academic researchers, national lab staff and industry partners. Such collaborations are rare and this project could be an outstanding example of technology transfer from academic/national lab to industry to commercialize innovative optimization and control techniques for improving data center efficiency.

- The project staff demonstrates excellent strategic collaboration or coordination with relevant stakeholders, including the company with the largest data center infrastructure provider in the US and found 2 facilities for case study testing.

- The collaboration among the partners to include the university, national lab and company is well organized and highly effective.

E. Remaining Project Work

This project was rated **3.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The project appears to be well managed from both technical and operational performance perspectives. The project PI has sufficient combination of education and experience, and appears to be well managing the project in order to maintain expected progress and produce on-time deliverables. This reviewer expresses no issues related to the potential of the project team not being able to deliver the project milestones and deliverables both on time and on budget.

- The project appears well positioned for the next phase of the workplan, which includes Implementing and validating the Modelica-ISAT-FFD models for data center airflow management and demonstration at the two partner data centers. In addition, the project's partnership with Schneider Electric helps ensure the success of the follow-on market strategy and commercialization plan.

- This project is in the year 2 demonstrating air flow management optimization and validation. Based on this success, it is very possible to continue to complete the remaining tasks and commercialization efforts in the remaining project performance period.

- Given the progress to date, project plan, and interest from stakeholders, the project plans are highly likely to meet the project-specific goals.

- The remaining work for the last year in half of the project execution is on track. The Modelica models are reusable as they are released in a library. New optimization sequence for a water side economizer. Future development of editors for HVAC controls models.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project provides real world demonstration of the use of Modelica based framework to solve energy analysis problems which have stymied energy analysis professionals for many years. Successful execution and documentation of this framework will provide a solid business case for the use of other frameworks that DOE / BTO is also investing in - specifically the Spawn framework.

- The project's biggest strength is the project team. It embodies critical expertise in the several areas of specialized modeling that are required for the successful realization of the project goals. The team also shows commitment and tenacity in overcoming DOE administrative challenges.

- High impact project with great potential for technology development and industry partnership for commercialization. Well proven technologies and highly reputed academic/national lab researchers leading the effort developing software tools and optimization models that can be incorporated in simulation tools.

- (1) Well designed and executed
- (2) Targets a key, relatively new, but quickly growing building sector. Success could have an outsized impact on energy consumption moving forward.
- (3) Project has received buy-in from stakeholders.

- The project strength is in the clear application for the Modelica-based optimization of datacenter performance.

2) **Project Weaknesses**

- A weakness of the project which may exist (it was not explicitly discussed as part of the Peer Review Presentation) are the details surrounding the Intellectual Property Management (IMP) Plan - it was not clear if this plan was meant to protect the results of this research (are cost share partners expecting to claim IP on these results) or if the IMP was more of a vehicle allowing data sets to be collected from 'others' and used as a part of conducting the project research. This should be clarified, as it is in DOE/BTO's interest to make publically available the results of government funded research to the maximum degree possible.

- None identified

- None.

- (1) Reliant on stakeholders to implement proposed energy conservation measures.

- The project should generate case study data for an implemented version of the Modelica-based controls algorithm in an actual datacenter.

3) **Recommendations**

- This reviewer would recommend that upon completion of this project (which covers modeling chilled water and DX cooling systems) the PI expand the work to include support for evaporative cooling methods. It would seem to be in DOE/BTO's interest to support follow on research such as this, as many large data center facilities are located in areas which use evaporative cooling technologies as key components.

- This is a minor consideration not really within the scope of work of this work. The project would benefit from increased use and disclosure of data center performance metrics. This could spur additional market interest and support identifying data centers with the highest savings potential.

- None.

- None

- N/A

Project #99160: Accelerating Energy Savings in Commercial Buildings with CBES & Lucid

Presenter: Tianzhen Hong, Lawrence Berkeley National Laboratory and Josh Wentz, Lucid
DOE Manager: Amir Roth

Brief Summary of Reviewer Comments

Most reviewers found value in this project's approach to extending the functionality of Lawrence Berkeley National Laboratory's (LBNL) Commercial Building Energy Saver (CBES) Pro software and further integrating it with Lucid's BuildingOS. These reviewers commented positively on the ways that this project leveraged and combined the capabilities of two different tools to provide enhanced retrofit analysis services—with an improved user interface—to a larger population of buildings. One reviewer, however, was very critical of the approach, remarking that it appeared to conflict with parallel investments in other DOE tools while "help[ing] a private sector commercial company achieve…short and medium term goals." Consequently, this reviewer found it difficult to see how the approach contributed to meeting national energy efficiency goals. Another reviewer similarly cautioned that it was important to ensure that LBNL's efforts to provide benefit to Lucid through this project were in balance with the public benefit that resulted from such engagement.

Most reviewers felt that this project was likely to have significant impact, with the enhancements made to CBES enabling Lucid's BuildingOS to tap into its large building database to identify new efficiency opportunities. One reviewer commented that the project was likely to contribute to BTO's program goals because it could provide stakeholders with an initial "reality check" of potential savings from energy conservation measures. Another reviewer, however, felt that DOE funding would have had a greater impact if it had been invested in DOE's own data tools rather than CBES, a LBNL licensed product; this reviewer was also unclear about the benefit to DOE from investments that improved Lucid's "ability to impact their customers."

All reviewers agreed that this project was making good progress, with one commenting that the project team had demonstrated a well thought-out plan and schedule for completing the project's goals on time and on budget. Reviewers also observed that the two primary stakeholders in this effort, Lucid and LBNL, were working well together in developing project deliverables. Given these assessments, reviewers agreed that the project's overall scope was reasonable, that remaining project work seemed achievable within the remaining project timeline, and that the project team was therefore very likely to meet project-specific goals.

Weighted Average: 3.26 # of Reviewers: 4
Approach: 2.75 Impact: 3.00 Progress: 3.50 Collaboration/Coordination: 3.75 Remaining Work: 3.75

A. Approach

This project was rated **2.75** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- From a DOE investment perspective, this project appears to conflict with parallel investments being made by DOE BTO towards improving the DOE Commercial Asset Score Tool. As such, while this project does appear to help a private sector commercial company achieve it's short and medium term goals, it is difficult for this reviewer to see how the approach taken provides DOE with any progress towards meeting national energy efficiency goals without diluting the limited DOE BTO investment dollars that are available.

- The project approach leverages Lucid's desire to develop a scaled retrofit application tool to expand CBES capabilities, while addressing interconnection issues and honing the tool supported workstream.

- Makes use of LBNL developed technology for commercial buildings and adds a compelling user-interface to help building owners and operators identify and prioritize energy saving opportunities.

- The project's approach is likely to contribute to overcoming barriers, technical challenges, and mitigating project risks. The project plan has already led to significant progress, including one of the most complicated task of developing the CBES Engine REST API to make all the tools interoperable.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The project does demonstrate a collaborative project between private industry and a national lab. However, the inclusion of DOE funds to improve the performance of a LBNL licensed product (CBES Pro), seems to this reviewer to be a poor use of DOE BTO funding dollars, as other investments which do not improve lab licensed products such as CBES would likely have far greater impact. This reviewer feels that LBNL has improved the functionality of CBES, improving their ability to positively impact subsequent adopters of CBES - both licensees of CBES Pro and consumers of CBES. It is this reviewers opinion that unless significant resources are directed towards CBES, it is not likely to have the impact that the DOE Asset Score will have, with respect to market adoption. Speaking from the perspective of a software developer, this project allows Lucid to have tighter and better integration with the full functionality of CBES-Pro, which improves Lucid's ability to impact their customer. The benefits to DOE, however, are not clear. For example, it was not clear if or how Lucid might be able to track and report on the tools usage, such that it might be able to attribute impact to the specific features that this project improved upon.

- The CBES expansion, enhancements, and RESTful APIs will enable Lucid's BuildingOS to tap into its large building database and identify efficiency opportunities.

- This project is likely to have great impact similar to the popularity of benchmarking tools. By providing pre-analyzed building models and savings potential, users will benefit from quick analysis and recommendations without investing much resource and time.

- The project is likely to contribute to the program goal(s) because the end result will be able to provide stakeholders with an initial "reality check" of the potential savings and costs. DOE tools will be made more accessible to the building sector through the CBES.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals*.**

- The Peer Review presentation demonstrated a well thought-out plan and schedule for completing the project's goals on time and on budget. The one year performance period seems realistically matched to the staffing and deployment plan.
- The team is making good progress. The CBES APIs and Interface design are complete and integration into BuildingOS is well underway with alpha version pending.
- The team has made significant progress with implementing a Rest API access for Building OS to access the CBES data, additional models and measures to cover new building types, and user-interface design.
- The project has demonstrated significant contribution to the project-specific goals, including completion of a functioning CBES REST API and progress on the remaining tasks to complete an alpha version of the software.

D. Collaboration and Coordination

This project was rated **3.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The technology stack related to this project limits the stakeholders to Lucid and LBNL CBES project team. The Peer Review presentation demonstrated that the two parties were working well together in developing project specific goals, mockup UI, etc. This reviewer has no concerns about the project team's ability to collaborate and coordinate with stakeholders.
- Through the partnership and cost share, LBNL is adding enhancements to CBES and Lucid is expanding the capabilities of its freely shared tool and creating a new revenue stream. The two efforts will help expand capabilities and access to energy saving modeling applications.
- The project team appears to be well coordinated between industry and national lab, making significant progress in knowledge transfer and software development.
- The project staff demonstrates excellent strategic collaboration or coordination with relevant stakeholders, including existing customers, planned stakeholder meetings to demonstrate the tool, and presentations at appropriate conferences.

E. Remaining Project Work

This project was rated **3.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- As demonstrated during the Peer Review presentation, the remaining project work seems achievable within the remaining project timeline.
- The work appears well planned with reasonable scope. It's good to see the list of multiple stakeholder engagements and future plans to continue the LBNL/Lucid collaborations.
- The project team is well along the way in completing the tool for deployment by end of July with webinars and outreach plans for early Sept 2018.

- The project plans are highly likely to meet the project-specific goals because of the progress to date on all tasks associated with the components of the final product and the planned stakeholder and engagement over the next year.

F. Additional Comments and Recommendations

1) **Project Strengths**

- This reviewer found it difficult to point out the project's strengths - as it appeared that this project might not be suitable for DOE funding in the first place because of the overlapping nature of capabilities that also exist within the DOE Commercial Energy Asset Score Tool. One strength that is an outcome from this project might be the skills obtained and procedures developed as part of the successful demonstration of a lab (LBNL) working as a technology integrator with a private sector company (Lucid).

- The commitment of the project team members, the LBNL expertise, and the Lucid access to clients and buildings.

- A truly unique collaborative project between industry and national lab with a simple and valuable tool for building retrofit analysis.

- (1) Provides greater accessibility to DOE tools to stakeholders.
- (2) Demonstrates how public-private partnerships can be designed and lead to a useful final product.

2) **Project Weaknesses**

- This project seems like it might have been better situated to a CREDA or other type of contract vehicle describing work to be done directly between LBNL and Lucid (i.e. without DOE involvement). It seems that the project has delivered a very limited set of value to DOE 9a set that is not available elsewhere in the DOE ecosystem of supported tools, such as the DOE Commercial Energy Asset Score Tool. From that perspective, this does not seem to be a wise investment of limited DOE resources.

- Not sure if this is a weakness but it is important to ensure that LBNL's efforts to provide benefit to a particular client are in balance with the public benefit that results from such an engagement.

- None.

- None

3) **Recommendations**

- This reviewer would not recommend addition DOE funds be used to improve this project.

- Highlight how the new capabilities can be leveraged by practitioners and service providers to provide similar services.

- Excellent work, good luck to the team.

- None

Emerging Technologies
Sensors and Controls

Adaptive and Autonomous Controls

Project #312117: VOLTTRON Compatible Whole Building Root-Fault Detection & Diagnosis

Presenter: Jin Wen, Drexel University
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers generally agreed with this project's approach in developing an automated whole-building fault detection and diagnosis (AFDD) tool. One reviewer observed that the project investigated only a small number of building faults, but commented that the scope is sufficient given the amount of DOE funding provided. This reviewer also commented positively on the project's utilization of undergraduate students as researchers, highlighting the project's engagement with students from different disciplines, its development of hardware and software tools for educational purposes, and its integration of research into coursework as strengths. Another reviewer similarly remarked that, given the project's small size, its technical approach is sound. However, this reviewer also commented that the project team spread itself too thin in its scope, and questioned the added value of utilizing VOLTTRON as an execution platform since it is not a commercialized product or industry standard at this time.

Reviewer comments were mixed in regards to project impact. One reviewer commented that the project is likely to contribute to BTO's goal of achieving 30% energy savings by 2030 from HVAC-based AFDD in the commercial sector. In contrast, however, a different reviewer remarked that the project's impact on workforce development—a primary objective of the project—was not clear, questioning the exact roles that undergraduates played in the research effort.

One reviewer described the overall progress made as outstanding given the project's small budget and reliance on undergraduate students. However, another reviewer questioned whether the accuracy and false alarm rate targets achieved are good enough, and was unclear about the next steps for technology development now that the project has been completed.

One reviewer was impressed by the project's level of collaboration by highlighting the involvement of multiple principle investigators in different geographic locations and the variety of organizations involved. Another reviewer, however, commented, that the team demonstrated only modest collaboration with the relevant team members.

Weighted Average: 2.98 # of Reviewers: 3
Approach: 3.00 Impact: 3.00 Progress: 3.33 Collaboration/Coordination: 2.67 Remaining Work: N/A

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The scientific approach on the technical side - using PCA etc. to develop FDD methods - is sound enough for a small project like this. Since they are collecting data from buildings with real faults to get ground truth data, that is also really useful.
- The value of the VOLTTRON - based FDD app(s) developed will depend on whether VOLTTRON becomes the industry standard. Since that is not sure yet, and since this project has a very small budget, the use of VOLTTRON seems like a distraction to me.

- The project approach includes developing AFDD strategies that can handle whole building datasets with high data dimensionality. Bayesian Networks are used for fault diagnosis. The project approach is likely to contribute barriers, technical challenges, and mitigating project risk. Are artificial faults physically introduced in the investigated buildings or just done in simulation environments? A small set of faults is investigated. Compare to the amount of funding provided by DOE, the scope of work is very sufficient.

- None.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Given that the main goal of the program was to involve UGs in research and not real technical advancement, it is not clear to me what is the impact on that front is. The PI deserves kudos for involving several UGs in such a small project, but it is not clear what their involvement was and what they learned from the project. Did the project actually achieve the "for workforce development" objectives, and if so, by what measure?

- If the project goals are met, the project is likely to help to achieve BTO's goal of achieving 30% energy savings by 2030 from HVAC-based AFDD in the commercial sector.

- Project goals should be quantitative.

C. Progress

Based on current project efforts, the project was rated **3.33** for the degree to which the project has met ***project-specific goals*****.**

- Given the small budget - and the constraint on being mostly reliant on UGs - the progress made is outstanding

- The project has demonstrated contribution to the project-specific goals.

- Good to see the accuracy and false alarm rate, but are they good enough?

D. Collaboration and Coordination

This project was rated **2.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- I am impressed by the collaboration, involving multiple PIs at different locations, FFRDRCs and industry, especially in the context of the small budget.

- The project staff demonstrates modest collaboration with relevant stakeholders.

- Next steps for the team/tech are unclear.

E. Remaining Project Work

This project has ended, and therefore was not rated for the degree to which the project had logically planned remaining work to meet the ***project-specific goals*.**

F. Additional Comments and Recommendations

1) **Project Strengths**

- Involvement of UGs, creation of ground truth fault data from buildings, evaluation of FDD methods against that dataset, strong collaboration with several stakeholders.

- Develop AFDD tool through statistical process control and machine learning methods.
- Engage students from different disciplines.
- Develop hardware and software tools for educational purposes.
- Integrating Research into coursework

- Interesting use case of VOLTTRON

2) **Project Weaknesses**

- The only weakness I see is that the project is spreading itself too thin, by trying to do too many things.

- Small set of faults is investigated.

- Not much distinguishes it from other AFDD projects.
- Is the accuracy good enough?

3) **Recommendations**

- Since it is already over, there is no point, but if the team were do it again, I'd recommend focusing on coming up metrics for UG workforce development and dropping the VOLTTRON part.

- N/A

- Clearly state processes that are not automated.
- Develop next steps.

Project #32438: Enhanced Cloud-Based Control System for Small Commercial Buildings (NorthWrite)

Presenter: Michael Brambley, Pacific Northwest National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Multiple reviewers agreed that the project approach for laboratory validation and field-testing of automated fault detection and diagnostic (AFDD) solutions for packaged rooftop units (RTU) in small commercial buildings is likely to contribute to overcoming relevant barriers and technical challenges. Multiple reviewers agreed that the project will contribute to meeting BTO's 2030 goal of 30% energy savings from AFDD in advanced and autonomous controls for the commercial sector. Multiple reviewers also noted that this project will facilitate adoption in the underserved small commercial buildings sector, and could enable significant amounts of savings in whole building energy consumption. One reviewer commented that while the project goal was to enable roughly 15% savings in whole building energy consumption, the project team did not confirm those savings in the presentation. Furthermore, the commercialization pathway through the small business partner, JouleSmart, to achieve these savings was unclear for one reviewer.

Multiple reviewers commented that the project was well planned and on schedule. One reviewer commented, however, that because there are only three months remaining, they would have liked to see more progress made. Another reviewer expressed that written documentation should include information on how successful the AFDD algorithms are in addition to how they are tested. All reviewers noted that the collaboration between JouleSmart and Pacific Northwest National Laboratory is strong, but one reviewer felt that the work distribution by performer was not clearly presented. A few reviewers commented that the remaining project scope appears appropriate and likely to be completed, but one reviewer was unclear on how well documented and universally presented the project's pseudo-code will be for the community at large. Another reviewer commented that the team should test the proposed algorithms in a larger set of different HVAC system types.

One reviewer highlighted that the project's focus is on the commercialization of methods previously developed under a separate award, complimenting this arrangement—whereby BTO initially funds early-stage technical solutions and then partners with industry once the solutions have reached some technological maturity and are ready for exploration into commercialization pathways.

Weighted Average: 3.40 # of Reviewers: 4
Approach: 3.25 Impact: 3.50 Progress: 3.25 Collaboration/Coordination: 3.75 Remaining Work: 3.25

A. Approach

This project was rated **3.25** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is quite sensible: PNNL works with JouleSmart to give them algorithms in pseudocode form, but JouleSmart is in charge of implementing the altos. And, PNNL provides test data with faults against which JouleSmart's implementation can be verified against. So the project provides a best of class vehicle for the PNNL developed FDD algorithms to be transferred to the industry.

- Provide technical assistance to small business partner (JouleSmart) in implementing three sets of AFDD algorithms previously developed through BTO funding and focused on operational improvements into the partner's analytics platform
- Formally document algorithms in pseudo-code and make publicly available for use by other interested energy and load management service providers
- Validate algorithm performance and accuracy through laboratory tests on a specially-equipped and instrumented representative RTU at PNNL
- Provide technical support to JouleSmart in interpreting unexpected results and other issues during initial installation and deployment in real world, operational buildings
- I agree that AFDD will save energy. However, the goal is to save 15% whole-building energy by applying AFDD algorithms for RTUs. The presentation shows 45% of whole building energy use is from HVAC systems. If 15% is applied for whole building, it is equivalent to 35% of HVAC system energy saving alone. It seems too big and may not be accomplished. I don't think AFDD alone will reach this goal.

- The project approach includes providing technical assistance to small business partner (JouleSmart) in implementing three sets of AFDD algorithms, documenting algorithms in pseudo-code and make publicly available for use, and validating algorithm performance and accuracy through laboratory tests. This approach is likely to contribute to overcoming barriers, technical challenges, and mitigating project risk.

- The following are the most valuable aspects of the approach:
    - The pairing of JouleSmart with PNNL is appropriate and should prove valuable.
    - The team has significant past experience working with RTUs, sensors, and AFDD.
    - The algorithms of interested are reasonably well defined.
- The following aspects of the approach seemed superfluous or could use improvement:
    - The approach descriptions lacks quantitative detail.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- It will directly impact BTO's goal of commercialization of BTO funded research.

- Documented and tested AFDD algorithms for rooftop packaged HVAC systems will:
- Facilitate adoption in the underserved small commercial buildings sector.
- Enable ~15% savings in whole building energy consumption or 1.0 quad primary/year from proper implementation of AFDD algorithms and repair of faults found.
- Inform future research and development (R&D) to overcome limitations identified in the field that will contribute to meeting BTO 2030 goals of 30% energy savings from AFDD in advanced and autonomous controls for the commercial sector as a whole.
- I am not clear to understand how to conclude " Enable ~15% savings in whole building energy consumption ". Please provide detailed calculation procedures and make realistic estimation.

- If the project goals are met, the project will help to contribute to meeting BTO 2030 goals of 30% energy savings from AFDD in advanced and autonomous controls for the commercial sector as a whole. The tested

AFDD algorithms will facilitate adoption in small commercial buildings sector and may enable significant amount of savings in whole building energy consumption.

- The following are the most valuable aspects of the impact:
    - There is a clear need for technology to help small commercial buildings become more efficient. AFDD in RTUs will address that impact.
- The following aspects of the impact seemed superfluous or could use improvement:
    - The path forward for JouleSmart to commercialize this technology is unclear.
    - The project does not necessarily address existing RTUs, as retrofit would likely be too expensive. However, such a task could easily be a whole other project.

C. Progress

Based on current project efforts, the project was rated **3.25** for the degree to which the project has met ***project-specific goals*.**

- Since there are only 3 months remaining for the project, I wish a bit more progress had been made, especially since this project did not involve any scientific research, but testing and validation of existing scientific results.

- Three sets of AFDD algorithms selected for deployment by JouleSmart fully documented in the form of pseudo-code.
- Modified the exhaust air damper of the test-RTU to allow for maximum achievable outdoor-air fraction.
- Testing completed on two of the three sets of AFDD algorithms except for testing requiring warmer outdoor conditions to detect an economizer fault.
- Testing of third set of AFDD algorithms will be underway in May 2018.
- From the project plan and schedule, everything seems on schedule.

- The project is well planned and the current project efforts lead to significant contribution to the project goals.

- The following are the most valuable aspects of the progress:
    - The test set-up is a valuable tool for testing such algorithms, and PNNL was a good partner to develop such an apparatus.
- The following aspects of the progress seemed superfluous or could use improvement.
    - The progress report should include how successful the algorithms are, not just that they were tested.

D. Collaboration and Coordination

This project was rated **3.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The only relevant collaboration is with JouleSmart, and the PNNL team seems to have an excellent collaboration with them.

- Through EERE SBV program, PNNL provided technical assistance to small business stakeholder, NorthWrite (now JouleSmart).
- Algorithms selected by JouleSmart tested by PNNL with results reviewed by JouleSmart.
- JouleSmart responsible for implementing algorithms into their commercial platform to provide enhanced services to their customers.
- Algorithms will be made publically available at the conclusion of the project.
- Collaboration and coordination performs well.

- Very significant partnership between PNNL and small business stakeholder (JouleSmart). The PNNL team has tested the algorithms selected by JouleSmart. This collaboration will lead to produce implementable and practical algorithms which will publically available.

- The following are the most valuable aspects of the collaboration or coordination:
    - The fact that PNNL is modifying source-code on commercial RTUs for AFDD is impressive and a valuable step forward to move previous research by PNNL towards market.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - Besides the cost-share, it's unclear how invested (e.g. intellectually and development pathways) JouleSmart is in the AFDD algorithms.

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- N/A

- One more test of the third set of AFDD algorithms will be underway in May. The remaining work will be Milestone 9: Final report preparation.

- The remaining project work includes testing and validation of the third set of AFDD algorithms, technical support to JouleSmart to implement algorithms in their cloud-and device-based platforms and software implementation, post pseudo-code of developed algorithms in public, and etc. The project plans are likely to meet the project specific goals

- The following are the most valuable aspects of the Remaining Project Work:
    - It is great to see PNNL technology implemented in commercial hardware and cloud services.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - The project work description fails to describe quantitative metrics that the testing should achieve.
    - It's unclear how well documented and universally presented the pseudo-code will be for the community at large.

F. Additional Comments and Recommendations

1) **Project Strengths**

- I am glad that the BTO is funding work like this, where the focus is on commercialization of methods developed previously under its award. Often I see the BTO focused too much on commercialization as part of the original method development projects. That is short sighted since sometimes when there is significant technical hurdles to cross to develop the method to solve a problem (FDD, for instance), the team ends up spreading itself too thin on trying to do both - technical work and commercialization - within the short horizon of a project. It is better for BTO to fund projects to develop methods first, perhaps still requiring involvement of industry to ensure that the methods are relevant to the industry, but then fund commercialization projects separately when the technical solutions have reached some maturity.

- Provide good document of AFDD algorithms for dissemination.
- Good collaboration with JouleSmart.

- Successfully deployment of FDD algorithms for packaged rooftop units (RTUs) in in laboratory conditions with a significant whole-building energy savings.
- Possible implement algorithms in the cloud-and device-based platforms.

- Project partner and commercialization pathway of previous PNNL research.
- The test apparatus is impressive and should prove valuable.

2) **Project Weaknesses**

- I wonder why after decades of work on FDD, a lot of out funded by BTO, why there is there need to generate test data as proposed in this project? Shouldn't such data already exist? Perhaps BTO can learn from this project and ensure that such test data is generated and curated as part of future projects? (this last comment is directed at the BTO, and not to the project PIs)
- AFDD alone may not reach DOE goal to save 15% of whole building energy consumption.
- Need to test the proposed algorithms in large set of different HVAC system types.
- It is unclear what work was done by PNNL vs JouleSmart.

3) **Recommendations**

- N/A
- Demonstration is needed to show capability to reach the project goals after performing AFDD.
- Test the proposed algorithms in in a large set of real HVAC systems (different size, types, applications, etc.)
- Ensure that the objectives that PNNL is meeting are very well aligned with internal business plans of JouleSmart.

Project #32601: Automated Fault Detection and Diagnostics Data Curation and Benchmarking

Presenter: Jessica Granderson, Lawrence Berkeley National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Most reviewers agreed that this project's approach of developing public testing procedures and data sets for evaluating the performance of automated fault detection and diagnostic (AFDD) solutions from both industry and the research community will likely contribute to overcoming relevant adoption barriers and technical challenges for AFDD applications in the buildings sector. One reviewer, however, that this type of benchmarking does not exist after decades of research on FDD. Several reviewers also expressed concerns with the broad nature of the project's scope. One reviewer recommended that the project team should focus on either creating a test facility for benchmarking commercial AFDD solutions or developing a dataset for AFDD research testing, but not both. Another reviewer was concerned with the ability to provide a uniform comparison amongst products that remain relevant due to continual developments and advancements in products without funding the project in perpetuity.

Reviewers generally agreed that the team has made great progress, and expect that future work will likely meet project-specific goals. One reviewer, however, expanding the focus beyond chilled water variable air volume systems and a small set of faults. Another reviewer noted that the anticipated project impact is not quantitative in nature and the presentation did not address trade-offs or sub-markets. Multiple reviewers commented positively that this project is creating public datasets that could enable uniform comparisons of various FDD products, but one reviewer questioned whether the resulting data will be similar to the MIT load disaggregation dataset, while another reviewer cautioned that the project team needs to ensure the dataset remains available to the public after project completion.

Most reviewers positively commented on how the national labs are working together without duplicating efforts. One reviewer felt that the project needs to have other relevant stakeholders and industry experts more heavily involved in the development of the test procedures and benchmarking beyond the technical advisory group. Another reviewer noted that collaborations should be expanded to include large hardware manufacturers. One reviewer commented that Berkley Lab's FLEXLAB appeared to be a powerful facility for testing AFDD algorithms, but they also wondered if FLEXLAB was the only test site, and whether it covered sufficient breadth of the AFDD problem. Another reviewer was unclear about whether the project team will be providing the benchmarking or if commercial partners will come to the lab to benchmark on the lab's testing equipment.

Weighted Average: 3.14 # of Reviewers: 4
Approach: 3.25 Impact: 2.75 Progress: 3.25 Collaboration/Coordination: 3.00 Remaining Work: 3.50

A. Approach

This project was rated **3.25** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The idea of using the controlled environment of the flexlab to get data for testing FDD algorithms is a sound one. The technical approach sounds good, but it is somewhat surprising to me that even after decades of work on FDD (some funded by the BTO), the project's approach sounds like something that would be adopted had there been no progress at all in this direction.

- Conduct R&D to define AFDD characterization framework, assess state of technology.
- Develop public procedure and data sets to performance test AFDD algorithms.
- Apply to benchmark AFDD solutions from industry and research.
- Make available to public for replication and ongoing use (longer-term).
- Leverage TAG to engage stakeholders, inform and guide the work.
- These good approaches are expected to reach project goals completely.

- The project approach includes conducting R&D to define AFDD characterization framework, developing public procedure and data sets to performance test AFDD algorithms, applying to benchmark AFDD solutions from industry and research, and making available to public. The project' approach is likely to contribute barriers, technical challenges, and mitigating project risk.

- The following are the most valuable aspects of the approach:
  - Benchmarking AFDD will be a valuable resource to the community.
- The following aspects of the approach seemed superfluous or could use improvement:
  - The approach to AFDD benchmarking is not described well, nor is the SOA.
  - AFDD is a very wide problem, and the scope of the project is not adequately set.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.75** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Good likely impact, especially due to the public FDD dataset the project will make available.
- One of the goals of the project to provide a uniform comparison among many FDD providers' products. But since FDD products will continually change, I don't understand how to get around that. The PI also acknowledged that problem. So it seems like BTO will have to continue to fund a project like in perpetuity.

- Project connects ET and CBI goals in AFDD technologies.
- Provides tests, benchmarks to guide R&D innovation and evaluate achievement in consistent uniform manner.

- If the project goals are met, the project may help to contribute to meeting BTO 2030 goals from AFDD by providing tests, benchmarks to guide R&D innovation and evaluate achievement in consistent uniform manner. The project connects ET and CBI goals in AFDD technologies.

- The following are the most valuable aspects of the impact:
  - Benchmarking and understanding tradeoffs in existing AFDD solutions is an important first step to developing the next generation of AFDD algorithms.
- The following aspects of the impact seemed superfluous or could use improvement:
  - Impact is not quantitative, nor does it address trade-offs or sub-markets.

C. Progress

Based on current project efforts, the project was rated **3.25** for the degree to which the project has met ***project-specific goals*.**

- N/A

- AFDD Tool Characterization
- Performance Testing Procedure
- Testing Procedure Options
- Testing Procedure Options
- Initial Experimental Data Curation & Vetting in LBNL's FLEXLAB
- Made great progress to reach project goals

- The project is well planned and the current project efforts lead to significant contribution to the project goals.

- The following are the most valuable aspects of the progress:
    - The FLEXLAB looks like a powerful facility for testing AFDD algorithms, since they can integrate faults.
- The following aspects of the progress seemed superfluous or could use improvement.
    - Is the FLEXLAB the only test facility used for benchmarking? Does it cover sufficient breadth of the AFDD problem?
    - The risk aspects of false-positives and false-negatives are not addressed.
    - It is unclear why condition, behavior, and outcome based approaches are explicitly considered when developing a testbed that should be agnostic to the approach.
    - Target AFDD applications are unclear.
    - Data management was mentioned as a barrier to scale; however, this may be a social barrier, it is no longer a technical barrier as many cloud solutions exist.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Excellent, multiple national labs are involved but without duplication of effort: the unique capability of each lab is utilized.

- Four national labs work together.
- A decent technical advisory group.

- This multi-lab collaborative work includes partnership between NREL, ORNL, LBNL, and PNNL. This project needs to have relevant stakeholders and industry experts to be heavily involved in the development of test procedures and benchmark (not just on advisory board or TAG).

- The following are the most valuable aspects of the collaboration or coordination:
    - Team has a breadth of collaborators.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - Collaborators are mainly small companies in the software space. In order to penetrate the market, collaborations with large hardware manufacturers are required. Or a strong plan is required for a software only approach.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- N/A

- Synthesize existing data, expand data set.
- Document test procedure, share data set with public.
- Use data and procedure to evaluate AFDD algorithms.
- Disseminate, build awareness, ongoing use by others.

- The remaining project work includes synthesizing existing data, expanding data set, documenting test procedure, evaluating AFDD algorithms, and disseminating the results. The project plans are likely to meet the project specific goals.

- The following are the most valuable aspects of the Remaining Project Work:
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - Will the team be providing the benchmarking, or will commercial partners come to the lab to benchmark on their test rig.

F. Additional Comments and Recommendations

1) **Project Strengths**

- A very well motivated project, as it seeks to remove some of the key bottlenecks in FDD market by creating public datasets that will enable uniform comparison of various FDD products.

- Test procedures
- Benchmark
- Dissemination

- Develop test procedures and public data sets to evaluate AFDD algorithms.

- The lab has a unique opportunity to use their FLEXLAB facility to provide public benchmarking data.

2) **Project Weaknesses**

- The lack of a clear plan for long term curation of the public dataset the project will generate.

- Make optimal control strategies easy implemented.

- The work is limited to chilled water VAV systems and small set of faults tested.
- The project needs to have relevant stakeholders and industry experts to be heavily involved in the development of test procedures and benchmark (not just on advisory board or TAG).

- The scope of the project is not defined.
- What work is to be done is simulations vs hardware? Is hardware in the loop simulation a viable option?
- What is the need? Research testing, product validation, technician training?
- Is the project actually testing, or just developing a testbed. The report showed a confusing mix.
- Would the resulting data be similar to the MIT Load disaggregation dataset?

3) **Recommendations**

- Ensure that the public dataset remains accessible to the public (and is well documented) after the completion of the project.

- Provide clear input requirements for fault detections.

- May need to have a larger set of faults to be tested. The faults may also include AHUs level, zone level, and chilled/hot water central plant. The work is limited to chilled water VAV system? What about other types of HVAC systems such as water source heat pumps, chilled beam, fan coil units, etc.
- Consider the possibility of industry experts' involvement in the test procedure developing.

- Clearly define the scope of the project.
- Focus on either creating a test facility for benchmarking commercial AFDD solutions, or on a dataset for research testing AFDD. Both is too broad a scope.

Project #32603: Advancements in Building Controls for Energy Efficiency: Adaptive Control

Presenter: Draguna Vrabie, Pacific Northwest National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers generally agreed with this project's approach to developing adaptive supervisory control for large commercial buildings with the specific goals of developing: (1) control algorithms for optimizing air handing and variable air volume (VAV) equipment, (2) VOLTTRON-compatible open-source controls software, and (3) a high fidelity virtual testbed with baseline control strategies. One reviewer commented that the testbed will be useful for testing control algorithms, but that technical issues remained to get this approach to work reliably (e.g., ensuring that the optimization problem is feasible at every planning instance). Another reviewer also noted that the project has a good approach for successfully reaching its goals, but commented that optimization of equipment operation may be limited to certain variables. A third reviewer recommended that it would be helpful if the project team clearly defined the optimal variables, the number of those variables, and the optimization techniques that will be used to solve the optimization problems. One reviewer remarked that more focus is needed on mapping the accuracy of the models developed and the effect of the learning algorithms, while another reviewer was uncertain of the potential to optimize HVAC equipment other than chilled VAV systems. Finally, another reviewer would have liked see additional details for a thorough review of the approach.

One reviewer noted that the project was well planned, and that current achievements could make a significant contribution to the project's goals, while multiple reviewers agreed that this project will contribute to BTO's energy savings goals through advanced controls. One reviewer noted that the project's overall impact could be high if research results are disseminated to all facility managers and operators for adoption. Multiple reviewers, however, were concerned about the adoption challenges presented by the project team, with one reviewer uncertain as to how these challenges will be addressed, and another reviewer expecting that the project's sophisticated calculations might prevent quick adoption. One reviewer recommended that more effort be put into addressing adoption barriers, with another opining on the potential need for real building testing.

Multiple reviewers noted the collaboration among multiple national labs on this project. One reviewer also appreciated the involvement of the stakeholder advisory groups. Another reviewer, however, felt that the project needed relevant stakeholders and industry experts to be involved in the development and testing of the proposed model predictive control algorithms as opposed to just participating in the technical advisory group.

Weighted Average: 3.21 # of Reviewers: 4
Approach: 3.00 Impact: 3.25 Progress: 3.25 Collaboration/Coordination: 3.25 Remaining Work: 3.50

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach involved self-learning models of building equipment and dynamics and then using them for MPC. The models seem to be of low-complexity, and the temperature dynamics linear, which is very useful for MPC. The simulation testbed being developed is useful for testing the algorithms.
- There are remaining technical issues in getting this approach to work reliably, such as ensuring that the optimization problem is feasible at every planning instant, which the project does not seek to address (at least to my understanding). Some work on these directions will be useful. Still, compared to the other projects in the panel that plans to use MPC, this project is much more technical sound.

- Machine learning, Model-based predictive control (MPC), Dynamic adaptation.
- Test performance in simulation and at building test sites.
- It is a good approach to reach goals with possible successfulness. However, optimization may be limited to certain variables.

- The project approach includes machine learning, model-based predictive control (MPC), and dynamic adaptation, and test performance in simulation and at building test sites. The project' approach is most likely to contribute barriers, technical challenges, and mitigating project risk. It will be very helpful if the team define clearly the optimal variables (controller set points??) and number of those variables and optimization technique that will be used to solve the optimization problems.
- I am not sure how the zone air flow rate will be optimized as they determine based on the required load in the space (minimum air flow rate setting can be optimized). Similar scenario for discharge air temperature in zone. If zone airflow rates (and zone discharge supply air temperatures) are included in the optimization as optimal variables, in a typical building you may have hundreds of variables to be optimized!
- Why the maximum limit of system supply temperature is too high (70°C).
- It may be better to present the min and max limits for zone air flow rates as a percentage of design values.
- It is not clear the fan model discussions and how obtaining optimized area as an opposed to trim and response operation area. The operation area follows the system curve resulted from required airflow rate, relative VAV damper positions, and duct static pressure set point not form optimization decision. The optimized area as shown may not be practical. Overview of machine learning methods used for system and component HVAC models will be very helpful, identifying the necessary data inputs and outputs.

- The virtual testbed will be of most value.
- Not enough details for thorough review.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- It is not clear to me how the adoption challenges mentioned (cloud-based, security concerns) will be addressed by this project.

- Contribute to 30% savings for HVAC by 2030 in the commercial sector through advanced controls and $0.12/square feet cost target.
- Meet cost & performance targets to enable optimized building performance.
- Mitigate the technical challenges to facilitate market transition.
- The impact will be high, if research results will be reached to all facility managers and operators to realize real savings.

- If the project goals are met, the project will help to contribute 30% savings for HVAC by 2030 in the commercial sector through advanced controls. In my opinion, it may be hard to apply such as sophisticated calculations in current BAS technologies and this will prevent this technology from quick adoption.

- Quantitative impact goals and targets are good.
- None.

C. Progress

Based on current project efforts, the project was rated **3.25** for the degree to which the project has met ***project-specific goals.***

- N/A

- Virtual testbed to implement baseline control.
- Online learning methods with FRP data.
- Control evaluated in simulation.

- The project is well planned and the current project efforts lead to significant contribution to the project goals.

- None.

D. Collaboration and Coordination

This project was rated **3.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- N/A

- Three labs' collaboration.
- Two advisory group meetings with representing controls providers, technical experts, and market users. The advisory meetings should provide good advisory to ensure the project is performed in a right direction and will be successful.

- This work includes partnership between ORNL and PNNL. This project needs to have relevant stakeholders and industry experts to be heavily involved in the development and testing of the proposed model based predictive control (not just on advisory board or TAG).

- None.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- N/A

- Improvements on computational scalability.
- Control performance evaluated in simulation.
- Testing at PNNL's system engineering building testbed.

- The project plans are likely to meet the project specific goals.

- The testbed building will be interesting. It'll be a lot of work to make it right, but could be very valuable to industry.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Control of building equipment based on real-time optimization, with models learned on-line.

- Supervisory adaptive control algorithms for commercial buildings with AHU and VAV equipment that can reduce >15% HVAC energy consumption relative to existing ASHRAE 90.1 supervisory baseline.
- Open-source controls software compatible with the open-source building control platform VOLTTRONTM.
- A high fidelity virtual testbed and baseline control strategies, to serve as a benchmark and to enable the R&D community to develop advanced building controls.

- Develop supervisory adaptive control algorithms for commercial buildings.
- Using machine learning for building efficiency.

- Virtual testbed - if easy enough to use...good for researchers.
- Real testbed - good for industry?

2) **Project Weaknesses**

- Prediction accuracy of the models learned on line will determine the success of the control system. More focus is needed in mapping the accuracy of the models, and the effect of learning algorithms.
- But this weakness is not specific to this particular project. Rather, all projects in the panel that involve learning models from data for control purposes (there are several such projects) are lacking in this respect. The program would do well by investing in improving this fundamental component of model/optimization based control.

- Real building demonstration may be needed. The testbed is able to provide all possible controls to optimize building performance. However, real building controls are limited, so that full optimization may not be realized.

- The approach is not clear. The optimal variables, optimization solver, model input and outputs are not well defined.

- Presentation lacked some detail that would have been helpful for reviews.

3) **Recommendations**

- Put more effort in addressing some of the adoption barriers listed in your slides (security, etc) to have more impact.

- The project should be able to document differences between testbed test results and real building responses. The project may provide solutions for real buildings with limited control variables, because some controls may not be available in real buildings. Therefore, partial optimization may be needed.

- Need to clearly define the optimal variables. Limit the number of variables to be calculated by the optimization solver.
- The work is limited to chilled water VAV system? What about other types of HVAC systems such as water source heat pumps, chilled beam, fan coil units, etc.
- Consider the possibility of industry experts' involvement in the optimization control development and implementation as it is really hard to implement such that high sophisticated calculations in existing BASs.

- Engage the community during testbed developments. Reduce learning curve.

Project #32618: An Open, Cloud-Based Platform for Whole-Building Fault Detection and Diagnostics

Presenter: Stephen Frank, National Renewable Energy Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

While several reviewers applauded this project's focus on the underserved small commercial building sector, some reviewers were skeptical of the model-based approach combining DOE's energy modeling tools with the industry partner General Electric's (GE) Predix machine learning algorithms for automated fault detection and diagnostics (AFDD). Two reviewers felt that the presentation did not provide enough information on the approach.

On the other hand, another reviewer positively commented on the potential of minimizing sensor requirements through the approach, reducing a barriers to AFDD adoption in the small commercial buildings sector. The effectiveness of the approach, however, will depend on the accuracy of the energy prediction models, which according to the reviewer is difficult even with a lot of manual and/or high-cost calibration. Another reviewer noted that two faults considered (i.e. duct leakage and excess infiltration) could be difficult to detect with few sensors and/or based only on energy consumption readings because two simultaneous faults might result in no net change in energy consumption.

Multiple reviewers noted that this project's technology solution, if successfully developed, could have a strong impact and contribute to BTO's energy savings goals. One reviewer remarked that the project is well planned and that current efforts could significantly contribute to the project's goals, while another reviewer felt that insufficient information on progress was presented.

Looking forward, one reviewer commented that the planned future scope is likely to meet project-specific goals. Another reviewer, however, felt that the proposed future work does not appear to address all gaps and challenges. Reviewers offered a number of recommendations, included applying the AFDD developed to real, operational buildings and revising the faults being considered (e.g., excluding duct leakage and infiltration).

Multiple reviewers highlighted the team's collaborations, noting the strong coordination and good partnerships amongst multiple national laboratories, industry and academia. One reviewer, however, was interested in better understanding the challenges to seamlessly integrating the team's models with the Predix platform developed by GE.

Weighted Average: 2.73 # of Reviewers: 4
Approach: 2.50 Impact: 2.75 Progress: 2.75 Collaboration/Coordination: 3.00 Remaining Work: 2.75

A. Approach

This project was rated **2.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is to use predictions of simulation models and then compare that against measurements to detect fault. It has the potential to reduce sensor needs, since only meter data is used, and thus help reduce barrier to end-use. I am bit a skeptical about its effectiveness, though, since the effectiveness of the method will depend on the accuracy of the prediction models, and even with a lot of calibration effort (with low level sensor data), energy prediction is difficult. So how will accurate meter data prediction be obtained without such manual/high-cost calibration? And if cannot be done, is this approach really going to work? The approach might be swapping one difficulty for another. An initial result presented is promising. I'll be curious to see how well it performs at other FDD tasks.

- This project combines DOE's energy modeling tools with GE's Predix machine learning algorithms to create and validate a model-based automated fault detection and diagnosis (AFDD) platform for the underserved small commercial buildings sector.
- The presentations provide limited information on the approach. In addition, presentation format does not follow DOE review guidance.

- The project approach includes FDD model development and implementation for small buildings with few sensors. This approach is somewhat likely to contribute to overcoming barriers, technical challenges, and mitigating project risk. The duct leakage and excess infiltration placed at the top of Fault Prioritization may be very hard to detect with few sensors and/or just based on energy consumption readings. Duct bluster test for duct leakage and blower door test for envelop infiltration can be used to detect accurately those faults. Detect the fault from only energy consumption may be impractical. Two simultaneous faults may result no effect on net energy consumption.

- The following are the most valuable aspects of the approach:
    - In general, the approach of using data for AFDD is a good approach, and GE is a good partner.
- The following aspects of the approach seemed superfluous or could use improvement:
    - Presentation and slides too high level - cannot adequately review.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.75** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- If it works, it will have strong impact.

- The impact to reduce energy use in small commercial buildings. Although there are more impacts, presentation materials do not show.

- If the project goals are met, the project may help to contribute to meeting BTO 2030 goals of 30% energy savings from FDD for small commercial buildings.

- The following are the most valuable aspects of the impact:
    - Effective model based controls and AFDD would have an energy impact within the programs goals.
- The following aspects of the impact seemed superfluous or could use improvement:
    - Presentation and slides too high level - cannot adequately review.

C. Progress

Based on current project efforts, the project was rated **2.75** for the degree to which the project has met ***project-specific goals*.**

- N/A

- Prioritize fault causes based on annual financial impact.
- Performed fault experiments.
- Fill knowledge gaps with data-driven diagnosis.
- Evaluate AFDD performance.

- The project is well planned and the current project efforts lead to significant contribution to the project goals.

- The following are the most valuable aspects of the progress:
    - The plot on slide 13 of the AEI and AFI for different faults will be a very valuable technical report.
    - The data is slide 17, 21, and 22 could also prove valuable with appropriate context.
- The following aspects of the progress seemed superfluous or could use improvement:
    - I hope that the AEI/AFI experiments were conducted thoroughly and appropriate for general analysis.
    - Presentation and slides too high level - cannot adequately review.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- N/A

- The project team has two national labs, a private company and a university. Collaboration and coordination are well done.

- Good partnership between Purdue University, GE Global Research Center, ORNL, LBNL, and PNNL. The project engages Industry Experts and Research Industry Needs.

- The following are the most valuable aspects of the collaboration or coordination:
    - Project partner GE could prove valuable down the line.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - PI said "This is an early stage research project focusing on scientific pubs"; however, other than benchmarking, it is unclear what technical hurdles the team is overcoming.
    - What challenges are there to seamlessly integrating this approach into GE Predix products?
    - Presentation and slides too high level - cannot adequately review.

E. Remaining Project Work

This project was rated **2.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- N/A

- Complete Fault Model Validation.
- Fault Model Repository & Signature Library.
- Final AFDD Algorithm Development.

- Automated Model Generation.

- The remaining project work includes completing fault model validation and final AFFD development. The project plans are likely to meet the project specific goals

- The following are the most valuable aspects of the Remaining Project Work:
    - The future work addresses important open problems.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - It would have been great to see the PIs thoughts and quantitative lit review on the open problems.
    - The team does not show how they will close these gaps.
    - Presentation and slides too high level - cannot adequately review.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The potential for automated FDD without requiring a lot sensors.

- Develop practical, cost-effective AFDD algorithms for the underserved small commercial building sector and prioritize causes.

- Research and develop practical, cost-effective AFDD algorithms for the underserved small commercial buildings sector

- The slide graphics look very nice.

2) **Project Weaknesses**

- The "science" behind this approach is unproven.

- If excess energy use is detected, a lot of causes can make it happens. The project should provide detect procedures to find a real cause.

- Detect the fault from only energy consumption may be impractical. Two simultaneous faults may result no effect on net energy consumption.
- The duct leakage and excess infiltration placed at the top of Fault Prioritization may be very hard to detect with few sensors and/or just based on energy consumption readings.
- Duct bluster test for duct leakage and blower door test for envelop infiltration can be used to detect accurately those faults.

- This project description was so high-level it was difficult to properly review.
- Project scope and goals are poorly defined.

3) **Recommendations**

- N/A

- The algorithms should be applied to real buildings with possible solutions after AFDD is performed.

- May need to revisit the faults considered in this study. Exclude duct leakage and infiltration.

- Re-review the project after they have provided summary quantitative and technical documentation.

Project #32690: OpenBuildingControl: Simulation, Specification, and Verification of Control Sequences

Presenter: Michael Wetter, Lawrence Berkeley National Laboratory
DOE Manager(s): Marina Sofos and Amir Roth

Brief Summary of Reviewer Comments

Reviewers highly rated this project's approach for developing standardized tools and processes to evaluate performance, specify, and verify advanced building control sequences (i.e. ASHRAE Guideline 36 for HVAC system operations). Several reviewers commented that the approach pursued is likely to contribute to the project's objective of helping to overcome barriers and technical challenges in the implementation of advanced building controls by reducing the learning curve for their uptake and application. One reviewer cautioned, however, that a large learning curve could still remain as a result of these approaches still being "foreign to the HVAC industry."

All reviewers stated that this project is likely to have a strong impact, with one reviewer noting that the project addresses an important need of the building controls industry, and another commenting that the project is highly likely to contribute to BTO's programmatic goal of 30% energy savings by 2030 through more sophisticated and optimized control solutions.

One reviewer highlighted the project team's strong engagement with the applicable standards bodies (e.g., ASHRAE), while also noting that engagement with potential end-users could be strengthened. Another reviewer recommended additional engagement, if not already planned, with building control manufacturers in the future. Overall, reviewers commented that future work seems well scoped and likely to meet project-specific and programmatic goals. One reviewer, however, noted that contractors may require training on the tools developed and encouraged the creation of a training program beyond the scope of the current project.

Weighted Average: 3.53 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 3.00 Remaining Work: 3.67

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- This is an extremely compelling project.
- The project approach includes developing tools and processes for the performance evaluation, specification and verification of building control sequences. The project approach is highly likely to contribute barriers, technical challenges, and mitigating project risk.
- Use of control standards CDL, will reduce learning curve for uptake of their approach. There is still a large learning curve for this, especially since it is foreign to the HVAC industry.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Because the project addresses such an important need of the building controls industry, and it has such a strong set of partners, it is likely to have very strong impact.
- The project is highly likely to contribute to BTO's 30% energy savings by 2030 through better control sequences.
- Good job enumerating impacts across DOE, design, control, commissioning, and standards sectors.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals*.**

- N/A
- The project has demonstrated excellent contribution to the project-specific goals.
- Hard to tell progress with testing what they've done or having user engagement surveys.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- N/A
- The project staff demonstrates strategic collaboration with relevant stakeholders. The staff may need to engage big control companies (JCI, Trane, Siemens, etc.)
- Engagement with standards bodies is great.
- Engagement with potential users is poor.

E. Remaining Project Work

This project was rated **3.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- N/A
- The remaining project work includes implementation of verification tool, helping control vendors in developing prototype CDL translators, implementation of sequences for primary systems, and specification of control design tools. The project plans are highly likely to meet the project specific goals. Working with ASHRAE to use OpenBuildingControl and CLD is a plus.
- Good job defining scope.

F. Additional Comments and Recommendations

1) **Project Strengths**

- N/A.
- Develop tools and processes for the performance evaluation, specification and verification of building control sequences.
- OpenBuildingControl will standardize control sequences & verification tests.
- Standards

2) **Project Weaknesses**

- For the resulting product to be widely adopted, user base will need to be trained. Perhaps it is beyond the scope of such an early stage project to also plan training sessions. If that is the case, BTO should have another project on creating training programs.
- Not engage big control companies. Limit the work for primary systems
- Learning curve for industry.

3) **Recommendations**

- N/A
- Engage control companies if possible their feedbacks /recommendations may be very helpful.
- What about chilled and hot central plant control sequence?
- Engage with potential users modify program to reduce learning curve and develop training.

Project #32691: VOLTTRON Testing Tool Kit (VTTK)

Presenter: Bob Barcklay, Kisensum
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers were varied in their evaluation of the strengths of this project's approach of validating the usability of the VOLTTRON platform for distributed energy resource (DER) management systems in buildings through the development of testing tools for use by both research entities and product vendors. One reviewer, however, also cautioned that to be successful, the platform will have to deliver a critical mass of solutions and minimized risks. Another reviewer questioned whether the testing tool kit under development is the "lowest hanging fruit to a minimum viable product" for VOLTTRON, depending on DER developer interest, and asked whether having private companies perform the work using federal funding would instead generate more interest. Reviewers were similarly split on specific elements of the testing kit developed. One reviewer, for example, commended the replacement of the VOLTTRON message bus with one more widely used in industry. Another reviewer, however, was concerned about scalability and adaptation. Specifically, the reviewer remarked that the new debugging tool is rather limited and that adding a specific historian to the VOLTTRON platform might be a barrier to adoption.

Reviewers generally agreed that the project has made significant progress toward its goals and achieving its potential impact. One reviewer, however, commented that final impact will depend on the usability of the debugging tool and historian, while another reviewer thought that it will ultimately hinge on the number of new users. Another reviewer also agreed on the potential impact of improving the VOLTTRON platform, but was unsure about the energy savings impact. Finally, the impact of the VOLTTRON platform itself will depend on whether it "really makes sense for DER applications," according to another reviewer, who was not sure if this will ultimately be the case.

Overall, the reviewers rated the team's collaboration and coordination highly, with multiple reviewers noting that hosting technical advisory meetings that bring stakeholders and potential users together is appropriate for meeting the project objectives. However, many reviewers also recognized the potential risk of potential VOLTTRON users already having their own proprietary development systems in place. As such, one reviewer recommended further discussions with these companies to identify the investment required for them join the VOLTTRON user community.

Most reviewers agreed that the remaining project scope is expected to be completed on time and with success. One reviewer remarked that potential users should not be dependent on the project team to adapt the new enhancements, highlighting that good documentation and online help tools should enable potential users to benefit from the project deliverables. Another reviewer, however, expressed concerns about the lack of a plan for future maintenance and technical support of the testing kit.

Weighted Average: 3.01 # of Reviewers: 4
Approach: 2.75 Impact: 3.00 Progress: 3.00 Collaboration/Coordination: 3.25 Remaining Work: 3.25

A. Approach

This project was rated **2.75** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- I can't really judge the approach, since this is mostly a software development project. The idea to replace the Volttron message bus with something that is widely used in industry is a good one, if Volttron is to be more widely adopted.

- Clear technology return on investment.
- The platform must deliver a critical mass of "solved problems".
- The platform risk must be minimized.
- Good approach to reach goals.

- The following are the most valuable aspects of the approach:
    - To achieve the goal of a sufficiently easy to use development platform for DERs control, the project aims to add important modules and testing environments required by commercial developers.
    - The work is well documented and searchable.
- The following aspects of the approach seemed superfluous or could use improvement:
    - It is unclear what commercial DERs developers would do if this work was not conducted. Has the team done a sufficient lit review and customer study to understand if this is the lowest hanging fruit to a minimum viable product for Volttron? It seems that it could be, it's just not clearly presented.
    - Would it make more sense to fund companies to do the work, that way companies get 'sweat-equity' (albeit paid by the US gov't) into the VOLTTRON platform?

- Debugging tool is deemed limited. Adding a specific historian may be a barrier. Scalability and adaptation may be an issue.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- If Voltron really makes sense for DER applications, then this project will have a strong impact. I am not sure about the hypothesis.

- Facilitate (and lower the cost of) DER integration by extending VOLTTRON into the DER domain to provide greater reliability and resiliency.
- Create an open source virtuous cycle in which labs and developers gain benefits from using VOLTTRON and contribute work back to it
- Demonstrate viability of VOLTTRON as a microgrid platform for real world testing in commercial projects.
- VOLTTRON for DER Management is happening: Kisensum is working with two commercial entities that have recently initiated VOLTTRON based projects for DER management
- If successful, it may create big impact to use open source tools.

- The following are the most valuable aspects of the impact:
    - In terms of improving the VOLTTRON platform towards a viable 'product', this work is high impact.
- The following aspects of the impact seemed superfluous or could use improvement:
    - The work still begs the question of the energy impact.

- The impact will depend on the usability of the debugging tool and the historian. Good documentation and online help tools should enable potential users to benefit from this project. The potential users should not be dependent on the project team to adapt the new enhancements

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- The project seems to have met almost all the milestones.

- Message viewer adds a valuable debugging tool to the platform.
- Simulation framework provides a suite of well documented code demonstrating how microgrid components interact within VOLTTRON.
- Jupyternotebooks provide detailed, interactive documentation across all project deliverables.
- OpenADRreference application demonstrates coordinated agent interaction to implement load shed.
- InfluxDbhistorian adds a time series historian with easy integration to third party analytics tools (egGrafana).

- The following are the most valuable aspects of the progress:
    - The team seems to have made significant progress towards the project goals in a high quality way.
    - The online documentation seems thorough.
    - Development tools like InfluxDb historian will further reduce the 'learning curve' for new developers.
    - I could potentially see the simulation framework valuable for my own research, and for companies looking to thoroughly test products.
- The following aspects of the progress seemed superfluous or could use improvement.

- The project has made good progress. However, the real impact will be measured by the number of new users who will adopt and utilize the new components.

D. Collaboration and Coordination

This project was rated **3.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- N/A

- Held a technical advisory meeting at SLAC.
- Key take away: For some DER companies, they already have their own proprietary systems.
- OpenADRprojects are under discussion.
- Architectural recommendations based on VTTK work are being implemented by the PNNL team. Most notably, using RabbitMQas the platform message broker.
- Very good cooperation with stack holder.

- The following are the most valuable aspects of the collaboration or coordination:
    - The TA meeting was appropriate for the project.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - The challenge of companies already having their own platform is serious. Open, and closed, discussion should be had as to what investment would be required to have these companies join the VOLTTRON community.

- Only two commercial entities have been engaged, so far.

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Project is nearly complete.

- Ansiblescript for deploying cloud-based Volttron instance.
- Hackathon/Learning Lab
-
- The remaining work is expected to be completed on time and success.

- The following are the most valuable aspects of the Remaining Project Work:
    - The team understands the importance of engaging and reducing the learning curve for new developers.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - A survey (published and peer reviewed) of development tools, languages, and standards used by DERs companies would be a valuable resource to the community and could help support the cause of VOLTTRON and ensure that it is using appropriate tools.

- Technical project goals within the scope of work will be likely met.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Helps reduce bottlenecks to industry adoption of Volttron for DER applications.

- Open source test tool kit.

- The focus on reducing the learning curve for new developers and producing a minimum viable VOLTTROL platform for industry to use in lieu of their own propriety platforms.

- Debugging tool. It should be robust and user-friendly, though.

2) **Project Weaknesses**

- N/A

- No plan for future maintenance and technical support.

- Existing propriety platforms.
- Convincing companies to use an open-source platform.

- Implementation of an alternate historian may not be the best way to an open-source.

3) **Recommendations**

- N/A

- Need a plan for future technical support.

- The VOLTTRON team should study other commercially successful open-source platforms for paths forward.

- Engaging more early adaptors.

Project #32745b: Transactive Whole Buildings as Integrated Assets (Economic Dispatch)

Presenter: Srinivas Katipamula, Pacific Northwest National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers had mixed reactions to this project's approach of designing, developing, field testing, and validating a VOLTTRON controller for economic dispatch of building-integrated combined cooling, heating, and power (CCHP) systems. One reviewer commented that the approach was well defined and well planned, while another reviewer highlighted that project risk is mitigated by testing the software platform using EnergyPlus. In contrast, one reviewer commented that the one use case modeled by the project team seems an unlikely implementation of the VOLTTRON controller, while another reviewer thought that the risks of field deployment were not well-communicated and that it was unclear if the field testbed has already been arranged. One reviewer acknowledged that VOLTTRON could serve as a nice platform to quickly prototype approaches for CHP plants with economic dispatch problems, but was uncomfortable with the project's ill-defined scope, unclear on the exact need being addressed, and questioned whether the project is intended to demonstrate that CHP can provide ancillary grid services, existing algorithms for CHP dispatch on real hardware, or that control algorithms can run on commercial computational hardware.

One reviewer remarked positively that the CHP method pursued has significant potential to reduce energy consumption in large commercial and institutional buildings, enabling potential energy savings. Another reviewer similarly noted that total energy savings can be over 25% if the proposed approach is successful, while a third reviewer highlighted the potential grid-services impact. More critically, one reviewer expressed concern over the project team's calculation of technical potential, remarking that it is not clear what market barriers to CHP the project's solution seeks to address. Another reviewer also posited that an open-source controller package could have a larger impact in the small and mid-size commercial building space where the controls market is less developed and where in-house control packages with expert assistance are less likely to exist.

Multiple reviewers commented that Frontier Energy is a good commercial partner, while one reviewer noted that the project's academic partners provide complementary technical expertise. One reviewer cautioned, however, that the lack of engagement with other potential commercial partners could reduce the chances of this project progressing out of the lab and having an impact in the field, while another recommended that more stakeholders engagement in the field-testing stage.

Reviewers agreed on the project's progress-to-date, with multiple reviewers highlighting the team's simulation work as an important step before validation. A few reviewers had no concerns about the project's remaining work, but others remarked that the project's field validation efforts should start earlier. One reviewer highlighted that a strength of the project was the software platform's flexibility to incorporate field data and target particular building types, and recommended that the project team analyze potential energy savings and challenges of the proposed approach by building type. Another recommended that the project team should improve the model forecasting accuracy, especially around load forecasting.

Weighted Average: 2.94 # of Reviewers: 4
Approach: 2.75 Impact: 2.75 Progress: 3.50 Collaboration/Coordination: 2.75 Remaining Work: 3.25

A. Approach

This project was rated **2.75** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Project risk is mitigated by testing software platform using EnergyPlus building simulation model. Software uses adaptive modules that incorporate field data.

- The approach is well-defined. It includes all aspects of the building to make a sound decision in operating the HVAC system. Nice to see the controller can dispatch both power and thermal energy, where energy is produced and consumed at the lowest cost.

- The following are the most valuable aspects of the approach:
    - Economic dispatch of CHP plants is an open problem, and the VOLTTRON platform could serve as a nice platform to quickly prototype approaches on.
- The following aspects of the approach seemed superfluous or could use improvement:
    - What need is really addressed in the approach. Is it showing the CHP and provide ancillary grid services? Is it demonstrating existing algorithms for CHP dispatch on real hardware? Is it showing that these algorithms can run on commercial computational hardware? The report touches on all of these. The scope of the project is ill defined.

- This project appears very academic in modeling a single use case and it is unclear how much work was leveraged from other projects in the economic dispatch of CCHP plants. The use case modeled was a hospital with a large number of energy options available and large HVAC and electrical loads for its complexity but would be an unlikely implementation of this controller.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.75** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- CCHP method has a significant potential to reduce energy consumption in large commercial and institutional buildings. The proposed project may potentially enable such energy savings,

- The total energy saving can be over 25% if the proposed approach can be achieved which is very promising!

- The following are the most valuable aspects of the impact:
    - CHP plants do have an untapped opportunity to provide grid services.
- The following aspects of the impact seemed superfluous or could use improvement:
    - It is unclear how much of an improvement their method is over conventional CHP, or what market barriers to CHP their solution addresses.
    - The scope of focusing on CHP is limited in today's use of CHP for markets.
    - The calculation of technical potential seems suspect: Current CHP buildings consume 8 quads. Yet, the movement from 51% efficiency to 75% efficiency from non-CHP to SOA CHP. Not SOA CHP to the proposed CHP.

- The integration of such large complex systems requires expert assistance that will likely have in-house control packages. An open source controller package will have a larger effect on the small/mid-size commercial building space where the controls market is less developed. The lack of engagement with potential commercial off takers also reduces the chances of this project progressing out of the lab and having an impact in the field.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals*.**

- EnergyPlus prototype for a hospital environment has been developed. Validation with real equipment is pending.

- No concerns on this. The work has been well planned.

- The following are the most valuable aspects of the progress:
    - The full testing in simulation is an import step before field deployment.
    - A significant amount of work must have been done to integrate these algorithms into the Volttron platform.
    - The use of three different optimization approaches provides good insight into the space, and trains a broader audience on the Volttron platform.
- The following aspects of the progress seemed superfluous or could use improvement:
    - The thoroughness of the benchmarking is ill-defined.

- The project appears to hit their interim milestones on time and has an adequate risk mitigation strategy in place.

D. Collaboration and Coordination

This project was rated **2.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Academic partners provide complementary technical expertise. Frontier Energy collaboration is critical for transition to market.

- Need to involve more stakeholders to do the field testing to make sure the proposed saving can be achieved.

- The following are the most valuable aspects of the collaboration or coordination:
    - Frontier Energy could be a great project partner.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - The risks of the field deployment do not seem to be properly summarized nor communicated.
    - Is a field testbed already arranged?

- There appears to be minimal contact with teams working on similar problems or potential off takers of the system. There has been discussions with end users during development but it is important to involve commercialization partners early in the process to ensure the work will be translated to a commercial product in the future.

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Project seem on track to meet remaining milestones.

- Well planned. No concerns on this.

- The following are the most valuable aspects of the Remaining Project Work:
    - Field-validation is an important next step.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:

  - What does "complete comprehensive testing" mean? Provide technical description of work.
  - Begin field testing much earlier. At least start collecting data on field testing rigs.

- Team has an adequate risk mitigation plan for testing of controls. Plan for field validation should be started as soon as possible to allow for installation during the upcoming summer.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project strength is the flexibility of the software platform to incorporate field data and to target particular building types. Energy savings potential is very significant, and transition to market seems viable.

- Maximum return-on-investment of CCHP system.
- Supervisory control and generalized economic dispatch developed with the inclusion of 24-hour weather and load forecasting.

- A good new use of the Volttron platform.
- Comparison of multiple optimization algorithms

- Strong analytical teams working to develop an open source controls platform.

2) **Project Weaknesses**

- Project has so far targeted hospital building for the first test case. It is not clear what would be the challenges for adopting this technology to different building types that may have more variable occupancy patterns (for example educational buildings).

- Nothing to be concerned at this point.

- Poorly defined scope of work.
- Poorly defined field testing

- Engagement with off takers for the project in the future and providing more likely use cases for a controller of this type.

3) **Recommendations**

- It would be interesting to analyze potential energy savings and challenges of the proposed approach by building type (hospital, office, educational, hospitality, etc.).

- Improve the model forecasting accuracy, especially the load forecasting.

- Get an early start of field testing.
- Clearly define the scope of work and short term goals.

- More engagement with potential off takers and users of the VOLTTRON system. A better target for an open source controller would be the small to mid-size commercial building market.

Project #32756: VOLTTRON Message Bus Protocol Adapter

Presenter: Bob Barcklay, Kisensum
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers generally agreed with the approach of adding common distributed energy resources (DER) protocol support to the VOLTTRON platform to assist in enabling utilization for DER management in buildings. One reviewer considered it a sound move to replace VOLTTRON's existing message bus with one that industry is already comfortable with. One reviewer, however, warned that VOLTTRON might not be the right tool for many of the control applications envisioned, while another reviewer suggested that the project's advancements should be broadened to platforms outside of just VOLTTRON.

Several reviewers commented that this project should make VOLTTRON more widely used, and multiple reviewers flagged the common bus protocols as an important step for an open-source controls execution platform like VOLTTRON. One reviewer remarked that out-of-the-box support for commonly used DER protocols could allow for DER resources to be integrated with VOLTTRON and leverage all other VOLTTRON services, while another reviewer commented that an open-source, inexpensive building management platform with the right analytics could encourage adoption of behind-the-meter distributed generation, storage, and renewables and support resilience. One reviewer noted that external users are already providing code back to the VOLTTRON community, showing at least modest uptake of the platform, and a few reviewers flagged that the software developer and project partner, Kisensum, for example, has existing projects underway exploring the use VOLTTRON as a DER management platform for large-scale DER deployments.

Reviewers disagreed in their assessment of the project team's collaboration efforts. One reviewer commented that collaboration between SLAC and Kisensum was good, but did not observe any activities from NREL. Another reviewer noted that the project team appeared to be collaborating with the appropriate partners in the protocol standards, software development, and grid services fields. A third reviewer felt that it was not clear how many stakeholders are actively engaged in the project. One reviewer noted that in order to adopt VOLTTRON, hardware manufacturers would need to be engaged, and ideally not just small start-ups.

Reviewers agreed that the project team had demonstrated significant progress, with one reviewer specifically commenting that adding the project's protocol adapter layer to the VOLTTRON platform will successfully meet project goals. Multiple reviewers commented, however, that the project team did not describe any plans to provide maintenance and technical support past the project, with one reviewer recommending that documentation should be provided for future users' use, while another suggested that the project deliverables should be self-sustainable by the users in order to keep up with the evolution of the existing protocols and to maintain the adapter layer. One reviewer suggested that the project team study other open source hardware projects that have come out of the national labs, and come up with a plan to keep the VOLTTRON community sustainable.

Weighted Average: 2.91 # of Reviewers: 4
Approach: 3.00 Impact: 2.75 Progress: 3.00 Collaboration/Coordination: 3.00 Remaining Work: 2.75

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Like the other related project, this one is also a software development project, so there is not much to say about the approach. The motivation is sound, to replace the Volttron message bus with something that industry is more comfortable with.

- Leverage existing platform services: Master Driver & topics.
- Map supported protocols to widely used SunSpecdata dictionary.
- Develop and contribute (as open source), common protocol implementations.
- Enable VOLTTRON for DER Management by adding common DER protocol support to the platform. These add-ons will meet the project goals.

- The following are the most valuable aspects of the approach:
    - The project seems like pretty standard development work integrating standard protocols into the new Volttron platform.
- The following aspects of the approach seemed superfluous or could use improvement:
    - The project was very in the weeds of message passing protocols, and I am unable to review whether the approaches they took are appropriate or the best.

- A protocol adaptor layer will certainly enhance early adoption of the technology.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.75** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- If Volttron makes sense for these applications, then project is valuable.

- Out of the box support for commonly used protocols will allow for DER resources to be integrated with VOLTTRON and leverage all other VOLTTRON services, historians, control agents, etc.
- An open, inexpensive building management platform with the right analytics will encourage adoption of distributed generation, storage and renewables behind-the-meter and support resilience.
- Kisensum has commercial projects underway to use VOLTTRON as a DER management platform for large scale DER deployments.
- It is expected to make VOLTTRON use more widely after enhancement by the project.

- The following are the most valuable aspects of the impact:
    - Integrating standard message passing protocols into the Volttron platform will be an important step.
    - Having Kisensum lined up to use these advancements to Volttron.
- The following aspects of the impact seemed superfluous or could use improvement:
    - What is the plan for the Volttron platform. In terms of start-up culture: what is the minimum viable product? How will it get in the field to be tested? Is it to be used just as a research testbed tool, or will it be integrated into products? What are the first products where it could be integrated? What other open-source platforms have been successfully transitioned out of a National Lab that could serve as an example?

- A common bus for protocols such as SEP2, DNP3, etc., is an important step for an open-source VOLTTRON.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- It's not clear from the presentation exactly where they are, but seems like they are close to meeting the milestones.

- Charge Point Implementation (communication with EVs)
- DER use cases for IEEE 2030.5 (communication with loads)
- Common Data Model (SunSpecMapping)
- Modbus Implementation (communication with storage)
- DNP3 Implementation (communication with bulk power system)
- Testing VOLTTRON on RabbitMQ
- Evaluate & customize monitoring/admin tools for new message broker
- The project is on schedule.

- The following are the most valuable aspects of the progress:
    - The team seems to be meeting their predefined goals.
- The following aspects of the progress seemed superfluous or could use improvement:
    - The project was very in the weeds of message passing protocols, and I am unable to review whether the approaches they took are appropriate or the best.

- The review demonstrates significant progress has been made towards project goals.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- I am not sure collaboration is relevant in this project.

- Collaboration between SLAC and Kisensum is well. However, although NREL is listed as a partner, I don't see any activities from NREL.
- A good point is that PI responded to PNNL request and revised the deliverables to add ChargingPoint Driver.

- The following are the most valuable aspects of the collaboration or coordination:
    - The team seems to be collaborating with the appropriate partners in the protocol standards committees, software starts, and grid services.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - In order to adopt Volttron, hardware manufacturers need to engaged, and ideally not just small start-ups unless they show clear interest in adopting the Volttron platform.

- It is not quite clear from the review how many stakeholders are seriously engaged or interested in this project's deliverables.

E. Remaining Project Work

This project was rated **2.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- N/A

- Contribute to RabbitMQport through early evaluation of RabbitMQfork and detailed feedback to core team.

- Build unit tests and automated regression tests for VOLTTRON on RabbitMQ.
- Evaluate, customize and document admin & monitoring tools for VOLTTRON on RabbitMQ.
- The remaining tasks was changed from demonstration to development work to support RabittMQ migration. Although I don't know why, I believe strong justification is behind. The project remains on schedule.

- The following are the most valuable aspects of the Remaining Project Work:
  - N/A
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
  - The project was very in the weeds of message passing protocols, and I am unable to review whether the approaches they took are appropriate or the best.

- There is significant work for the remaining portion of the project.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Make the Volttron core more along the lines of what industry would be comfortable using.

- A protocol adapter layer was created on top of the VOLTTRON Message Bus to enable the re-use of existing, widely used protocols between VOLTTRON agents and services.

- Corporations are provided code back to the Volttron community. Shows at least modest uptake of Volttron.

- The protocol adapter layer.

2) **Project Weaknesses**

- The main weakness might not be the weakness of this project at all, but that Volttron may not be the right tool for many of the control applications envisioned.

- Any development has bugs. The project does not mention any possible maintenance and technical support.

- The project's success hinges on success of Volttron. Could the advancements be broadened to be application to platforms besides Volttron?

- Keeping up with the evolution of the protocols adopted and maintenance.

3) **Recommendations**

- N/A

- Provide detailed documents for future users' use.

- Have the team study other open source hardware projects that have come out of labs, and come up with a plan to keep the Volttron community sustainable and vibrant.

- To keep up with the evolution of the existing protocols and maintaining this adapter layer, the projects deliverables should be self-sustainable by the users.

Emerging Technologies
Sensors and Controls

Advanced Sub-Metering

Project #32636: Low Cost Submetering

Presenter: Theodore Bohn, Argonne National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Multiple reviewers noted that this project's approach of reducing installed costs is an important step to overcoming the barriers to practical implementation of sub-metering. More specifically, one reviewer commented that the approach pursued should lead to the development of solutions for all building applications at a minimum installed cost and enable monitoring-based commissioning to optimize building operation. Another reviewer noted the value in creating a dashboard and analytics to verify installation, as well as piloting analytics to ensure requirements on sensing are understood.

On the technical side, one reviewer commended the inclusion of sub-meter development to measure both AC and DC power, while another reviewer noted the value of the planned integration of the electronics into the current transformer to enable calibration in the lab. It was unclear to this reviewer, however, if similar approaches are being pursued elsewhere. Additional concerns included the level of maturity of the research area, as well as the technical grounding of aspects of the meter development.

One reviewer noted that this project could contribute to BTO's energy savings goals from automated fault detection and diagnostics enabled by cost-effective sub-metering. However, multiple reviewers commented that the ultimate impact of project on energy savings is not clear because either energy savings was not quantified or energy savings will ultimately depend on the application. One reviewer encouraged the team to quantify energy savings in order to consider trade-offs between power meter accuracy, energy savings, and installation costs. However, another reviewer felt that installation costs were also poorly quantified.

Many reviewers commented on the good collaboration and engagement with key stakeholders, including hardware, firmware, and software engineering companies, as well as standards bodies (e.g., National Conference on Weights and Measures). One reviewer remarked that more collaboration is needed with industry in order to commercialize the meter, while another recommended working with other organizations to standardize the test procedure and certify the meter accuracy.

Overall, reviewers agreed that the project is on track and has demonstrated significant contributions to the project goals to date. Several reviewers also noted that the project is near completion and likely to meet project specific goals. One reviewer commented, however, that minor execution risks remained, while other reviewers offered a variety of recommendations, including engagement with weights and measures stakeholders, as well as addressing the current absence of an embedded fault-diagnostic algorithm that could identify if and when the meter failed to properly measure loads.

Weighted Average: 3.00 # of Reviewers: 5
Approach: 3.40 Impact: 2.40 Progress: 3.00 Collaboration/Coordination: 3.00 Remaining Work: 3.00

A. Approach

This project was rated **3.40** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Project focus on reducing installation cost is an important factor to overcome challenges for practical implementation of submetering.

- This is a mature research area. A number of similar products are already available on the market. The debating area is the cost. If the cost of this kind of metering sensor can be dramatically reduced, then the market will be larger.

- The project approach includes review/benchmark of current electric sub-meter hardware, interviews provided stakeholder engagement, interviews revealed that total installed system cost, two tiered approach used to reduce sub-meter measurement hardware size and cost, flexibility on packaging this compact meter, dashboard/analytics software covers three core use cases: multi-family dwellings, building load by load type, and building portfolio. This approach can overcome the barriers and technical challenges and lead to produce sub-metering solution for all building equipment, systems, and loads at minimized net cost of installed system, enabling monitoring-based commissioning to optimize building operations

- Highly commend the project team on considering total all-in cost including installed cost and spending considerable effort to understand and address multiple installation challenges and responses.
- I understand the value in creating a dashboard and analytics to verify installation (e.g. diagnose incorrect installation). Piloting analytics to ensure requirements on sensing are understood is also important. Beyond that I am not sure this project should invest additional resources in application specific analytics as this typically requires domain expertize. It does not appear that the project is over investing in this area.

- The following are the most valuable aspects of the approach:
    - Technical and cost benchmarking of existing hardware and software.
    - Stakeholder engagement to determine the balance between features and costs.
- The following aspects of the approach seemed superfluous or could use improvement:
    - The hardware-software interface is not described as part of the approach.
    - The development of a meter that meets project objectives does not seem technically grounded. For example, what is the physical limit of current sensor accuracy? What are the trade-offs of different current sensing approaches. What is the state of the art and the state of practice? The PI seems to have a vague understanding of these questions, but they were not presented as integral to the project development, nor were the answers to the questions summarized well.
    - Is the primary purpose of developing the prototype to understand the limits of technology and explore the paths forward, or is it to develop a prototype to be turned into a product?

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.40** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Impact of this work on energy savings was not quantified. It is not clear if high precision submetering would have a significant impact on energy savings.

- Would recommend working with other organizations to standardize the test procedure and find a way to certify the meter accuracy.

- If the project goals are met, the proposed sub-metering solution may enable monitoring-based commissioning and contribute to BTO goal of enabling energy savings from automated fault detection and diagnostics through cost-effective sub-metering. Not clear what the energy saving could be obtained from this solution (which could depend on applications!)

- Effective submetering is a key need for energy management and reporting as well as analytics.

- The following are the most valuable aspects of the impact:
  - The figure of merit is net installed cost.
  - Qualitatively, an accurate and low-cost submeter would enable energy use reductions through the methods mentioned.
- The following aspects of the impact seemed superfluous or could use improvement:
  - While the figure of merit is net installed cost, the costs mentioned throughout the report, were component costs. The installation costs were poorly quantified.
  - A specific $15/ch target is chosen, but the curve of cost vs quality was not provided as described in the approach.
  - The impact slide poorly explains the trade-off of cost and/or quality of impact.
  - The impact of developing the prototype is unclear. Is it to create a new product that will be commercialized, explore the design space, or test brand-new technology (i.e. not COTs designs).

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals.***

- Project milestones seem to be on track for completion.

- It seems everything is on track.

- The project has demonstrated significant contribution to the project goals.

- Good progress.

- The following are the most valuable aspects of the progress:
  - Generally, the team is meeting the project goals.
  - The durability testing seems successful.
  - The benchmarking exercise, if conducted well, could be very valuable to the community.
- The following aspects of the progress seemed superfluous or could use improvement:
  - The progress report lacks even summary details that would enable a more valuable review. For example, briefly display the table summarizing the products tests.
  - Lots of mention of degradation vs time, but plenty still identify sub-watt loads.
  - Dissemination of uptake of the results by non-project partners is unclear, but would be a valuable part of the project.
  - The Q4 go/no-go cost-accuracy seemed to be about component cost, while it should have been about installed cost. The mismatch of metrics was not well justified.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Collaboration with both hardware/firmware and software engineering companies is appropriate for the project and important for technology transfer.

- More collaboration needs to be made with industries to commercialize the meter.

- The project includes a partnership between ANL, 2G Engineering, and Amzur Technologies. Team has expertise in the buildings sector and capability to complete benchmark assessments of components, systems

and meter performance. The project team demonstrates significant strategic collaboration with relevant stakeholders.

- Good collaboration and engagement of stakeholders.

- The following are the most valuable aspects of the collaboration or coordination:
    - The fact that the PI is on the W&M committee is important and bodes well for the project.
    - The stakeholder engagement for benchmarking was important.
    - The PI is considering other first markets besides AC building metering.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - Dissemination of uptake of the results by non-project partners is unclear, but would be a valuable part of the project.
    - A brief technical overview of the W&M committee's work and plan would have been helpful.
    - It's unclear why the DC meter work is part of the engagement, when the impact requires saturation in the AC load/metering market. Is the DC market (and other first markets) leading the team too far astray for the important high-impact goal?

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- This project is near completion and seems on track to meet milestones for project completion.

- Well planned.

- The project plans are likely to meet the project specific goals. The remaining work will include refinement of user/installation/configuration documentation and fault diagnostics, refine the cost estimates to scale up production of the platform electronics and mechanical packaging, and exploring follow-on funding opportunities to manufacture and commercialize this family of electric sub-meters designs.

- Project is nearing completion and minor execution risks remain.

- The following are the most valuable aspects of the Remaining Project Work:
    - The team should continue to engage with the W&M committee, bringing to the table what they have learned from the benchmarking.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - The future work does not include quantitative go/no-go milestones.
    - Three phase metering was neither part of the impact nor future work. Why was it part of the remaining work?
    - The definition of a "near-final HW and SW product" is very unclear.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Comprehensive analysis and testing of existing solutions is a plus. Focus on reducing installation cost is the strength of this project.

- A new submetering sensor that can measure both AC and DC power.

- Accurate sensor with low total installed cost

- Using customer discovery to understand the requirements for meeting all-in cost has resulted in a focus on installation cost and use-case factors in addition to lowering hardware cost. This is a key need for

addressing barriers and achieving deployment. I commend this and would encourage more project to address all-in cost including installation.

- Great lit review and benchmarking.
- The future approach of integrating the electronics into the current transformer so that the sensor and signal conditioning can be calibrated in the lab is a valuable path forward. However, is similar work occurring elsewhere?

2) **Project Weaknesses**

- Impact on energy savings is not clear. In particular, mA level of accuracy may not be critical for energy savings, while it may increase the cost and complexity of submetering.

- More experiment results regarding the measurement accuracy should be presented because this is important in evaluating the sensor performance.

- Not clear what information can the meter report?
- Lack of fault diagnostic embedded algorithm if the meter fails to properly measure intended loads (this may address in the future works)

- No major weaknesses.

- The report lacked important quantitative and technical descriptions and results, which made properly reviewing the project difficult. Brief quantitative technical summaries should have been provided for each milestone.
- The prototype development seems to be simple assembly of COTs components. Either this work should not be within the scope of an "emerging technologies" project, or the PI should better explain the technical challenge.
- The technical challenge of this work is unclear. If the project is just a benchmarking project, then why the prototype development?
- Confused as to what they are developing and why.
- Poor summary of work.

3) **Recommendations**

- Energy savings potential should be quantified. Trade-offs between power meter accuracy, energy savings, and installation cost should be considered.

- Working with other Standard agency to set up a certification procedure for this type of sub-metering.

- Develop fault diagnostic embedded algorithm if the meter fails to measure the loads (this is plan to address in the future works).
- Use lower accurate sensor to reduce the cost.

- It is not clear what level of project resources is invested in analytics. Understanding this for requirements and installation diagnostics is valuable. Application related analytics (e.g. to reduce energy consumption) should be left to other targeted projects.

- Focus on summarizing and disseminating the benchmark, ensuring it was does to specifications that are useful for decision makers and developers of new technology.

Project #32692: Reducing Plug-Load Electricity Footprint of Residential Buildings through Low-Cost, Non-Intrusive Sub-Metering and Personalized Feedback Technology

Presenter: Christoph Meinrenken, Columbia University
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project's approach of leveraging existing nonintrusive sub-metering to investigate occupant feedback strategies was solid. One reviewer commented that the project's use of natural language processing to provide automated feedback was novel and potentially transformative. Another reviewer described this project as the first of its kind in type and size, especially in terms of the ability to conduct human-in-the-loop tests of feedback strategies. One reviewer thought that the data generated from this study would be invaluable for further DOE studies. Another reviewer, however, commented that it did not appear that lessons learned from other similar studies are being applied, while another reviewer noted that additional work beyond the project will be needed to mature the technologies.

Several reviewers commented that it was unclear how much energy would be saved by the personalized feedback approach. One reviewer expected that the project will likely have a positive impact on energy savings, but another reviewer e that it was not clear if the targeted disaggregation accuracy will be sufficient to identify loads that may be faulty or ghost loads, thus limiting potential energy savings. One reviewer similarly posed questions about the robustness of the feedback personalization process in terms of false positives or negatives, over stimulation, and over-rides.

One reviewer saw great value in this project's efforts to better understand effective mechanisms to educate end-users to take action. A second reviewer referred to end-user behavior and education as key factors in addressing energy consumption of plug loads, noting that for these reasons, this project should make significant energy savings impacts in these loads. Two reviewers expressed concern about the project's social science and human behavior elements, however, noting the project team's lack of a social scientist.

Multiple reviewers noted that the project team had strong collaborations, including good coordination between principal investigators. For example, one reviewer pointed out the good collaboration between facility managers, a local utility company, and partner Lucid. Another reviewer noted that the interaction with building residents is very valuable, but questioned the value of the collaborations with Lucid and ConEd. Another reviewer also questioned how the different aspects of the research effort will be integrated to achieve the project goals.

All reviewers commented that the project appears to be on track, and reviewers agreed that remaining work appears to be moving towards achieving project-specific goals. Moving forward, one reviewer recommended exploring some control algorithms based on the dataset to further help correct abnormal energy consumption, and another cautioned the project team about potential participation fatigue. Finally, several reviewers had questions about the technology's tech-to-market pathway.

Weighted Average: 2.98 # of Reviewers: 6
Approach: 3.00 Impact: 2.67 Progress: 3.33 Collaboration/Coordination: 2.83 Remaining Work: 3.17

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is solid at high level. Each step is pretty involving.
- I believe this work will demonstrate the feasibility of the concept, additional work beyond this project will be needed to mature the technologies are being leveraged here. A good example is the natural language processing in step 5.

- One of project risks was mitigated by purchasing higher time resolution power meters to validate disaggregation performance with lower resolution data.
- Another risk is mitigated by manually checking user feedback for technical accuracy.

- The proposed approach is nice but hard because lots of social study and human behaviors are included. To inform the customer about the energy waste/abnormal energy consumption has been well studied in this research. But to reduce the energy wasted caused by these behaviors/people, more control algorithms are expected.

- The project will evaluate the impact on energy savings of various feedback mechanisms and content for a range of end-users. This will be very valuable to better understand effective mechanisms to educate end customers and have them take action to achieve reductions in energy costs. Correctly assessing the impact of these factors will be difficult and I commend the team for running preliminary tests to help inform the design of the final test. This will improve the likelihood of statistically significant findings.

- The following are the most valuable aspects of the approach:
    - The use of NLP to provide automated feedback is novel and potentially transformative at reducing cost and effectiveness of feedback.
- The following aspects of the approach seemed superfluous or could use improvement:
    - It is unclear if the study is developing automated methods for determining the efficacy of feedback approaches, and adapting in real-time.

- There is a lack of social scientist on the team to ensure the demographics of the resident population will accurately represent the makeup of the city. It appeared from questions to the PI that the group are technologically advanced and would likely follow any advice to cut energy use. A number of companies and teams are providing similar load disaggregation sensors and this project does not appear to be leveraging the lessons learned from those projects.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- It's unclear how much energy will be saved by the personalized feedback approach. However, the data to be generated from the study will be invaluable for further DOE studies.

- Feedback to users is likely to have a positive impact on energy efficiency. What is not clear is what are the potential savings that could be achieved.

- The impacts can be bigger if more control algorithms can be embedded. The dataset based on the apartment is unique and can have good impacts on others who want to do other types of data-driven research.

- End-user behavior and education is a key factor in addressing appliance and MEL energy loads. This project should make significant impact in that area. The human factors side has received less attention in general so this project will make a welcome addition.
- The following are the most valuable aspects of the impact:
    - First study of its kind in type and size, especially in terms of the ability to conduct human-in-the-loop tests of feedback strategies.
    - For multi-family buildings, the focus touches all relevant stake-holders: reduction and load-shifting: costs, CO2, comfort.
- The following aspects of the impact seemed superfluous or could use improvement:
    - The dataset is less novel (e.g. Pecan Street)
    - Not clear how truly scalable the approach is.

- While there are few published studies on the acceptance rates of energy efficiency advice, the makeup of the test group participants may skew the results overly positive. The natural language processing to obtain advice on specific devices is novel but risks obtaining inaccurate tips if not validated by engineers.

C. Progress

Based on current project efforts, the project was rated **3.33** for the degree to which the project has met ***project-specific goals.***

- On track.

- This project is in the second of three years. While there were some delays initially with procurement and installation of equipment, previous milestones were met and project is on track now to meet upcoming milestones.

- Well-done! The research progress seems on track. No concerns on this.

- Field demonstrations that include M&V, human subject testing, and multiple stakeholders can be very challenging. The team appears to have made great progress and the use of a preliminary test to shake-down the procedures and incorporate lessons-learned into the full 12 month test is welcomed.

- The following are the most valuable aspects of the progress:
    - Adjustments seem appropriate.
- The following aspects of the progress seemed superfluous or could use improvement:
    - What is the process of personalization? Is it robust in terms of false positive/negatives; over stimulation; and over-rides? Is the personalization appropriately grounded in thorough scientific research?

- Progress appears on track from presentation. Risk mitigation plans are adequate.

D. Collaboration and Coordination

This project was rated **2.83** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- A strong team to address this challenging problem.
- Good coordination between the PIs.
- It's clear how the different aspects of the effort will be integrated to achieve the project goals.

- Collaboration with facility managers and local utility company is important for meeting the milestones. Collaboration with Lucid is important for transition to market.

- This is a well-defined teamwork. It includes experts from all related areas.

- Great level of engagement of range of stakeholders.
- The following are the most valuable aspects of the collaboration or coordination:
    - The interaction with residents is properties owners (albeit a university) is very valuable.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - It is unclear how valuable and materials the collaborations with Lucid and ConEd are.
    - It is very unlikely that utility smart meters will be able to do load disaggregation. However, this work could demonstrate just another use case.

- Team does not appear to be leveraging the work of other research and commercial entities that are working on load disaggregation and energy efficiency providers.

E. Remaining Project Work

This project was rated **3.17** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The remaining project work seems to be well thought out.

- Project seems to track to meet project-specific goals.

- Well planned. But would be good if you can explore some control algorithms based on the dataset to further help correct abnormal energy consumption or maybe waste.

- Seem well prepared for full test campaign.

- The following are the most valuable aspects of the Remaining Project Work:
    - The results from the feedback experiments should be very exciting.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - Is the personalization strategy scalable?
    - The team must focus on reducing the number of features used for personalization. It would be very helpful for the community if this was done in a rigorous scientific way.
    - What is the T2M approach?

- Technical plans for algorithm development are adequate. Recommend earlier engagement with stakeholders to ensure T2M opportunities and feasibility. These activities are listed in year 3 with workshops but the initial data from year 1 and early year 2 is useful to steer future development. It's important to engage with potential off takers early in the process to avoid re-work.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Focus area: I am not aware of any other study for multi-family apartment housing.
- Use of virtual sensing (low cost software solution) to provide load specific feedback and actionable insights for users.

- The project strengths include a low cost strategy for reducing plug-loads electricity consumption, and personalized feedback generated using natural language processing.
- Access to CU housing provides a diverse platform for analyzing a large apartment building.

- It is a great work of collecting data from so many different apartments. The dataset itself will make great impacts.

- Appears to be well prepared and thought out test campaign. Appreciate the team has focused on the occupant behavior factors and are using known methods for NILM and sensing.

- The diversity of residents in the study. A unique capability of Columbia University.

- The natural language processing to scrap potential tips and personalized feedback is novel and can be applied to other areas.

2) **Project Weaknesses**

- Relying on users to act on the information provided, there is the risk of participation fatigue.

- It is not clear if disaggregation accuracy is sufficient to identify loads that may be faulty or ghost loads, since electricity consumption variations may fall within disaggregation accuracy limits. Thus disaggregation accuracy may limit potential energy savings.

- Lack of the control part. The message or email itself can only inform the apartment owners of possible energy waste, but do nothing to save energy. To make a bigger saving, automatic control of the appliances must take place.

- Test results could be inconclusive. Pilot testing appears to have helped strengthen the test design and reduce the likelihood of this.

- T2M
- Scalability of the personalization approach.
- The reliance on 10s data for NILM.
- The statistical significance of the personalization feature set.
- Manual vetting of NLP and tuning of personalization.

- Lack of coordination with industry partners that are working on similar products.

3) **Recommendations**

- To avoid end user loss of interest or fatigue, we may want to learn the individual preferences over time and adjust feedback based on their historical response to feedback messages
- Some utilities are already providing high level monthly feedback to their customers (e.g. "you use 10% electricity more than your neighbors"), benchmarking this study and results with the state-of-the-art feedback mechanism (if it exists for multifamily homes) will be helpful to quantify impact.
- This low cost solution requires a meter for each apartment. Can we quantify the ROI for an average home?

- Trade-offs of disaggregation accuracy and potential energy savings should be analyzed.
- Can energy usage patterns be used to classify demographics, for more effective feedback messages?

- Please see the previous one.

- Continue to focus on robust test design so the resulting test data and conclusions can make significant contributions.

- Secure T2M strategy
- Continue rigorous and scientific approach to personalization.

- More stakeholder engagement and use of a social scientist to validate mix of test subjects and approach for trying different feedback methods.

Project #94150c: CERC: Direct Current (DC) Buildings & Smart Grid

Presenter: Rich Brown, Lawrence Berkeley National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Overall, reviewers agreed that this project's approach of validating energy savings models of direct current (DC) power distribution in buildings and developing new digital controls to manage this distribution is good. Specifically, reviewers noted that the techno-economic analysis will be useful in driving adoption of DC-based technologies by quantifying and validating cost savings. One reviewer, however, commented that it was unclear whether the team has considered the full cost of the technology (i.e. capital costs for installation, operation, and maintenance), which could push the system's payback period beyond one year (i.e. BTO's goal). Another reviewer also highlighted that the project's modeling is based on an all-DC-buildings scenario, which the reviewer described as unlikely in the near term.

One reviewer commented that the project scope is limited to mid-sized commercial and residential buildings. Another reviewer remarked that it could be interesting to first assess the feasibility of DC power in the residential sector before transitioning to commercial buildings. Because there may not be DC alternatives for some commercial applications, one reviewer suggested also modeling hybrid DC/AC applications. One reviewer recommended that the project team conduct more field tests, while another reviewer raised concerns about the reliance on mostly Chinese-based venues for testing because of logistical and other unknown constraints. The same reviewer also recommended that cybersecurity of the system be considered, noting that it was not mentioned in the presentation.

One reviewer commented that this project will likely have a significant impact on BTO's energy savings goals, joining other reviewers in describing the potential impact of maximizing local generation and storage to greatly reduce energy losses from inverters, existing distribution systems, and other sources. Another reviewer remarked that this project should have multiple potential positive impacts on the building industry as long as photovoltaics and other types of DC-based distributed energy resources become more affordable. A reviewer encouraged the team to quantify power quality impact in terms of increased equipment resilience (e.g. fewer failures).

Multiple reviewers noted that the project scope is well defined and project work is on-time, even considering the increased complexity of working with researchers overseas. Reviewers commented further on the strong collaboration within the U.S-China project team, highlighting the project's clear benefits to both countries.

Weighted Average: 3.62 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 3.67 Remaining Work: 3.33

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- It's great to see the progress of the work between US and China. It is definitely a new research area and draws lots of attention from different aspects.

- Good approach. Team starts by showing (via modeling) the energy savings realized with buildings with DC distribution (using a bottom up/localized approach) compared to an AC baseline. The project then transitions to actual measurements and demonstrations to validate models and feasibility of the technology. Team has industry partners. Project plan is reasonable.

- The modeling and techno-economic analysis approaches are sound. The indirect benefits of better power quality should be quantified, in terms of more resilient equipment with fewer failures.
- Project is limited to mid-size commercial buildings which are likely to not have large machines for HVAC, like large commercial, or residential which make up the majority of current load (in the aggregate). All modeling is based on all DC buildings, which is unlikely for a long time into the future.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- There are lots of potential positive impacts to the building industry as long as the PV or other types of distributed renewable energy become more affordable. For PV, it will be extremely important if the DC power can be directly used instead of converting to AC and then changing back to DC.

- The project is focused on maximizing local generation and storage which should greatly reduce energy loss (invertors, distribution loses, etc.). This will no doubt make an impact in meeting BTO energy usage goal (2030 goals). Fits in with drive to coupling storage to PV for residential and commercial applications. One risk to the project is overall installation and operation costs to the technology. Not clear the team has taken this into consideration.

- The techno-economic analysis portion will be useful in driving adoption by proving cost savings. The majority of the modeling effort appears to be US led with most of the field trial engagement on the Chinese partners. The project is early and it appears that they are looking for US field trial sites. Overall, the efforts placed in engaging US and Chinese manufacturers should be commended.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals.***

- The working progress is well defined. Everything seems right on time.

- Team has demonstrated energy usage reduction via modeling. As previously noted, it is not clear if the team has considered capital costs for installing, operating and maintaining the proposed system. The payback may be much greater than one year (BTO goal).

- Project is hitting milestones on time despite the increased complexity of working with researchers that are several time zones away and speak another language.

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Would be great if the proposed work can be tested not only in the lab but in some real buildings/house. More field tests are needed.

- Based on discussions with the P/I, the team meets frequently (e.g., teleconferences with team members in China) and hosts researchers from their Chinese partners. Plans call for relying on Chinese partners for demonstration venues. Industry partners play an active role in advising research team.

- There are several clear benefits to both the US and Chinese, in terms of modeled savings, standards development, and engagement with industry participants.

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Would love to see more field tests results. Can work with other government agency to do the field tests.

- The project appears to be on schedule. I have some concern on relying on Chinese venues for most of the field demonstrations. This could take considerable time to arrange given local and country-wide customs, regulations and other unknown constraints. It would be good to start the process early in securing demo sites.

- Plans laid out appear to allow for continued success.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Great collaboration with either the university in China and other related research agencies here in the US. Good job!
- It will be really interesting to see if the DC power can be used at the residential level first, and then expand to other small or bigger size of commercial buildings.

- Focusing on the DC marketplace, establishing standards, good project team, international partners, industry advisory board. The approach taken is also a strength...start by modeling and collecting data, then develop technology and test

- Great work in enabling collaboration between the US and Chinese researchers.

2) **Project Weaknesses**

- Haven't found any.

- For some commercial applications, there may not be DC alternatives. It would be good to model mixed DC/AC applications. For command and control, there doesn't appear to be any focus on security.

- Very limited in scope for building types.

3) **Recommendations**

- More field tests.
- Standardize the tests and their results if possible.

- Secure as soon as possible the availability of the field test sites in China to avoid unexpected delays due to red-tape. Consider adding security to the design. Add modeling to support mixed AC/DC applications and closely examine the capital costs associated with installing, operating and maintaining the proposed system...especially for retrofit applications.

- Examine the total addressable market for adoption and model the building types that would have the largest impact. Don't undervalue the indirect impacts of utilizing DC power with power quality issues.

Project #99308: Experimental Validation of a New Cost-Effective and Nonintrusive BTU Meter (FluxTeq)

Presenter: Xiaobing Liu, Oak Ridge National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Several reviewers found this project's approach for validating a BTU meter's design and data processing algorithm to be technically sound and feasible for overcoming relevant barriers and technical challenges. Reviewers posed a number of questions about the project's technology, however, including how the meter will operate during a real (versus experimental) measurement, the power requirements, the accuracy required for different use cases, and usability for different fluids as well as steam. One reviewer also would have liked to see more variability between the experimental data set used for training the meter signals and the data set used for validation, while another highlighted the value of testing for edge conditions. Multiple reviewers recommended that future work should address the meter requirements for applicability across a range of pipe thicknesses, materials, and conditions.

Most reviewers expressed that this technology can have a significant impact if the price of the meter is reduced. One reviewer commented that low-cost BTU meters are a key need for energy reporting and optimization, while multiple reviewers specifically noted that the project should help facilitate more effective monitoring and control of HVAC systems in order to meet BTO's goal of 30% energy savings by 2030.

Reviewers noted that the project's collaboration is between a small business and a national laboratory, which provides access for the small business to measurement facilities and a platform for transitioning the technology to market. Reviewers agreed that the project was progressing and appeared to be on track, and most reviewers also thought that remaining work seems well-planned to meet project goals. One reviewer observed, however, that a commercialization plan does not yet exist, and another questioned whether future work is sufficiently focused on what is needed to get the technology out of the lab and into the market.

Weighted Average: 2.88 # of Reviewers: 5
Approach: 2.80 Impact: 3.20 Progress: 2.80 Collaboration/Coordination: 2.80 Remaining Work: 2.80

A. Approach

This project was rated **2.80** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Proposed approach to develop a low cost BTU meter seems technically sound and feasible.
- From slide # 6, it is not clear how these procedures will take place during a real measurement. Are they computerized and can happen automatically?
- BTU meter consists of a sensor to measure flow rate of the heat-conveying liquid and algorithm to solve convection heat transfer coefficient equation to find water flow rate. Great approach and this would overcome the barriers and technical challenges and produce BTU meter with at least 50% cheaper than conventional flow meters.
- Given the modest project budget the approach is understandable. Would have liked to have seen more variability between the experimental data set used for training the meter signals and validating them. The meter approach will need to work with a range of pipe thicknesses, materials, and conditions (e.g. degraded or scaled pipe walls). The training set only contained copper and new pipes. If there is follow on activity it would be good to address these other requirements.
- What is the power required?
- What is the accuracy required for use case?
- Does it work with steam? Probably not.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.20** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- A low cost BTU meter technology may facilitate HVAC energy savings.
- It will be good if the cost of the sensor can be dramatically reduced. The current big concern for the non-intrusive flow meter is the cost.
- If the project goals are met, the proposed cost-effective BTU meter may help facilitate more effective monitoring and control of HVAC systems to meet BTO's goal of 30% energy savings by 2030.
- Low cost BTU meters are a key need for energy reporting and optimization. Even for large chiller plants we often see customer forgo metering due to cost.
- What cost will be required for impact?

C. Progress

Based on current project efforts, the project was rated **2.80** for the degree to which the project has met ***project-specific goals*.**

- Progress has been demonstrated in hardware evaluation and design, as well as in algorithm development for estimation of heat transfer coefficients and flow rates.
- No concern on the progress. But I think the performance of these sensors should be evaluated on different size of pipes to have a fair evaluation.
- Great Progress to meet the project goals!

- Progress is on track.
- Is the accuracy good enough?

D. Collaboration and Coordination

This project was rated **2.80** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- This project is a partnership between a small company and a National Lab.
- There is no plan of commercializing this new type of sensor. Is it too early?
- The project includes a partnership between FluxTeq, a small business technology developer, and ORNL.
- The project staff had discussions with a heat pump manufacturer on integrating the FluxTeq sensor into their energy performance monitoring system. It may require further coordinate with relevant stakeholders
- This is a business voucher program and the national lab worked directly with an industry partner.
- How far away is first customer?

E. Remaining Project Work

This project was rated **2.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Project seems on track to complete remaining milestones.
- Sounds fair.
- The project has planned very well the remaining project work to meet the project goals. The work includes exploring new sensor configurations and better algorithms, conducting additional tests and integrating the meter into existing control and monitoring system at ORNL FRP.
- Project appears on track and has met its goals given its short timeline and budget. Would be good to see testing for edge conditions.
- Is the remaining work focusing on what is needed to bring this to market?

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project strength is in addressing a need for a low cost BTU meter that is currently not commercially available. Partnership between small business and national lab provides access to measurement facilities, and a platform for transition to market.
- New technology has been applied to develop a new sensor for flow measurement. If the unit price of this sensor can be reduced as promised, it will help facilitate more effective monitoring and control of HVAC systems.
- New nonintrusive way to measure flow rate, cost effective BTU meter with at least 50% cheaper than conventional flow meters.
- The meter could be a cost effective way to monitor and control of HVAC systems to meet BTO's goal of 30% energy savings by 2030

- Novel approach to developing a low-cost BTU sensor that would be a key enabler for metering.

- Not many players in market, and there is a need.

2) **Project Weaknesses**

- In this project only one type of pipe (copper) has been considered so far.

- The evaluation of the new sensor is not a full factorial test plan. Lots of important parameters are missing such as fluid being measured (water? gas? or something else).
- The minimum and maximum flow rate the sensor can be measured is not clear.
- What are the minimum and maximum process temperatures?
- The size of the pipe should be varied during the test and evaluation process. Please be careful when you just give a single number on the accuracy based on one type of test.

- Need additional tests covering a wide range of operations and configurations.
- The meter needs a power supply.

- The training and validation data set was small and appeared to overlap. The scalability of this approach to a range of pipe types, sizes, and conditions (including old poorly maintained and documented pipes) is a key risk.

- Cost and power requirements.
- Accuracy.

3) **Recommendations**

- Different pipe types should be considered, for example stainless steel.

- Please refer question 12.

- Additional tests covering a wide range of operations and configurations.

- Would like to see the team address these challenging edge cases - potentially through field demonstration to demonstrate all-in cost and scalability.

- Identify first customers. Determine required accuracy.

Emerging Technologies
Sensors and Controls

Multifunction Plug-and-Play Wireless Sensors

Project #31690: Passively-Powered Adaptively-Located Flexible Hybrid Sensors

Presenter: David Schwartz, PARC, a Xerox Company
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Overall, reviewers agreed that this project is implementing an innovative and well-thought-out approach for a low-cost, remotely-powered sensor platform, with one reviewer highlighting the strong capability of the platform's equipment to be adapted to multiple communication protocols, building management systems (BMS), and transducer elements. Most reviewers, however, also pointed out limitations or uncertainties with the technology, including concerns over the power supply, communication distance, integration of multiple sensors within a single zone, and possible line-of-sight interference. One reviewer was also unclear about the backward communications from BMS to the sensors.

Multiple reviewers noted that the project is likely to meet programmatic goals related to wireless communication, reduced installation cost, and interoperability. However, reviewers disagreed on whether the project will meet its energy savings targets. One reviewer commented that the amount of energy savings from improving the granularity of building environmental (e.g., temperature and humidity) monitoring through additional sensors remains to be proven. Occupant comfort and thermal management might be more impactful applications. Another reviewer was concerned about the payback period limiting adoption and resulting energy savings.

All reviewers agreed that the project has progressed very well to-date and looks to be meeting scheduled planned milestones and deliverables. Reviewers also agreed that the project has a good mix of appropriate stakeholders, including BMS providers.

While most reviewers described the remaining work as meaningful, reasonable, and expected to be completed within the envisioned timeframe, one reviewer expressed concern over the short amount of time remaining to complete development of the remaining electronic components as well as to conduct the final testing and validation. Another reviewer noted that the project presentation did not include a commercialization process or plan. Finally, multiple reviewers suggested addressing cybersecurity issues, particularly in regards to vulnerabilities related to communication protocols.

Weighted Average: 3.49 # of Reviewers: 4
Approach: 3.50 Impact: 3.25 Progress: 3.75 Collaboration/Coordination: 3.50 Remaining Work: 3.50

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The RF power delivery and sensor localization mechanism is fascinating.
- Limitations of RF power -amplification of the signal

- The locations of these sensors can be figured out through the angle, but some level of redundancy is needed in case the failure of sensor communication.
- The sensor network seems like a star topology which limits the communication distance. I am not sure if your RF hub can talk to each other as well to further extend the communication distance.

- The overall project is well thought out. The economics look good and the project is on schedule. The P-PAL technology is a great solution to handling situations where there is insufficient sensors or sensor placement needs to be adjusted. A RF-powered sensor that sticks to any surface is definitely going to help industry achieve the DoE's energy efficiency goals. I have some concern over possible line of sight interference and how multiple sensors within a single zone are handled by a BMS, but overall....I really like this project and I do believe the product that is developed will be of great use to the industry.

- The proposed approach is reasonable and convincible to reduce related sensor costs, especially about hardware and commissioning.
- The project also proposed an innovative approach for the self-sufficient power supply.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Program goals related with wireless communication, reduced installation cost, interoperability etc. are likely to be met. However the amount of energy savings that can be realized, by having additional temperature or humidity sensor in a thermal space (fine grained building sensing), remains to be proven. Sensor fusion strategies and customized controls may be needed. We will also need systems with multiple VAVs per zone.
- Guidelines for sensor placement is needed to maximize the technology benefit and reliability. How will the tag sensor be protected from physical abuse?
- Occupant comfort and productivity may be a stronger derivative of the sensor solution. These sensors may also be more useful for localized thermal management system e.g. ARPA-E Delta program

- If the communication distance can be further expanded, the technology will be more attractive.

- As noted in the approach, I do believe the P-PAL technology is going to definitely make an impact in meeting DoE energy usage goals. One concern I have is that the payback...at least in commercial sector is greater than 3 years. The BTO has expressed a desire for a one-year payback period. If the cost of the technology can be driven down a bit more that would clearly be helpful....definitely help with marketability.

- The expected sensor developed by this project may achieve light, portable, and self-sustaining features, which may have very broad impacts. Particularly, it may achieve the benchmark for power supply of sensors. It also shows strong interoperability features to be adapted to other protocols and sensor types.

C. Progress

Based on current project efforts, the project was rated **3.75** for the degree to which the project has met ***project-specific goals*.**

- Planned completion date is 9/30/2018- 5 months away with ~170K to go.
- The major remaining task is demonstration. Sensor to BMS communication is established.

- Seems good to me. Everything is on track.

- Based on the original goals of the project, the team is spot on and achieving their objectives. Again, payback period is a concern.

- The calculations using cost models to determine the life-cycle cost are reasonable. The current status of the project is at the testing and validation process of the developed hub design and algorithms. It seems that the project has been progressed very well and meet or slightly beyond the scheduled plans. The last BMS implementation part has not been accomplished, but the collaborations with BMS collaborators and the software integration with BMS may ensure the successful final implementation and demonstration.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Interaction with stakeholders OK. Choice of platform agnostic partner is a good idea.
- Eventually wants sensor to work with other commercial BMS providers / OEMs

- Strong industry support.

- The technical team has extensive experience in flexible electronics, sensors and RF. Industry partner is focused on building control integration, BMS software and provides a field testing site. Team is also working with NextFlex to ensure manufacturing is considered in the design and product development.

- The current collaborations with energy management system firms for leveraging electronics developed are important, and the presented activities and plans are meaningful. In overall, the project has appropriate and good mixture with stakeholders. Only one concern during the presentation Q&A, although the connections between BMS and their electronics are/were able to be set up available, it seems that the backward communications from BMS to the sensors are still unclear.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Remaining project work and funding seems reasonable.

- I would like to see by applying this sensor, how the energy can be saved.

- Overall, the project looks in good shape, however, I'm a little concerned about the short length of time left in the project. Given that some of the electronics/integration are still being developed along with a final demonstration (which typically produces some unexpected design/rework issues), there is some risk that the team will not complete their project by the end of Sept 2018. Just a concern.

- The final testing activities are meaningful. Also, from the current status and achievements of the project, it can be envisioned that the remaining works can be achieved within scheduled timeframe and objectives.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Flexible hybrid printing - for reduced cost.

- This is the research about new low-cost, easy to install, fully-functional sensors. If the collected sensor data can be combined with advanced control strategies, the energy savings can be achieved as projected.

- Lots of strengths: Low cost (although payback is a concern), ability to place the sensor just about anywhere, remotely powered with RF, self-locating sensors and adaptable to multiple sensors. Project team is seasoned/experienced. Overall plan is reasonable (with some risk). A very good project with many strengths.

- The project approach and plan are quite clear with innovative solutions for self-sufficient power supply to sensors. It also shows the strong abilities to be adapted to other protocols, multiple sensors, and BMS. The collaborations with BMS and other stakeholders are appropriated identified and performed.

2) **Project Weaknesses**

- Cost model is based on multiple assumptions especially for RF hub installed cost. How many will be needed?
- How useful will this technology be for small zones? Are we assuming it is targeting large multi-occupant spaces? Need to be specific and discount baseline energy cost based on target space type. Projected energy savings is most likely not 30%.
- What is the accuracy target for the sensors especially humidity?

- Please be specific about the target market. Are these sensors for commercial building application or residential house? For a commercial building, more RF hub will be needed which will increase the total cost of the sensor network.
- The application will be indoor, so how these RF signals penetrate through objects, walls or other obstacles? The communication frequency must be very high. Therefore, the correct frequency must be chosen to make sure it can navigate through the household objects.

- It's not clear how the technology will be impacted by line-of-sight blockages or interference from other RF sources. Also, what is the plan for integrating multiple sensors within a single zone? Specifically, it's not clear how a BMS will utilize data from multiple sensors from the same zone. Finally, it's not clear if the design has considered cyber security. Information from these sensors can be used to determine if a space/office/room/zone is or is not occupied. Patterns of usage could be collected and used for nefarious reasons. Also, what about built-in fault detection?

- The project presentation does not include the commercialization process and plans. Some practical limitations on the RF modules and sensing network may exist. The communications between BMS and sensors could be stronger.

3) **Recommendations**

- Assess vulnerability of the sensor system, consider cybersecurity issues especially with communication protocols.
- How reliable are the sensors--can we tell when a sensor is faulty? E.g. battery not charging or discharging?

- Thanks for the presentation, it is very neat.

- I recommend addressing the line-of-sight problem and the cyber security issues. I also recommend bringing the payback down to something in the 1 to 1.5 year range for the commercial sector to improve the technologies marketability. Again, these are recommendations. As is, I think this project will have an impact on the energy efficiency sector.

- N/A

Project #31692: All-Digital Plug and Play Passive RFID Sensors for Energy Efficient Building Control

Presenter: Hai Xiao, Clemson University
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Most reviewers agreed that this project's approach in eliminating the analog to digital converter (ADC) logic and developing an all-digital wireless sensor to reduce cost is quite innovative. One reviewer particularly appreciated the use of gray code pattern embedded in the common plane, while another reviewer identified the reliance on RFID for identification and positioning as a major strength. Another reviewer, however, was unclear on the power supply approach and expressed concerned about power consumption issues. Clarification was also requested by one of the reviewers on the digital acquisition system attached to the sensor for wireless temperature measurements.

Multiple reviewers noted that this project is likely to contribute to meeting the BTO programmatic goals for low-cost, wireless sensor networks. In terms of programmatic energy savings goals, however, one reviewer remarked that the amount of energy savings realized will ultimately depend on the sensor application or service, while another reviewer commented that the sensors could have a significant energy savings impact if they can be scaled to form a network and connected with advanced control strategies. One reviewer stated that the current cost per unit is already considerably less expensive than existing products on the market, remarking that this platform will be quite competitive and enable BTO's energy savings goals if the price target can be further reduced to yield a 1-1.5 year payback.

All reviewers agreed that this project has a strong team, which demonstrates appropriate skills, experience, and range of expertise. One reviewer, however, commented that the project's industrial engagement seems weak, while another specifically recommended that the project team initiate engagement with building scientists to improve sensor design, implementation, and integration.

Multiple reviewers agreed that the research completed to date is on schedule and demonstrates clear progress, including temperature sensor hardware design and software processing, as well as demonstration of the temperature sensor prototype. Most reviewers remarked that remaining project work also appears appropriate and logically planned, although one reviewer had some concerns regarding completion within the performance period of the award due to activities that could cause some delays (e.g., development and testing of the humidity sensor, development of a non-contact reading approach using self-capacitance). One reviewer also observed that the plans and related activities for practical integration and commercialization were not clear. Reviewers offered a number of recommendations for the project team to consider moving forward, including engaging in additional studies on communication distance where obstacles are present, stress-testing the sensor to better understand sensor reliability, conducting measurement accuracy and uncertainty analysis, reducing the size of the sensor to fit into more applications, and taking steps to address cybersecurity concerns.

Weighted Average: 3.50 # of Reviewers: 4
Approach: 3.50 Impact: 3.25 Progress: 3.25 Collaboration/Coordination: 3.75 Remaining Work: 3.75

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- New way of thinking. Particularly like the idea of digitization.
- The project claims the RFID sensors wirelessly measure the temperature at a certain distance, but from slide 11, figure (b), there is still a digital acquisition system attached to the sensor (wired). So it is a little bit confused here, how this sensor been claimed wirelessly measure the temp. and transmit the signal? Please clarify if possible?
- The overall concept is great...reduce power consumption by eliminating the ADC logic and relying on low-power sensor components. One item that I missed was how the device was getting its power and how much power is being consumed by the device. So although I really like the idea, I'm concerned about power consumption issues. I particularly like the idea of using the gray code pattern embedded in the common plane...great idea.
- The project approaches to achieve low-cost and simplified processing sensors are quite innovative upon their sensor redesign and sensor material reselections. The approach for temperature sensors utilizing bimetal materials are not new methods but the leveraging between sensor itself and simplified processing method in this project is still very interesting and valuable. The approach for humidity sensor design and process is still underway, and the PI didn't show any potential methods to resolve that barrier using the same design and process logic.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Program goals related with low cost, wireless communication etc. are likely to be met. However the amount of energy savings that can be realized depends on the application or service they are used for.
- If the sensor can be further connected to form a network and combined with advanced control strategies, it will make greater impacts on the overall building energy savings.
- During the presentation, the cost/per unit was specified at $8.35 which is considerably less expensive than current wireless technologies. On the other hand, similar price targets were specified for other products and the advertised payback was in the 2-3 year range. If the price target can be brought down resulting in a 1-1.5 year payback, I believe this product will be quite competitive in addition to help in meeting the BTO objectives of producing energy savings of 17% for HVAC and 35% for lighting by 2030.
- If successful, the project may get rid of batteries and signal processing module. The major impacts are to achieve very simple (without complex sensing, processing, and related components) but effective sensors for building environment. Even though some environmental variables' sensing methods are not that clear, the potential impacts on both market and practical could be great.

C. Progress

Based on current project efforts, the project was rated **3.25** for the degree to which the project has met ***project-specific goals.***

- OK
- The research showing in the presentation seems good. Everything is on track.

- According to the project schedule, the team is on track. Having said that, the humidity sensor still needs further development and testing which adds some risk to the project in meeting its overall goals by the end of Dec 2019. I also believe the development of a non-contact reading approach using self-capacitance might add some delay to the project. Just some concerns.

- The project shows very detailed and clear progress in temperature sensor hardware design and software processing. The demonstration of the temperature sensor prototype is also completed. In overall, as the project funded in 2016, the project has progressed very well and achieved the expected outcomes at this stage.

D. Collaboration and Coordination

This project was rated **3.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Strong team.

- Got stakeholders from all different aspects range from academia to industry and national lab.

- The project team has multiple experiences and expertise that span tech development, building control/management and commercialization. Relying on bi-weekly meetings to coordinate and collaborate appears to be working well. A very strong team and management plan.

- The project has very strong research collaborations from material science, sensors, signal processing, electronics, to commercialization. The team shows very combined and appropriate skills for this project. It seems that working collaboratively with some building physics or environment specialists may improve the sensor design, implementation, and integration.

E. Remaining Project Work

This project was rated **3.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- OK

- The projected remaining work showing in the slide is well defined. Please do study the communication distance when there are obstacles presented.
- Both humidity and temperature monitoring are important, make sure you can make both of them available but in a relatively small size.

- Looking at the schedule and what remains (e.g., humidity sensor development, distance reading blocking, integration and testing/demonstrations) appears to be appropriate. I do have some concerns with unexpected events stretching out the schedule, but at this point, the project appears to be in good shape.

- The technical parts of the next phase are meaningful and logically planed. Humidity sensor design and processing will be challenge but should be able to be achieved upon the research team skills and current achievements.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The team seems to consist of all required skill-sets. Not sure what Harvard contributions are and how they work together.

- A new type of sensor which can be used to help identify and detect faults in building operations.

- A major strength of the project is that energy usage of the device is reduced as an ADC is not needed. Another major strength is relying on RFID for identification and positioning due to the maturity of the technology and availability of existing technology. Finally, the team is a major strength as they have the expertise and experience to develop and transition the technology.

- In overall, the project aims to a very interesting but valuable aspect in the field building environment sensors. The research team is highly interdisciplinary and mixed very well, and the collaboration activities are meaningful and logically planned. The current project progress is clear and meet the expected objectives.

2) **Project Weaknesses**

- All hardware - reliability may be an issue. Lots of moving parts, contact based technology.
- Industrial engagement seems weak.

- The title of the project is plug and play passive RFID sensors, but from the slides, the sensor is still connected to the digital acquisition system through hard wires. Will the wire be physically eliminated by the end?
- It will be ideal if the size of the sensor can be reduced to fit into more applications.

- Again, it's not clear how much power is consumed by the device nor how the device is powered (by the RF?). Also and as noted by the P/I, there are potential problems with communications interference complications that need to be worked out. Another weakness is the apparent lack of taking cyber-security into consideration in the design. The actual transmission of sensor data (temp, humidity, etc.) itself can expose information that occupants may not want known by others (i.e., when I'm home or not home).

- Building environmental experts/stakeholders should be involved into the project at certain stages in the future. The plans and related activities for practical integration and commercialization are not clear.

3) **Recommendations**

- Critically consider the reliability of the sensor. Stress testing could be useful.

- Make it clear which part is wireless and which part is wired.
- Do some measurement accuracy/uncertainty analysis.
- Be clear how does the sensor transfer out its measurement results if no power source is provided, is it hard wired or wirelessly?

- Definitely determine the power requirements of the overall system - particularly under different operating conditions. Expose the temperature and (eventually) the humidity sensor to every-day elements (high, low humidity, smoke, vibrations, etc.) to fully test the device. You might want to address cyber-security.
- Overall, I like the project.

- Adding building environmental specialists/stakeholders into the team.
- Humidity sensor design may be achieved using conventional building physical concepts - air motion/ moisture mechanism.

Project #31693: Hamilton: Flexible, Open Source $10 Wireless Sensor System for Energy Efficient Building Operation

Presenter: David Culler, University of California, Berkeley
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed that this project's approach for developing a low-cost wireless sensor network is sound, with one reviewer referring to the approach as being "right on target" and another describing it as "hit[ting] on all cylinders." Multiple reviewers also specifically noted the thorough technical approach taken by the team to develop robust system-level cybersecurity for the platform. One reviewer, however, noted that it did not appear that a new framework was being developed, but rather the innovation was in the integration of existing methods and hardware into a single platform.

Reviewers were varied in their assessment of the project's contribution to BTO's programmatic energy savings goals due to the enabling nature of the technology being developed. One reviewer remarked that if the project team can keep the sensor cost under $10, then the project will definitely contribute to the 2030 energy savings goals. However, another reviewer noted that the quantitative impacts of this technology were not addressed in terms of energy in the presentation, with another reviewer similarly commenting that energy savings impact will ultimately depend on the application and services the sensor networks are used for.

In terms of BTO's technical, non-energy savings goals, reviewers noted the interoperability and cybersecurity features being developed may have strong impacts on building management systems and controls. Reviewers commented that the project's open-source approach may also facilitate commercialization through the integration of other devices and systems. Furthermore, the scalable design of the platform may result in new findings and changes in practice, including overcoming the technical hurdles to implementing shared-controls for home appliances and grid services.

Reviewers generally agreed that the project benefited from a capable team with good connections and interactions with universities, labs and, industry. One reviewer, however, expressed a lack of clarity about how much the project team had interacted with industry partners in the development of its technology, while another encouraged the project team to explore the possibility of further collaboration with government entities for field testing purposes.

Although multiple reviewers described some risk of possible schedule slippage due to unforeseen events, one concerned reviewer explicitly expressed confidence in the project team's capabilities to overcome uncertainties and remain on schedule. One reviewer was supportive of the team's exploration of buildings-to-grid applications and learning-based models, while another reviewer expressed a desire to see more focus on learning-based models and sensor data analytics. Multiple reviewers commented that a commercialization plan should be considered.

Weighted Average: 3.49 # of Reviewers: 5
Approach: 3.60 Impact: 3.60 Progress: 3.60 Collaboration/Coordination: 3.20 Remaining Work: 3.40

A. Approach

This project was rated **3.60** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Proposed approach seems OK.

- Right on target. Very solid technology to help reduce building energy waste and provide situational awareness for optimization of environmental conditioning, lighting, and other building functions.

- A project that hits on all cylinders - develop a low cost wireless sensor, a resilient information bus/sensing platform that connects all sensors and components (plug and play) and security via the block-chain and other technologies. Research builds on prior DoE and DoD (DARPA) research. Objectives are well defined. Team has integrated security into the design. Overall approach is very sound.

- The approaches to this project are to develop open source wireless sensors and integrative platforms. The methods and project activities are meaningful. However, from the presentation and reported slides, the methodological innovations (such as integrated analytic and control algorithms, sensor system design, etc.) are vague and not to develop new framework but rather integrate the existing methods and hardware into an integrative platform.

- The following are the most valuable aspects of the approach:
    - The team has valuable experience developing wireless sensors.
    - The teams CS expertise is impressive and a welcome addition to the BTO community.
    - The thorough technical approach to cyber-security is innovative and impressive compared to other work just saying they'll use existing cyber-security standards.
    - The focus on design-time modularity is important for commercialization. End-use modularity is not required.
- The following aspects of the approach seemed superfluous or could use improvement:
    - The PI did not address the issue of cost vs price. A $10/node cost could be a $20/node price, which isn't too far from where we are today (e.g. Amazon Dash).

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The energy savings impact depends on the application and services the sensor is used for.
- This technology is an enabler.

- If the deployment of the low-cost sensor can be made possible, and the communication infrastructure can be made secure and robust, this wireless communication technology can be very attractive.

- If the team can keep the sensor cost to less than $10 while maintaining performance, the project will definitely contribute to the 2030 BTO energy efficiency goals. The plug-and-play support and the built in security - although not directly related to energy reduction - greatly adds to the robustness and utility of the technology.

- The potential interoperability and security of this developed system may have strong impacts to BMS and building control areas. The open source-method may also facilitate the integration of other devices and methods towards technological commercialization.

- The following are the most valuable aspects of the impact:
    - This project could overcome the technical hurdles to implementing shared-controls for home appliances and grid serves that would ultimately contribute to BTO program goals.
    - The hardware side of the project is impressive, but the project really shines in the network layer cyber security.
- The following aspects of the impact seemed superfluous or could use improvement:
    - The quantitative impact of such a technology is not addressed in terms of energy. Neither is how technical tradeoffs effect energy impact.

C. Progress

Based on current project efforts, the project was rated **3.60** for the degree to which the project has met ***project-specific goals*.**

- Ok

- From their slides no. 7, the progress of the project seems very promising!

- According to their project plan, the project is on schedule. The team has quite a bit still do so there is some risk in meeting all objectives by the end of the project. On the other hand, the project team is very experienced and capable - risk is low.

- The major functional modules have been developed at this time, and the demonstration of resilience and security is also completed and showed some reasonable results.

- The following are the most valuable aspects of the progress:
    - The team designed a WSS that could conceivably hit the $10/node target.
    - The team solved an important problem in the field with their "proof of authorization" approach.
    - The testing of the algorithm on the whole of SF is impressive and shows that the team is thorough in their approach.
- The following aspects of the progress seemed superfluous or could use improvement:
    - Does the existing "CORE" PCB require special PCB materials? E.g. how simple is the CORE to integrate into any arbitrary design.
    - How easy is the system to program? Language and API specifics were not mentioned.

D. Collaboration and Coordination

This project was rated **3.20** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Seems to have a strong team. Good industrial interest and engagement.

- Will it be possible to have more collaboration with the government entities to do some field testing? To quickly commercialize the technology will be another anticipation.

- A very capable team with considerable knowledge and expertise. It's not clear how much the team has interacted with industry partners in the development of their technology.

- The project has strong collaborations and connections from universities, labs, and industry. The activities, such as academic-industrial meetings and co-publications, are also well performed.

- The following are the most valuable aspects of the collaboration or coordination:
    - The team is disseminating results well both through academic channels and their commercial partners.
-

- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
    - It is unclear what the next steps are for the tech after the project concludes.

E. Remaining Project Work

This project was rated **3.40** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- OK

- Would like to see more work on the sensor data analysis and learning-based models. Other than this, the remaining work is well planned.

- Overall, some risk to possible schedule slippage due to unknowns, but the project team is seasoned. I really like the idea of exploring learning-based models (advanced analytics and control algorithms). The work with bldg-to-grid (e.g., maximizing DR events, etc.) is also something that I'm pleased to see the team planning to investigate.

- The building scale implementation and demonstration need to be conducted in the remaining project. The commercialization plan and activities are not that clear.

- The following are the most valuable aspects of the Remaining Project Work:
    - The team has made the first step over many of the hurdles (e.g. low-cost hardware and the delegation of trust algorithm).
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - It is unclear how bumpy to anticipate the road ahead of smoothing out issues of the major breakthroughs the team has made.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Cyber-security focus.
- Integrated solution to reduce assemble cost.

- A new sensor infrastructure with wireless sensor cost lower than $10 seems promising. If the corresponding savings can be achieved, this technology will be really attractive to the building industry.

- Security is built-in at the foundation level! Support for plug-and-play, the plan to investigate learning-based models, and support for bldg-to-grid....all major pluses. Great project.

- The project has great potential impacts on the existing building sensing and processing system applications. Especially, its open-platform and scalable design of infrastructure may achieve some new findings and changes in practice.

- The delegation of trust algorithm is the biggest breakthrough the team has made.
- The low-cost WSS is an incremental, yet important, improvement over the SOA

2) **Project Weaknesses**

- The project deliverables are not clear.

- Not sure.

- This project has a large number of moving parts...low-cost wireless sensor, plug-and-play architecture, built-in security and so on...possible integration challenge. On the other hand, this also is what makes the project appealing...a true system-of-systems solution to complex problems. Other than that, I think this is a very sound project and great platform.

- It doesn't show strong innovative methods/solutions in this project. It seems that the developed analytic and control algorithms upon advanced techniques (learning-based models, etc.) for securing resilience are the major improvements at here but yet to be developed at this time.

- The team may have trouble convincing the market to adopt their tech, specifically the software, given that it is such a transformational change.

3) **Recommendations**

- N/A

- N/A

- Focus on getting the cost of the sensor as far below $10 as possible given that BTO wants to see one-year paybacks. Other than that, keep doing what you are doing.

- N/A

- The market is hot for block-chain tech, I hope that the team has good advisors to help them navigate the start-up and VC space.

Project #32693: Energy-harvesting, Self-calibrating Wireless Sensors for Improving Energy Efficiency in Buildings

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

Brief Summary of Reviewer Comments

One reviewer noted that the project's approach is sound, highlighting its focus on developing a low-cost, self-powered, multi-sensor platform that can easily be placed on any surface; this reviewer was concerned, however, because cost data and expected payback were not presented. The other reviewer found the information presented on the project's novel technical improvements and innovation to be unclear. One reviewer identified one of the project's strengths as its reliance on low-power consuming components and energy harvesting to prolong the operational power lifetime and increase recharge rates. The other reviewer, however, recommended focusing future work on either (1) new power-supply methods for wireless sensing and processing or (2) new algorithms to balance and utilize energy.

One reviewer commented that this project will contribute to BTO's programmatic energy savings goals. The other reviewer, however, remarked that while synergistic efforts and platforms from this project may lead to great impacts for building environment sensor technologies, the presentation was vague on how the project will achieve some key potential impacts in terms of energy savings, sensor optimization relative to initial design, and interoperability.

Reviewers agreed that a majority of the project's expected objectives have been completed. However, one reviewer noted that it is not clear if the team has accounted for issues such a signal blockage or on-board fault detection, and was concerned that there may not be sufficient time to fully test the technology in various environmental conditions.

Reviewers found solid collaboration and coordination across the team, including manufacturing partner to ensure cost and payback are considered. Both reviewers also recommended that cybersecurity be considered in implementation of testing of the platform.

Weighted Average: 3.03 # of Reviewers: 2
Approach: 3.00 Impact: 3.00 Progress: 2.50 Collaboration/Coordination: 3.50 Remaining Work: 3.00

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is sound...focusing on a low-cost, self-powered, multi-sensor platform that can easily be placed on any surface. I do have some concerns in that I didn't see cost data or expected payback. On the other hand teaming with Molex does provide confidence that the economics are there to support pursing this technology.

- The project focuses on developing multidisciplinary integrative platform for low-power wireless and multifunction sensors. It also adopts optimization methods to balance the energy storage and use in terms of PV cells. In overall, the project is quite developmental via integrative and collaborative way but the technical improvements and innovations are not clearly presented or provided.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- As noted in the approach section, a low-cost, low-power, multi-sensor platform that can be placed anywhere within a space (residential and commercial) is going to help BTO achieve its 2030 energy usage goals.

- The synergistic efforts and platforms may lead great impacts on the building environment sensor technologies. The impacts of general sensor and control technology are reported. However, for this particular project, how to achieve some key potential impacts in terms of energy savings, optimizations vs. initial designs, and interoperability abilities is vague. The major accomplishments area about PV cell-powered wireless sensors using additive manufacturing techniques. However, using PV cells as the power source for wireless sensors has been developed for years, and many types of such sensors have been applied in the area of environmental monitoring systems.

C. Progress

Based on current project efforts, the project was rated **2.50** for the degree to which the project has met ***project-specific goals.***

- It appears that the project is on-schedule with final testing/demonstrations to be completed. As previously noted, it is not clear if the cost per unit will be below $10/unit. In addition, it's not clear if the team has accounted for issues such as signal blockage or on-board fault detection. I believe these items will need to be addressed to meet the project goals.

- The key tasks about circuit and sensor printing/manufacturing, PV power supply, wireless transmission, and real implementation and testing have been accomplished. It seems that the original expected objectives have been achieved.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- A solid team that clearly is collaborating. The fact that the team has produced a working prototype clearly demonstrates a close partnership.

- Three industrial partners including manufacturing partners and printed electronics have been involved in this project. It presents good multi-disciplinary collaboration and integration.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- I do have concerns that there may not be sufficient time to fully test the technology in various environmental conditions. For example, what if smoke lands on the sensors...what is the performance hit? Is this part of the current testing?

- The project is reaching to the final period of the project. The demonstration in real buildings will be continued but most proposed/developed techniques have been validated. More dissemination activities may be needed.

F. Additional Comments and Recommendations

1) **Project Strengths**

- A very thin flexible sensor platform that contains multiple sensors, requires little power and can be located just about anywhere within a building is very attractive. Teaming with Molex is also a major strength...ensures market/economic issues are considered. The sensors themselves appear to have a very stable operating range. Relying on low-power consuming components and energy harvesting to prolong battery life and stretch out recharge rates.

- The project has appropriate and strong integration among different disciplines, partners, and techniques. The developed prototype makes a good example for such good collaboration and integration. Most technical tasks have been successfully achieved and finished.

2) **Project Weaknesses**

- It's not clear if the price target was met (less than $10/unit). Also, it doesn't appear that the team took signal blockage into consideration or addressed cyber security issues. Also, what about on-board fault detection capabilities?

- The project is more to do with development and integration leveraging the existing techniques and methods but lacks technical innovations and improvements.

3) **Recommendations**

- Address some of the weaknesses previously noted with unit cost being a priority (if not already addressed...again, I may have missed this during the presentation) followed by thorough testing. Cyber-security is also important.

- For the future work, the teams could either focus on new power-supply methods for wireless sensing and processing or new algorithms to balance and utilize the energy.

Emerging Technologies
Sensors and Controls

Occupant-Centric Sensors & Controls

Project #30008: SBIR: Optical Humidity Sensors for Building Energy Performance and Air Quality Control

Presenter: Jesús Delgado Alonso, Intelligent Optical Systems
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers agreed that this project's approach to the development of an optical sensor for humidity monitoring and air quality control is well-structured to meet the project's goal, with one reviewer flagging that the project's rigorous approach is borrowed from safety-critical applications in the aerospace industry. One reviewer expressed a minor concern that the methodology for simulating long-term sensor operation (i.e. stress testing) could be better defined. Another reviewer inquired as to how the team will estimate the final cost target of less than $10 per unit since it was not included in the presentation.

Most reviewers agreed that if the project team is successful in producing a humidity sensor at the targets specified (i.e. less than 1% drift after 10 years of operation and $10 per unit), then the project will contribute to BTO's programmatic goals related to building environmental monitoring for energy management. However, multiple reviewers were concerned about the progress to-date and remaining schedule, with one reviewer commenting that the three months planned for field validation seems short, and another reviewer recommending the development of a risk mitigation plan to assist the project team with their schedule.

All reviewers agreed that the project team possesses relevant expertise with meaningful collaboration. However, one reviewer commented that the project could benefit from collaboration with the building environmental systems integration community, which is currently lacking.

For future work, one reviewer suggested tailoring performance testing to the humidity sensor requirements for building energy efficiency, while another reviewer encouraged the project team to make sure to address cyber security concerns.

Weighted Average: 3.18 # of Reviewers: 3
Approach: 3.33 Impact: 3.33 Progress: 2.67 Collaboration/Coordination: 3.33 Remaining Work: 3.00

A. Approach

This project was rated **3.33** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Rigorous approach borrowed from safety critical application - aerospace and space.

- The approach is very straight forward and well thought out. Testing methodology for simulating long-term operation (stress test) could be better defined, but the teams involved (Intelligent Optical Systems, Circuit Seed, LLC, etc.) are seasoned so this is a minor concern. One area of concern is how the team will estimate the final cost of the technology. The target cost is less than $10/unit, but nothing presented backs this up.

- The project approaches are clearly presented and well-structured to achieve the project goal. The central feature is to develop and use small size low-cost and -power luminescence detectors. With additive manufacturing techniques, the design and architecture of the sensors could be well accomplished.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.33** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Didn't see much of interoperability etc. Seems to focus on the sensor element.
- Most useful where requirement for Humidity sensor is high -hospitals?
- Buildings, you want to be within a range. Can you optimize around the bounds rather than the full envelope?
- With optimized materials, will sensor system cost still be less than $10-- what is the
- Sensor element target is $10. What is the installed cost?
- Sensor element vs chip failure- is the idea here to license a sensor on a chip?

- If the team is able to produce a humidity sensing device capable of less than 1% drift after 10 years of operation for under $10/unit will definitely contribute to the program goals.

- If successful, the project can provide more stable miniature humidity sensors which may greatly impact on building environmental monitoring and other element applications.

C. Progress

Based on current project efforts, the project was rated **2.67** for the degree to which the project has met ***project-specific goals*.**

- Looks good.

- The team is currently working Tasks 3-5 (tasks 1 and 2 are completed). Although the team appears to be on schedule (roughly in the middle of the project) I'm concerned that these tasks (3-5) evaluating the RH sensor and the development of the electronics for the overall unit could take longer than scheduled. In addition, scheduling only three months for system validation in the field seems short.

- It seems that the project progress is a little behind the scheduled tasks. Only two tasks have been completed since the start of the project in 2016. The stress tests described in the report and presentation are clear and performed very well and reasonably under extreme conditions.

D. Collaboration and Coordination

This project was rated **3.33** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Good combination - a sensor and an electronic company.
- The team is executing well here. They partners consist of the technology developer, a product developer, a market research firm and a firm that is focused on creating business opportunities. Team meetings/discussions are frequent ensuring all members are on the same page. Good job here.
- The collaborative activities and methods are meaningful, and the expertise skills of the team members are well structured and blended. The major concern is that the building environmental system integration and collaboration is lacking and should be valuable and appropriate to the project.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- OK
- Again, I have some concerns about the team overshooting their tasks 3-5 (and possibly task 6) timelines and, therefore, putting pressure on the remaining tasks...particularly task 9 which is focused on incorporating sensing other gases, etc. A risk mitigation plan would be good.
- Eight tasks are still remained, but the general activities for conducting these tasks are reasonable.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Accuracy & robustness of the sensor element.
- Strong team with considerable experience. Considerable depth and knowledge in the relevant technical areas.
- In general, the project has been clearly described and presented, and the research approaches are also well and logically structured. The stress test with extreme conditions is also meaningful.

2) **Project Weaknesses**

- Stakeholder engagement seems weak.
- Not clear if the team has a project schedule risk mitigation plan in place (i.e., what if a task requires more time to complete than scheduled?). It's also not clear if the team will achieve their $10/unit cost target. There is no indication on how they will achieve this.
- The project schedule seems need to be adjusted according to the current accomplishment. Some connections to the building management systems would make the project stronger and the implementation / demonstration part.

3) **Recommendations**

- Tailor performance testing to the humidity sensor requirement for building energy efficiency.

- I would definitely take another look at the schedule and come up with a risk mitigation plan to address possible schedule slippage. I also recommend coming up with the appropriate calculations to demonstrate that the cost for the product will meet the cost target.
- I also would address how the team will handle cyber-physical security. This is an edge device that has a microprocessor that will be communicating with other systems. What steps are being taken to ensure this device/technology is cyber-secure?

- The connection to BMS collaborators is recommended, especially for the second-half of this project.

Project #31691: Human-in-the-Loop Sensing/Control for Commercial Building Energy Efficiency and Occupant Comfort

Presenter: Anthony Rowe, Carnegie Mellon University
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers expressed mixed feelings regarding this project's approach. One reviewer, for example, noted that the approach may help overcome barriers and technical challenges for effective occupancy sensing and comfort solutions that can be implemented in real buildings. Another reviewer, however, was unsure of the practical applications of the occupancy sensors being utilized, even though they are innovative. Similarly, a third reviewer found the sensor development approach to be sound, but was unsure about other areas (e.g., the use of occupancy prediction as part of the model predictive control (MPC) strategy for buildings. One reviewer commented on the number of existing comfort models available, remarking that the project team should present their justification for further model development, while another reviewer raised concerns about preserving occupant privacy.

One reviewer noted that good occupancy sensors are currently lacking in the market, so this project has real potential for strong impact on intelligent building controls. Another reviewer expressed their expectation that project will meet its 20% energy reduction target via HVAC and lighting scheduling optimization either during experimental or simulation stages. Another reviewer thought that if the project is successful, the higher accuracy sensing and control solutions that are enabled will contribute to BTO's goals for primary energy savings from occupant-centric sensors and controls. However, this reviewer also noted that accurate counts of people may not specifically have a great impact on energy use, at least compared to traditional methods (e.g., time-of-day scheduling, traditional occupancy sensing, CO_2 sensors). On a related note, another reviewer highlighted an apparent lack of focused estimation algorithms that are needed to convert raw signal from the sensors to the number of persons passing through a sensor's field of vision.

All reviewers agreed that the project has demonstrated significant progress to date, and that remaining work appears well-planned and on-schedule. However, one reviewer advised the team to focus on sensor development and its characterization rather than on the MPC development. All of the reviewers also noted good collaboration between the project team and its academic and industry research partners.

Weighted Average: 3.09 # of Reviewers: 4
Approach: 2.75 Impact: 3.00 Progress: 3.50 Collaboration/Coordination: 3.25 Remaining Work: 3.25

A. Approach

This project was rated **2.75** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The sensor development part of the project is sensible and compelling. But the rest of the project, especially doing MPC for building control (with occupancy prediction as part of it) is neither compelling nor sensible. First, there is the problem of drift of occupancy count errors since any error by the sensor on measuring how many people came in or left persists in the total occupancy count. Second, even with perfect historical measurements, predicting occupancy in single zones is extremely difficult. In fact, it is not even clear that MPC has anything to offer in these small spaces. There are papers that have shown that even with perfect occupancy prediction MPC cannot do much because of the IAQ constraints. If IAQ constraints are relaxed, then extremely accurate predictions will be needed since the cost of wrong occupancy prediction can be severe: people will walk into hot and stuffy rooms!

- The project clearly lists problems and solving approach to use human-in-the loop sensing and control to reach BTO goals. They use privacy-preserving estimates of occupancy count and comfort. It seems successful to count people. However, how to get comfort estimates from sensing?
- The project develops a novel data driven comfort model. There are a lot of comfort models available. Authors should present their justification for model development. Otherwise, it may reinvent wheels for the same results.

- The project approach includes development of depth-imaging sensors for granular estimates of occupancy counts and comfort, novel data-driven comfort model, data-driven models of building thermodynamics, and open-standards for integrating with building automation systems. This approach can overcome the barriers and technical challenges and lead to produce occupancy sensing and comfort estimation solutions that could be implemented in real buildings.

- Innovative occupancy sensing. Not sure how practical.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Good occupancy counting sensors are lacking currently, something that this project seems to be on its way to addressing (based on the claims that their sensor outperforms existing commercial ones, though they couldn't share the data to support the claim due to IP issues). This has a real potential for strong impact on intelligent building controls.

- The project use depth-imaging sensors to provide higher accuracy occupancy count. It helps to make precise control of HVAC system performance with closed-loop control. So far, I have not seen results yet, either from experiment or simulations, since it is an early stage.
- It targets 20% energy reduction via HVAC and lighting scheduling optimization. I expect to see demonstration from either experiment or simulations to meet the target after incorporating the occupancy information into a MPC framework.

- If the project goals are met, the higher accuracy sensing and control solutions may contribute to BTO goals for occupant-centric sensors/controls of 25% reduction in primary energy savings. The team may need to identify how better accurate occupancy count and associated control will result in higher savings as compared to traditional methods that use time of day schedule, occupancy sensor (for light control), CO2 sensor, etc. What is advantage of using the proposed comfort model as opposed to other existing models?

- Uses standard occupancy sensing argument.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals*.**

- Great progress, but I'll advise the team to focus on sensor development and its characterization rather than MPC and all that.
- The progress is on schedule, since the project is in the early stage.
- The project has demonstrated significant contribution to the project goals.
- Good testing, benchmarking, and comparison of their depth sensing occupant tracking approach.

D. Collaboration and Coordination

This project was rated **3.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Excellent.
- The team has 2 universities and a research center. Every player has their own responsibilities and tasks. So far, collaboration and coordination are pretty well.
- The project includes a significant partnership between Carnegie Mellon University, Bosch, and Stony Brook University. Bosch leads the market research and commercialization planning and Carnegie Mellon University leads field demonstrations.
- Potentially good partner in Bosch.

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Clear plan.
- It seems everything is on schedule. The remaining work has no technical difficulties. Hope to see results to meet goals at Q4, 2018 to determine Go/No-Go.
- The project plans are likely to meet the project specific goals.
- None.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Development of an occupancy counting (actually, people crossing) sensor that can provide accurate occupancy data for advanced building control, and perhaps other non-energy related services in the workplace.
- The strength is to provide high accuracy occupancy count and perform closed-loop control.
- Human-in-the-loop sensing and control system for energy efficiency of HVAC.

- Incorporation of occupancy/comfort information into a model-predictive control.
- Depth-imaging sensors.

- Innovative sensing approach.
- Thorough testing.

2) **Project Weaknesses**

- The claim of privacy preserving might be a bit pre-mature. Just like gait can be revealing of identify, it is quite possible that an overhead view of a person passing under a door can be quite revealing. Also, estimation algorithms will be needed to convert raw signal from the sensor to number of persons passing through its FOV, but the project does not seem to have focused on those filtering techniques (may be lack of expertise in the team on signal processing). Instead, the project has a distracting component - use of MPC to do building control. A related weakness is that none of the team members have expertise in control. They will have stronger impact by focusing on sensor development, its characterization, and developing algorithms for occupancy predictions (which the project claims to do) and characterizing the performance of such algorithms based on the sensor data under various situations, in multiple building types (by use). This will provide extremely useful information on limits of occupancy prediction to the research community and industry.

- I am not sure about comfort model development. There are may be comfort models available. I have not seen big advantages.
- Closed loop control may not reach the project goal.

- Accurate counts of people may not have great impact on energy use or at least as compared to traditional methods using the time of day schedule, traditional occupancy sensor, CO2 sensor, etc.

- Defining and achieving required accuracy.

3) **Recommendations**

- See my comments to the previous question (on weaknesses).

- Develop a good algorithms for closed-loop control to reach energy reduction goals.

- May need to compare the new comfort model with existing models
- May need to compare energy saving from the proposed sensor and control solution as compare to existing methods.
- What about including cloths, activities, air moving, etc. in the comfort model.

- None.

Project #32631: Home Battery System

Presenter: Dane Christensen, National Renewable Energy Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Reviewers were generally supportive of this project's approach, with one reviewer noting that it has the potential to reduce residential electricity use while also reducing the effects of intermittent PV electricity generation. Another reviewer considered the approach "understandable" to demonstrate to utilities the magnitude of grid services that homes can provide, but was unsure that demonstrating predictive optimization of residential loads will address major barriers to the deployment of the developed technology. Another reviewer echoed this sentiment, commenting that greater end-user benefits will likely be needed to drive the technology's adoption.

One reviewer positively commented on the merging of multiple technologies (e.g., advanced controls, cyber security, machine learning interaction) to achieve the desired project outcomes. Another reviewer, however, was unclear about whether the project is developing a battery or whether it is instead developing an energy management controller that provides "battery like" services to the grid. Similarly, one reviewer noted that it was hard to determine what technologies were being developed as part of this project, versus what technologies have been developed previously by the project team.

There was general agreement among reviewers that successfully providing value to both the grid and to end-users (e.g. maximizing energy efficiency) without compromising resident comfort will be an impactful outcome. There was some disagreement, however, about the scale of energy savings that homes will experience. While reviewers generally accepted the forecasted 5% energy savings, one reviewer commented that this number seems "very modest," while another was not clear on how a "battery" produces energy savings or how attributable savings will be accurately measured.

All reviewers agreed that the project is progressing on time, and most reviewers agreed that the remaining work is well planned and on track. However, one reviewer commented that a particular project component (i.e. aggregated impact simulations) could be considered a project all on its own, and recommended that down-scoping be considered in order to complete this project on time. All reviewers also agreed that the project team had conducted broad stakeholder engagement, though a few reviewers had questions about the depth of these engagements, and were also unsure about how project responsibilities are distributed. One reviewer commented that the extensive involvement of diverse stakeholders could result in more project benefits (e.g. higher solar penetration).

Moving forward, reviewers offered a number of recommendations to the project team, including that they should consider battery size and payback time for consumers, consider the potential degradation of the assets and home appliances when providing the grid services, and conduct more thorough human-factors testing. Multiple reviewers also noted that this project could potentially be used for resiliency services, and encourage the project team to incorporate resiliency into future efforts.

Weighted Average: 3.21 # of Reviewers: 6
Approach: 3.00 Impact: 3.17 Progress: 3.17 Collaboration/Coordination: 3.50 Remaining Work: 3.33

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The method (slide 8) for the multi-criterion MPC is based on a weighted scalar cost function. How are the appropriate weights selected to guarantee optimality? Just using ratios based on the user preferences maybe insufficient, especially in the presence of constraints.
- What is the interplay between the MPC prediction horizon, frequency of solution updates, and how often the user can or is allowed to change his/her preferences.

- The project's approach of using home battery to achieve grid-interactive improvement in residential energy efficiency has the potential to reduce residential electricity use while also reducing the effect of intermittent PV electricity generation.

- The title is a little confusing, but after hearing the presentation, it is clearer to me.

- It is not clear that demonstrating predictive optimization of residential loads addresses the major barriers to deployment of these technologies (cost/ROI, and interoperability). If the goal is for this project to demonstrate to utilities the magnitude of grid services that homes can provide by ~2025-2035 the testing is understandable, however, the focus on cyber security seems premature as this landscape will likely change before deployment.
- Given this is a CRADA activity the approach may have been heavily determined by the customer.

- The following are the most valuable aspects of the approach:
    - The goal to maintain quality of service (e.g. comfort) is laudable.
- The following aspects of the approach seemed superfluous or could use improvement:
    - The use of the word "optimal" is non-technical. The problem is surely too hard to say the solution is exactly optimal.
    - Are they actually developing/using a battery? Or is it just an energy management controller that provides "battery like" services to the grid?
    - I don't understand what the ">2 kW/home" metric means? This is greater than most homes average electric load.
    - What are the results of step 1 of the approach "interface for homeowners' engagement, preferences"? This is an important aspect to the problem does not seem integrated into the project report.
    - What methods are used to ensure that the ML methods learn about the important corner cases?

- This project has incorporated user, industry, and utility feedback to ensure the program will provide energy savings while maintaining user comforts and cybersecurity concerns. They have demonstrated energy savings and demand response participation that can significantly increase hosting capacity.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.17** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- Providing values to the grid and end-users without compromising the residents comfort is good, what is even better is doing this automatically with minimal input from the users while ensuring the security of the connected devices.

- Simulation results indicated that greater than 5% energy savings can be achieved with home battery use and load optimization.

- The impacts should be large if the win-win situation can be achieved. People are looking for the balance of maximizing the energy efficiency while maintaining the occupants' comforts.

- It is not clear that this work is addressing the key barriers to widespread deployment of residential energy management systems. It would have been good to have seen this activity in the context of other related efforts that address cost and interoperability.
- The stated roadmap goals (5% energy savings and 10% active devices by 2035) seem very modest. Greater end-user benefits will likely be needed to get adoption.

- The following are the most valuable aspects of the impact:
    - There is a clear market and need for residential batteries and 'battery-like' behavior from home appliances.
    - Not sacrificing occupant comfort is an import constraint to achieve the impact.
- The following aspects of the impact seemed superfluous or could use improvement:
    - It is unclear how a "battery" produces energy savings.
    - Can 5% savings be measured with statistical significance?
    - How can homes with less than 2kW of load provide 2kW of resources to the grid?

- System has demonstrated energy savings in the residential space and has an expandable control algorithm that will incorporate more controllable loads as they enter the market.

C. Progress

Based on current project efforts, the project was rated **3.17** for the degree to which the project has met ***project-specific goals.***

- Good progress till date.

- This project is in its final year, and most milestones have been achieved. Software platform has been implemented and simulations have been completed. Laboratory implementation is in progress, including cyber security layer.

- It seems the project is progressing right on time. It will be finished in a few months.

- Progress to plan looks good.

- The following are the most valuable aspects of the progress:
    - The architecture seems appropriate.
    - ESIF could prove to be a valuable testbed for these controllers.
    - The testing across various homes in the PNW is valuable.
    - Drawing from NERC and automobile testing is a good base for cybersecurity.
- The following aspects of the progress seemed superfluous or could use improvement:
    - The use of amazon mechanical turk opens many questions regarding the usefulness of the survey results. These issues were not addressed in the report.
    - Is the data sufficiently broad to learn the necessary parameters with statistical significance? Especially since the parameters are time varying.
    - What aspects will be tested in ESIF that couldn't be just as effectively tested in simulation?

- Despite a late start, the team has been able to meet their projected timeline for decision points and interim milestones.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Strong team but it is not clear who is doing what.
- Team includes experts with diverse expertise from grid integration to behavioral science. Industry advisory board is extensive and includes utilities and appliance manufactures.
- Solid connection from academia, government, and industry. Nice job!
- Stakeholder team has great mix of utilities, industry, and academia.
- The following are the most valuable aspects of the collaboration or coordination:
  - Broad stakeholder engagement.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement:
  - It is unclear how deep and meaningful these engagements are.
- The team has engaged with a number of utilities, industry partners that manufacture batteries and controllable loads, academia, and user surveys. A number of publications from the project have been produced to share results.

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The project plan to closure is well laid out. However, it could be challenging to complete the remaining tasks by the project end date of 09/18.
- This project is in its last year, and most milestones have been completed. Laboratory experiments including cyber security layer are in progress. The remaining work seems to be on track for project completion.
- The remaining project work is well planned.
- Appears on track.
- The following are the most valuable aspects of the Remaining Project Work:
  - Remaining work seems appropriate given the project is wrapping up.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
  - The aggregated impact simulations could be a whole second project. How will that be down-scoped appropriately for the end of this project?
  - Better explain what equipment could be controlled by this system.
- The final demonstration and cyber penetration tests are underway.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Bringing together the different technologies (advanced control, cyber security, human machine interaction etc.) to realize the project goals.
- Strong publication records.

- Demonstration of benefits of using a home battery are the strength. Improvement in energy efficiency, without negative impact on user comfort has been demonstrated in simulations. Grid-interactive operation with cyber security layer is another strength. Extensive involvement of diverse stakeholders may results in more benefits, such as allowing for higher solar penetration.

- Find the balance between the occupants' comforts while maximizing energy savings.

- Such testing and analysis will help utilities and planners understand the roll that homes and home appliances can play in offering grid services in the future.

- Broad stake-holder engagement.
- Architecture incorporates important aspects.

- Proper coordination with stakeholders and the utilization of resources at ESIF.

2) **Project Weaknesses**

- Test results seem to be limited to water heaters and HVAC.

- The project did not seem to consider battery size. Considering battery size and payback time is a critical issue for home owner adoption of this technology. Home owner adoption should be considered concurrently with grid integration trade-offs for the utilities.

- N/A

- It is not clear that the key performance metrics (5% energy savings) are compelling. In my experience 5% is typically too small to measure accurately in the field and for customers to care about. It will likely not compel any investment in the required capital.

- It is unclear what was developed as part of this project, and what was previously developed by the team. E.g. foresee.
- Quantitative and technical descriptions are lacking throughout the report
- What is the technical challenge of the project? How does the teams approach differ from the SOA. Many teams are using MPC for building energy management.
- The end product of the project is unclear.
- The presentation and slides were very high level, making it difficult to properly rate this project.

- A product like this could potentially be used for resiliency services and providing the home with power during utility outages. Those goals were not addressed in the scope of this project.

3) **Recommendations**

- The team may also consider the potential degradation of the assets & home appliances when providing the grid services.
- This or next project may consider using the same framework for fast-time scale ancillary services.
- Consider classifying energy savings in terms of percent of baseline (e.g. slide 12)

- Trade-off of battery size for shortening payback period and optimum grid integration should be considered. Additional benefit may be impact on resilience that was not considered.

- The recommendations about the battery storage selection process should be specified in the presentation. Please make sure the whole decision-making process is based on real-time data and the data quality can be promised.

- It would be useful to understand the role of this project in the overall roadmap and strategy of the utilities or DOE for residential energy management. That would help clarify if this complements other activities that will help address key market barriers for this technology.

- Clearly define the end product of the project.
- Consider more thorough human-factors testing.
- Compare to SOA and other research.
- Better explain the role of simulation vs ESIF.

- Add resiliency to future efforts.

Project #94150b: CERC: Hierarchical Occupancy Response Model Predictive Control at Room, Building and Campus Levels

Presenter: Mary Ann Piette, Lawrence Berkeley National Laboratory
DOE Manager: Marina Sofos

Brief Summary of Reviewer Comments

Overall, reviewers rated the hierarchical and occupancy-responsive strategy pursued in this project for developing and implementing model predictive control (MPC) in buildings highly. One reviewer commented that the approach is likely to contribute to overcoming the barriers and technical challenges for MPC in building applications, and another highlighted the value of developing open-source MPC software for the community at large to test on common benchmarks and platforms. Reviewers, however, raised several specific concerns about the technical details of the approach itself. These included the use of MPC at room scale, noting the difficulty of predicting load at that level, as well as occupancy prediction, which does not yet have a reliable solution. One reviewer also described several technical weaknesses in the project's MPC formulation that could create a lot of exceptions requiring operator overtake. One reviewer commented that the project should focus on removing technical barriers in deploying MPC instead of working on a multi-level approach, with another reviewer recommending that the project team clearly define the optimization problem, including constraints and the variables to be optimized, and demonstrate the energy and thermal comfort advantages of using occupancy-responsive MPC over typical MPC.

A few reviewers highlighted the potential benefits of this project, including energy savings, grid integration, and MPC technology adoption acceleration. One reviewer stated that the project is likely to contribute to BTO's programmatic energy savings goals, while another reviewer highlighted the global impacts due to the project's international partnership. All reviewers agreed that the project has excellent collaboration, including industry, ASHRAE committees, and Chinese collaborators.

Reviewers generally agreed that the project had made good progress toward project-specific goals. One reviewer commented on the project's "impressive" progress in simulation and experimentation, while another noted the strong buy-in from the community at large that has been engendered by the project's MPC work. This reviewer, however, also flagged that field testing has been limited to one building and identified scalability of the technology as a concern.

Most reviewers noted that remaining scope is likely to be completed on time, and that the project is likely to meet its goals. One reviewer, however, expressed uncertainty on meeting the technical objectives due to the limited technical information provided in the presentation.

Weighted Average: 3.43 # of Reviewers: 4
Approach: 3.25 Impact: 3.25 Progress: 3.50 Collaboration/Coordination: 3.75 Remaining Work: 3.50

A. Approach

This project was rated **3.25** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- I am not sure about the merit behind the technical approach. Is there any basis for using MPC at all spatial scales, campus, building and zone? I can see that a larger spatial scale such as building or campus, MPC might be useful. But why not leave the smaller scales of zones with the usual rule based control? To do predictive control at that small scales, the algorithm will need prediction of the load at those scales, which is extremely difficult. This project approach also suffers from another fallacy: the insistence that they will predict occupancy. This is a very hard problem without a reliable solution yet (or even a proposed solution with a known accuracy bound), especially in the small spatial scales of individual zones. In campus or large building level it is a bit easier due to the averaging effect.
- The MPC formulation being used suffers from technical weaknesses too, and it will create a fragile software which will need lots of exception/special case handling, and require operator overtake in many times. For instance, the team is using complex nonlinear dynamic models, which means the problem is not convex. The search method will thus get stuck at local minima (which might be poorer than a rule based control, since there is no theoretical analysis of the objective value at those minima), and worse still, might never converge depending on the geometry of the objective function. The software will therefore have lots of exception cases to handle, probably resorting to rule-based control when the optimizer fails. Also, there is no guarantee that the optimization that runs every sampling period is feasible.
- Although my comments above are critical, they are not a criticism of "MPC for buildings", merely the approach used to translate that idea to reality. I am happy to see the BTO is finally waking up to the value of real-time optimization for building controls. But it should recognize that MPC is a philosophy, and it requires quite a bit of technical research to get it right for a particular application. In this project in particular suffers from the malaise of “doing MPC wrong”, which happens often. The BTO should first focus on removing technical barriers in deploying MPC that works reliably 24-7, 365 days a year and delivers good performance, instead of investing in a massive project with a diffuse focus.
- On the other hand, the PI deserves kudos for managing such a large project with so many partners.

- The project provides a clear pathway to solve the existing problems. It develops hierarchical, occupancy-responsive model MPC framework, demonstrates multiple buildings sites and distribute open source for industry adoption.
- The project also has good collaboration between US and China, so that it has big potential to make the approach world-wide accepting.

- The project approach includes developing model predictive control software (MPC) framework, testing on multiple buildings sites, and distributing open-source for industry adoption and research collaboration. The project approach is highly likely to contribute barriers, technical challenges, and mitigating project risk. It will be very helpful if the team defines clearly the optimization problem and identify the variables to be optimized. What is the advantage (s) of including occupancy model as compared to other non-occupancy existing MPC methods? Are you planning to use any existing optimization algorithm (such as GenOpt)?

- The following are the most valuable aspects of the approach:
    - The team has a good approach for managing this large project with many players.
    - The development of open source MPC software for the community at large to test MPC approaches on common benchmarks and platforms.
    - Development of occupant model, and integration with ASHRAE committees and international partners.
- The following aspects of the approach seemed superfluous or could use improvement:
    - The PI said this was a "Low TRL project" however the development of platforms for testing and demonstration, indicate a higher TRL. This ideological mis-match should be clarified with the PIs and program directors. The project could be split into two parts: the MC development platform, which is higher TRL, and the occupant modeling, which is lower TRL.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Its impact is likely to be weak because of the weakness of its approach (see previous comment).

- The project presents potential saving, grid integration benefits, and acceleration of MPC technology adoption.
- The project has global impacts shown below:
- Optimize building operations in U.S. and China to reduce energy use and environmental impact.
- Provide software platform to test, evaluate, and scale MPC technologies by researchers and industry.
- Establish a strong foundation for future international collaborations on MPC and other advanced building technologies.

- If the project goals are met, the project is likely to contribute to BTO's 30% EUI savings by 2030. The occupancy-based MPC proposed may result a significant energy saving and provide an opportunity for grid integration and MPC adoption.

- The following are the most valuable aspects of the impact:
    - An effective occupant-integrated MPC solution would significantly contribute to the program goals.
    - The work on predicting behavior seems to be well supported by the community.
    - The use of standards (Modelica) in developing the MPC platform.
- The following aspects of the impact seemed superfluous or could use improvement:
    - What is the scope for the approach? Large commercial? Small commercial? What are the long term limits of scope of the approach?

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals*.**

- It is a massive project with many moving parts. The progress they have made so far in the simulation and experiments is impressive.

- The project developed MPCPy v0.1, occupancy model, and obModelica and performed field test of MPC at room and building level.
- The model development and field test can meet the project goals.

- The project has demonstrated excellent contribution to the project-specific goals.

- The following are the most valuable aspects of the progress:
    - All the MPC work looks high quality and well documented and contributing with buy-in from the community at large.
- The following aspects of the progress seemed superfluous or could use improvement:
    - The field testing is limited to one building.
    - How much work went into the field testing? Is the approach scalable?
    - Limited information presented on progress of occupant comfort work specific to this project.
    - Is the occupant discomfort reporting strategy scalable?

D. Collaboration and Coordination

This project was rated **3.75** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The collaboration is impressive. Apart from JCI and Disney, they also have a strong collaboration with China. I am curious to see the precise outcomes of the collaboration with JCI, since (according to the PI) JCI is investing so much in MPC that they are being paranoid (my word) about IP overlap with the rest of the project team.

- The project team has many members, including national labs and industry partners. In addition, the project also has collaboration with China team. Therefore, research deliverables show interest not only from US, but also from China.

- This collaborative project is under US-China Clean Energy Research Center. The project staff demonstrates significant strategic collaboration with relevant stakeholders.

- The following are the most valuable aspects of the collaboration or coordination:
    - Excellent broad collaboration, and deep collaboration with JCI and other important entities.
- The following aspects of the collaboration or coordination seemed superfluous or could use improvement.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- N/A

- The remaining work is composed of Task 3, 4, 5 and 6. Since they are clearly defined, the team should be able to accomplish the remaining tasks on time with success.

- The project plans (Task-3 through Task 6) are highly likely to meet the project specific goals.

- The following are the most valuable aspects of the Remaining Project Work:
    - The field tests and campus-level work should be exciting.
- The following aspects of the Remaining Project Work seemed superfluous or could use improvement:
    - It is unclear from the limited technical information provided how likely the team is to meet the technical goals.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Strong collaboration with many partners. A good simulation framework involving EnergyPlus and Modelica in which MPC controls can be tested in silico.

- The research topic cover interest from both countries and will make big impact for energy savings in both countries.

- Develop and test cost-effective occupancy-responsive building and district scale MPC.
- Develop and open-source MPC software.
- The project is well planned. The testing MPC in real building is a plus.

- The large collaborations with important large players.

- The interaction and buy-in from the community at large for the MPC (Modelica integration) and behavior (ASHRAE committees) work.

2) **Project Weaknesses**

- See my comment on approach.

- The project has no problem to reach goal.

- The testing was conducted for UFAD; what about typical VAV systems. The optimization problem is not well defined.

- Limited technical details presented.
- How steep will the learning curve for the MPC platform be?
- How appropriate are the occupant models for integrating into the closed-loop controls?

3) **Recommendations**

- Scope is too broad for an untested technology (MPC for buildings). The project will have better impact by focusing more narrowly on a few compelling applications than doing MPC on every spatial scale.

- Hope to optimize building performance using occupancy-responsive MPC.

- Clearly define optimization problem, including the constraints and the variables to be optimized.
- Show the advantage (s) of using occupancy-responsive MPC over typical MPC (in terms of energy and thermal comfort).

- Keep up the good work.
- Clarify scope.
- Provide succinct technical progress reports.

Emerging Technologies
Transactive Energy Management

Project #32739: Connected Homes & Neighborhoods

Presenter: Nora Wang, Pacific Northwest National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

While this project's approach earned high marks, reviewers disagreed on the merits of certain element. Two reviewers described the approach as well-designed, and structured in a way that encourages collaboration to identify and mitigate project challenges. One cited the project's approach as one of the project's key strengths, saying that it targets "significant issues that have prevented transactive control strategies to be adopted in residential buildings." Another reviewer, however, thought the chosen test bed had "significant limitations" with regard to mimicking real-life environments. A second reviewer echoed this criticism, adding that they lacked enough information about the model (e.g. how it behaved across a range of weather conditions, whether their load algorithms were custom-made or adapted from existing literature) to effectively evaluate it.

Most reviewers remarked that the market impact of this project, if successful, could be significant. Several reviewers speculated that this project could produce a "highly attractive opportunity" for consumers and utilities that would accelerate the market adoption of transactive control solutions in residential buildings. However, one reviewer cautioned that the project team had not sufficiently calibrated the project's value proposition for utilities, commenting that it was not clear how the product's control strategies "align with different utility challenges across markets," nor was it clear "what is required for either a third-party or a utility to leverage the system as a resource."

Nearly every reviewer expressed some degree of concern about the project's progress to date, particularly in relationship to its remaining work. While one reviewer's comments suggested comfort and confidence in the project's pace, the remaining reviewers noted that "significant interoperability challenges remained," characterizing the project's customer engagement and control systems across building types and devices as "non-trivial hurdles." One reviewer added that no quantifiable evaluation results were even available to adequately judge whether or not the project would ultimately achieve its goals. Several reviewers urged the team to "rush" and "hurry up," cautioning that the project's experimental field test phase was occurring too close to the project's end; in their estimation, this did not seem to "leave enough time for implementation errors, data collection and analysis."

Most reviewers generally made supportive remarks about the project's collaboration and coordination efforts, while two reviewers offered suggestions for improving the project's outreach, with the potential to significantly shape the project's overall impact. One reviewer questioned if the project team was aware of competing technologies that are already on the marketplace, which is a concern that reviewers felt the team's advisory board should mitigate. Another reviewer suggested that including other stakeholders—aside from manufacturers and utilities who influence state and federal regulations—would be useful because the ultimate application of this technology "will involve utility rate and EE/DR/storage program design regulatory and legislative actions." A different reviewer went further, calling into question the team's understanding of utility value streams and drivers. This reviewer surmised that "weak partnerships with end customers" would make it challenging to ascertain how customer value was created, in both new and retrofit residential home markets.

Weighted Average: 3.18 # of Reviewers: 4
Approach: 3.50 Impact: 3.25 Progress: 2.75 Collaboration/Coordination: 3.25 Remaining Work: 2.75

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The team has the expertise and experience to accomplish the technical project goals. However, significant limitations exist given the test bed utilized for product testing and integration. More work should be done to determine how a system will integrate in a real environment.

- It's well designed and presents a reasonable path.

- This project's strong interaction with partners in identifying challenges and possible solutions and then working on one possibility is excellent. The specific solution seems credible, the implementation seems to be progressing well.
- As this project matures, greater interaction with utilities, manufacturers, and other policymaking stakeholders will be very important, so it's good to see that under way.

- It is difficult to evaluate the approach for this project due to the lack of the following critical details:
    - It is unclear what algorithms are used to learn about the house/appliance load patterns and whether the algorithms are developed in this project or adopted from literature/previous studies.
    - A typical shortcoming of data-driven (learned) load models is the scalability and extendibility, i.e., how well the model behaves under very different weather/operational conditions. There is a lack of discussion on this critical issue.
    - There is a lack of discussion on results in general.
    - The differences between the approaches in this project and those in the ORNL projects are not clearly discussed.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Building the control algorithm is only one part of the value proposition. It is not clear how the project aligns with different control / market objectives, and what is required for either a third-party or a utility to leverage the system as a resource. The product is focused specifically on utility ownership / management / control, but this is not necessarily the appropriate approach. Additional work should be done to understand how the control strategy aligns with real utility challenges across markets.

- It presents a great potential impact. This is based on my close observation, study and practice in this specific field for almost 30 years. In the last two decades, I personally walked through and assessed more than 600 buildings and campuses globally, and was the lead Principal Investigator for a comprehensive energy management program on the Texas A&M university campus, for which cumulative savings exceeded $90 million over a period of 16 years. I was also the PI or lead PI for numerous similar programs. In 2010, Dr. W. Dan Turner and I co-founded the Theory of Nodal Partners, which reflects our view of today's world, IT, energy and utility's supplies, transportation and consumption, smart grid of everything, interplay and readiness. We foresaw this was coming from the front seats.

- If successful, this project will deliver a credible solution to a real challenge and facilitate a highly attractive opportunity for consumer, reliability and environmental benefit. The clear stakeholder interest is a testament to that. Unfortunately, BTO's Emerging Technologies Program goal (techs capable of 45% reduction in energy use /sqft by 2030) is not well-suited to the full range of responsive load beneficial opportunities. I give this project the top rating on Q3 based on my sense of what would be a more useful BTO ET goal.

- The objectives of the project are targeted. If successful, the project will lead to better market adoption of transactive control solutions in residential buildings.

C. Progress

Based on current project efforts, the project was rated **2.75** for the degree to which the project has met ***project-specific goals.***

- It is clear that significant interoperability challenges remain and that the technology development curve is still underway. Given the time left in the project, it is not clear how the team will accomplish all goals ahead of September.

- The time left is a little rush to finish the original plan. Need to hurry up!

- The project seems to be making progress as planned.

- The project is about to end in this summer. However, there is no quantifiable evaluation results that can be used to judge if the progress has met the project goals.

D. Collaboration and Coordination

This project was rated **3.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- It is not clear that the team is aware of current technologies in the marketplace that are capable of similar integration and bidding into the wholesale market (i.e. major DERMS providers). As the team builds out their advisory board this concern should be mitigated. The primary challenge will be testing across multiple home types with real consumer devices - both from a customer engagement standpoint and a technology evolution standpoint. It's not clear what the roadmap to accomplish this is.

- Well done on this regard.

- Looks great. It would be good to track how SkyCentrics, the individual participating coops, and NRECA take the project results and move forward. Going forward, the advisory panel will be a good step. It would be useful to also include other stakeholders (beyond manufacturers and utilities) who influence state and federal energy utility regulatory outcomes, as the ultimate application of this technology will involve utility rate and EE/DR/storage program design regulatory and legislative actions. Insights from policymakers and influencers will be helpful.

- The collaboration and coordination seem to be strong.

E. Remaining Project Work

This project was rated **2.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The customer engagement and control system development (across building types and devices) are non-trivial hurdles. Not unique to this project, it's challenging to see a real path to implementation. The model is also unclear when you consider utility vs third-party control and management. Significant thought should be given to how this might impact a control strategy (if at all).

- Feel it needs to speed up to accomplish the original goals and plan.

- The next steps seem sensible, building out the initial Yarnell results to additional test homes and calibrating that. The progress to date gives confidence in your future project plans. And if you hit a snag, or discover something new and unexpected, it seems most likely that you'll prioritize and adapt well.

- The experimental/field test phase is at a very late stage of this project, which does not seem to leave enough time for implementation errors, data collection and analysis.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Strong technical team with clear understanding of control algorithms.
- Good technical partnerships with external parties

- Well defined approach and a clear path to carry it out.

- This project has identified a technical solution of interest to industry and is taking a thoughtful, deliberate approach to demonstrating it. A key strength, in addition to technical competence, is getting that external stakeholder perspective to ensure that the effort is likely to be worthwhile.
- The bottom up, transactive approach could be an attractive way to economically and flexibly tap the time-varying conditions of responsive loads. Having this working example of technology will make for more concrete exploration of utility pricing and program options for EE, DR, storage. Congrats.

- Strong collaboration with the industry and other labs.
- The project is targeting at significant issues that has prevented transactive control strategies to be adopted in residential buildings.

2) **Project Weaknesses**

- Lack of understanding of the diverse nature of utility value streams / value drivers
- Weak partnerships with end customers to understand how the value is created - and the magnitude of that value. While that is a later stage question, it informs the trade-offs in time/speed of control and the cost of control.
- Not a clear value proposition for retrofit for customers or value for utilities.

- A strong finish-up is a little in doubt in mind.

- A major challenge for much of the work in this area will be ensuring a fit between capabilities developed and the regulatory and market structures under which they might be eventually deployed. EE/DR/storage program design and related rate/market design will need to evolve to un-tap the potential.
- That's not a criticism of this project by any means. Rather, it suggests that more and earlier interaction with utility regulators and policymakers will be valuable, going beyond the project's currently excellent efforts to interact with utilities and equipment manufacturers.

- Accomplishments, progresses, as well as evaluation criteria for success are not clearly demonstrated.
- The experiment phase is planned too late in the project and does not seem have a long-enough duration to allow typical issues in a real experiment and a thorough data analysis.

3) **Recommendations**

- Increase conversations with teams modelling the value of the control systems and the communications teams looking at interoperability.

- May need an extension to fully complete the study as planned. I would recommend a Co-PI system for such projects to well support each other and keep the methodology in check and progress on track for the future.

- Go Go GO!
- Keep the technology work going. As that matures, more exploration of utility regulatory, rate/market design and EE/DR/storage program design issues will help ensure that those policy steps evolve along with these emerging technical capabilities.
- One useful step might be to engage policymakers more, to gain a better mutual understanding of what's possible and attractive from future regulatory and legislative developments that will guide/facilitate/drive the electricity markets & rate design and EE & DER program design. Those policy developments will be vital in unleashing the enormous potential of this project's transactive technology.

- Clearly demonstrate the innovations, unique achievements, evaluation criteria and results in the final report.

Project #32740a: Transactive Whole Homes as Integrated Assets - Connected Homes

Presenter: Helia Zandi, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers generally agreed that the project's approach was one of the its greatest strengths: clearly defined, thoughtfully crafted, and primed with the right stakeholders to explore interoperability challenges in pursuit of developing supervisory and optimal model predictive control (MPC) strategies. Several reviewers shared their belief that the project's partners would play a key role in this project's success, but they also brought up several issues that the project approach had not addressed. First, one reviewer wished for more information about the challenges associated with achieving true machine-to-machine communications for technologies lacking APIs, which the reviewer characterized as a critical technical component for easing consumer adoption in terms of both time and money. Another reviewer identified two challenges that "often limit [the] real-building adoption of control approaches," and which the project team needed to consider further: first, the unlikely reality that homes are well-instrumented enough to provide enough data input, and second, the variable performance of load forecasting models under different operational conditions that directly affect the control performance of an MPC strategy.

While nearly every reviewer gave the project high marks and praise for the project's collaborations and coordination—which many considered part and parcel to the project's success—a few reviewers still wished that the project would engage a more diversified set of stakeholders. One reviewer suggested that the project team should work more with vendors, utilities, and telecommunications providers to better understand how the Home Assistant interface would work with customers. Another reviewer thought the project team should look beyond utilities to other stakeholders who influence legislative decisions, because "the ultimate application of this technology will involve utility rate and EE/DR/storage program design."

Several reviewers agreed that this project had targeted a significant market barrier to implementing advanced control strategies in residential buildings, which could be very impactful if successful. One reviewer, however, was concerned that the energy savings goals were too aggressive, and unlikely to be met within the project's timeframe. Reviewers were in disagreement over the amount of progress the project had made, as well as the fate of the project's remaining work. One reviewer expressed skepticism that the project team could reach its "lofty" goal of building a platform that "seamlessly facilitates the peer-to-peer information exchange" within the remaining project time, or even at all "given the project's limited test bed and interoperability challenges." While another reviewer expressed concern about the numbers of steps remaining, two reviewers were impressed with the project's progress to date, and one characterized the remaining tasks as "reasonable," noting that the project team was positioned to accomplish them. Another reviewer concurred, commenting that progress-to-date and stakeholder interactions gave the reviewer confidence in plans for remaining work and the project team's ability to overcome unforeseen barriers.

Weighted Average: 3.39 # of Reviewers: 4
Approach: 3.50 Impact: 3.50 Progress: 2.75 Collaboration/Coordination: 3.50 Remaining Work: 3.50

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The technical approach seems adequate to explore questions and challenges regarding interoperability. Limited information was provided on the challenges associated with achieving true M2M communications for technologies without APIs. This is a critical technical component that reduces friction for customer adoption from the lenses of both time and cost to deploy.
- The team's interaction with Whirlpool and Southern provides an important relationship to explore these questions, but challenges remain when considering scalability beyond a proof-of-concept.

- Well-thought and defined.

- Outstanding.
- This project's strong interaction with partners in identifying challenges and possible solutions and then working on one possibility is excellent. The specific solution seems credible, the implementation seems to be progressing well.

- A major approach in this project is to develop supervisory and optimal MPC strategies for the house appliances. The objective function and a case study (PV-HW) are clearly discussed. The following challenges that often limit real building adoption of such control approaches need more consideration and discussion:
    - What are the sensor needs to support the proposed control strategy? The testing house seems to be very well instrumented. It is unlikely to expect such level of measurements in a real house.
    - How the loads are modeled. I assume that data-driven modeling approaches are adopted here. Model accuracy, scalability, and extendibility (accuracy under very different weather and operation conditions) are not discussed. Considering that the performances of load forecasting models directly affect the overall control performances for a MPC strategy, these issues need to be considered and discussed.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- The program energy savings goals are aggressive and given the early technology stages of the control architecture, meeting the goals on the time horizon is unlikely. This is not unique to this specific project. To enhance the likelihood of adoption, more focus needs to be given to how technologies will be used inside the home, and who will be actively using them. While interoperability is not affected, the response timing required and the communications architecture integration is impacted. A more direct line to industry and deployment partners in a broader segment of the market is encouraged.

- Potentially very feasible and impactful. This is based on my close observation, study and practice in this specific field for almost 30 years.

- If successful, this project will deliver a credible solution to a real challenge and facilitate a highly attractive opportunity for consumer, reliability and environmental benefit. The clear stakeholder interest is a testament to that. Unfortunately, BTO's Emerging Technologies Program goal (techs capable of 45% reduction in energy use /sqft by 2030) is not well-suited to the full range of responsive load beneficial opportunities.
- I give this project the top rating on Q3 based on my sense of what would be a more useful BTO ET goal.

- The project is targeting at a significant problem. If successful, the outputs from the project can help remove some market barriers for implementing advanced control strategies for residential buildings, which further lead to energy saving and better infrastructure connectivity. The cost-benefit (additional hardware and installation cost) and effectiveness (control accuracy and effectiveness) of the proposed solution should also be considered and evaluated.

C. Progress

Based on current project efforts, the project was rated **2.75** for the degree to which the project has met ***project-specific goals.***

- The remaining project work to build a platform which "seamlessly facilitates the peer to peer information exchange" is a lofty goal to accomplish in the last few months. It is not clear, given the limited test bed and interoperability challenges, how the remaining goals will be met. However, the progress made on the MPC with the current field demonstration appears impressive.

- Quite a few steps to be figured out and tested out.

- Looks great.
- It's great to have had Southern Company in the room, and attesting to their perception of progress. It will be great to see how they and the other project partners take the results and move forward over time.

- The project has made good progresses, especially toward the VOLTTRON integration, field demonstration, and software architecture design.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The current collaboration with Whirlpool and Southern provides a valuable pathway to understand utility needs and inform external technologies. Additional partnerships should be sought to understand if the technology specifications differ in restructured/competitive utility markets

- No further comment.

- This project inherently relies on collaboration, with the builders, Southern Company, and the equipment suppliers. That's outstanding, and helps ensure that the approach and objectives are of real and practical interest.
- Going forward, it would be useful to also include other stakeholders (beyond manufacturers and utilities) who influence state and federal energy utility regulatory outcomes, as the ultimate application of this technology will involve utility rate and EE/DR/storage program design and regulatory and legislative actions. Insights from policymakers and influencers should be helpful in both directions (i.e., ensuring that the approach and goals are well defined, and in facilitating policy-maker consideration of changes that they will need to explore).

- Good collaborations among labs and with the industry partner.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- It is not clear how the team will accomplish the remaining project goals during the project horizon. Each contains significant technical challenges which may only be overcome by more direct interaction with test facilities. Specifically, the peer-to-peer information exchange is yet to be explored in meaningful detail as is the networked functionality. More consideration should be given to what expectations are realistic and how the project will continue to evolve past the project end.

- Very necessary and important steps.

- Looks great. Will be keen to see the Final Report.
- The progress to date and stakeholder interaction gives me confidence in the project plans for remaining work. And if you hit a snag, or discover something new and unexpected, it seems most likely that you'll prioritize and adapt well.

- The remaining tasks seem to be reasonable and the team is positioned well to accomplish them.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Strong technical team
- Diverse approach in modelling to test efficacy of control algorithms, and thoughtful approach to system architecture design.

- The approach is a very promising one.

- The project has identified a technical solution of interest to industry and takes a thoughtful deliberate approach to demonstrating it. A key strength, in addition to technical competence, is getting that external perspective to ensure that the effort is likely to be worthwhile. Well done.
- The approach could be an attractive way to economically and flexibly tap the time-varying availability of and need for DER. Having this working example of technology will make for more concrete exploration of utility pricing and program options for EE, DR, storage.
- Congrats.

- Targets at a significant problem;
- Experimentally implemented and evaluated the proposed solutions;
- Develops both control strategy and software architecture for IOT based control.

2) **Project Weaknesses**

- Limited applicability of field demonstration trials, and tentatively unrealistic test bed when considering real world deployment.
- Unrealistic product development timeline for additional component / feature development.
- Minimal understanding of how the platform interacts with different types of customers.
- Unclear how the Home Assistant interface will impact usability of the control architecture and if customers will be willing to engage.

- Lack of essential progress of software development and testing beyond the home level to make it truly interactive with the "grid" or outside world through demonstrations.

- A major challenge for much of the work in this area will be ensuring a fit between capabilities developed and the regulatory and market structures under which they might be eventually deployed. EE/DR/storage program design and related rate/market design will need to evolve to un-tap the potential.
- That's not a criticism of this project by any means. Rather, it suggests that interaction with utility regulators and policymakers will be valuable, going beyond the project's currently excellent interaction with the utility and equipment manufacturers.

- The cost-effectiveness of the proposed solutions is not discussed. It is unclear whether additional sensors and extensive model training/learning are needed to implement the solutions. If so, they will significantly restrict the application of the proposed solutions.
- The effectiveness of the proposed control strategies need to be evaluated more rigorously to study their accuracy and scalability. Inaccurate load forecasting and poor scalability have been the major barriers for such control strategies to be used in a real building.

3) **Recommendations**

- Beyond the technical development still required, further collaboration needs to occur with vendors, utilities (or aggregators), and telecommunications providers to understand industry requirements.

- Hope the PIs could achieve reasonable extra funding to finish the originally planned project. I would recommend a Co-PI system for such projects to well support young PIs and keep the methodology in check and progress on track for the future. In other words, some mentorship may be necessary for the PIs.

- Go Go GO!
- Keep the technology work going, and write up that report. As this and successor projects mature, more exploration of utility regulatory, rate/market design and EE/DR/storage program design issues will help ensure that those policy steps evolve along with these emerging technical capabilities.

- Include cost-effectiveness, control accuracy and scalability as evaluate criteria when developing the solutions.

Project #32740b: Transactive Whole Homes as Integrated Assets - Connected Neighborhoods

Presenter: Michael Starke, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers generally agreed that the project's approach was sound and well-matched with the project's objectives. One reviewer, however, did not understand why the project team was using such computationally burdensome resistor-capacitor models to simulate building envelope and HVAC components for an aggregated control problem, which they feared would "slow down the overall solution" and bring the cost-effectiveness of these models into question.

All three reviewers agreed that the project's outcomes would advance the implementation of transactive controls in residential buildings by addressing market barriers. One reviewer commented that the control approaches could be an attractive way to economically and flexibly tap the time-varying capability of distribute energy resources (DERs), while technologies developed in this project could—if successful—help explore utility pricing and program options for energy efficiency, demand response, storage, and DERs generally. Reviewers expressed equal comfort with the project's progress-to-date, especially around single-house demonstration and multiple house simulation. Reviewers did not express any concerns with the project's remaining work, although several did acknowledge that a lot of work remained.

The project's collaboration and coordination efforts with its stakeholders were well regarded by reviewers, who understood these project elements to be critical to the project's basic structure and success. Reviewers commented, however, that including other stakeholders beyond manufacturers and utilities would help the project achieve its ultimate goals.

Weighted Average: 3.85 # of Reviewers: 3
Approach: 3.67 Impact: 4.00 Progress: 3.67 Collaboration/Coordination: 4.00 Remaining Work: 4.00

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- No further comment.

- Looks great!
- This project's strong interaction with partners in identifying challenges and possible solutions and then working on one possibility is excellent, and the overall approach seems like a natural and thoughtful extension of the precursor project. The specific solution seems credible, the implementation seems to be progressing well.

- Overall speaking, the proposed solutions are appropriate for the project objectives. However, for such an aggregated control problem, it is unclear why detailed RC models are needed for building envelope and HVAC components. Such detailed models seem to add a computation and implementation burden and will slow down the overall solution. They are appropriate for single house optimal control but may not be for micro-grid level control.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- This is based on my close observation, study and practice in this specific field for almost 30 years.

- If successful, this project will deliver a credible solution to a real challenge and facilitate a highly attractive opportunity for consumer, reliability and environmental benefit. The clear utility and manufacturer interest is a testament to that. Unfortunately, BTO's Emerging Technologies Program goal (techs capable of 45% reduction in energy use /sqft by 2030) is not well-suited to the full range of responsive load and coordinated DER beneficial opportunities.
- I give this project the top rating on Q3 based on my sense of what would be a more useful BTO ET goal.

- The project is targeting at a significant problem. If successful, the outputs from the project can help remove some market barriers for implementing transactive control strategies for residential buildings and help a microgrid to be better integrated with its buildings.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals.***

- No further comment.

- Seems to be going well, and keeping up with the home construction. Well done.

- The project has made good progresses, especially toward single house demonstration and multiple house simulation.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- No further comment.

- This project inherently relies on collaboration, with the builders, Southern Company, and the equipment suppliers. That's outstanding, and helps ensure that the approach and objectives are of real and practical interest. Well done.
- Going forward, it would be useful to also include other stakeholders (beyond manufacturers and utilities) who influence state and federal energy utility regulatory outcomes, as the ultimate application of this technology will involve utility rate and EE/DR/storage/DER program design and regulatory and legislative actions. Insights from policymakers and influencers should be helpful in both directions (i.e., ensuring that the approach and goals are well defined, and in facilitating policy-maker consideration of changes that they will need to explore).

- This project has demonstrated excellent collaboration with utility companies and other industrial partners.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- No further comment.

- There's lots left to do, but it sounds like it's on a very good path.

- The remaining tasks seem to be reasonable and the team is well-positioned to accomplish them.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Well planned, coordinated and developed.

- The project has identified a technical solution of interest to industry and takes a thoughtful, deliberate approach to demonstrating it. A key strength, in addition to technical competence, is getting that external perspective to ensure that the effort is likely to be worthwhile. Well done.
- The control approaches under development could be an attractive way to economically and flexibly tap the time-varying capability of DERs the variation in grid value. Having this working example of technology will make for more concrete exploration of utility pricing and program options for EE, DR, storage, DER generally.
- Congrats.

- Targets at a significant problem;
- Proposed two control framework for microgrid-building integration;
- Experimentally implemented and evaluated the proposed solution in a single house.
- Excellent collaborations with the utility and industrial partners.

2) **Project Weaknesses**

- Don't see any yet.

- A major challenge for much of the work in this area will be ensuring a fit between capabilities developed and the regulatory and market structures under which they might be eventually deployed. EE/DR/storage program design and related rate/market design will need to evolve to un-tap the potential.
- That's not a criticism of this project by any means. Rather, it suggests that interaction with utility regulators and policymakers will be valuable, going beyond the project's currently excellent interaction with the utility, builder, and equipment manufacturers.

- The cost-effectiveness of the proposed RC models is questionable and should be further examined.

- The effectiveness of the proposed control strategies need to be evaluated more rigorously to study their accuracy and scalability.

3) **Recommendations**

- Keep up the current fashion and please don't let it skid.

- Go Go GO!
- Keep the technology work going. As that matures, more exploration of utility regulatory, rate/market design and EE/DR/storage program design issues will help ensure that those policy steps evolve along with these emerging technical capabilities.

- Include cost-effectiveness, control accuracy and scalability as evaluate criteria when developing the solutions.
- Some plots in the presentation lack necessary legends.

Project #32741: Virtual Battery-based Characterization

Presenter: Jeffrey Munk, Oak Ridge National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Reviewers expressed interest in this project's goals, but not much confidence in the project's ability to adequately test and account for the full, requisite range of battery attributes (i.e. capacity, reliability, and dispatchability) needed to accurately characterize the components of building systems that could enable buildings to serve as virtual batteries. One reviewer questioned whether a narrower approach focused on a less diverse mix of loads would be useful, since "home [air conditioning (AC)], small commercial HVAC, and supermarket refrigeration seem like sufficiently large and dissimilar loads to each merit separate consideration and technology development." Another reviewer was not sure how the project planned to identify the virtual batteries' technical capabilities—their reliability, capacities, and other uncertainties—based on the data researchers were collecting. This same reviewer also questioned if this research was sufficiently novel, alluding to similar research efforts that has been published in existing literature and/or conducted by various national labs.

While one reviewer repeatedly cautioned that the project's goals were "quite lofty and broad," reviewers gave high marks for the project's potential impact, which one reviewer summed up as: more seamlessly integrating buildings and the grid. However, reviewers frequently questioned if the project could deliver results that would ultimately achieve those impacts. One reviewer commented that the AC predictive control modeling approach was "far from completion" and that significant questions remained about whether supermarket refrigeration controls would fall within acceptable food preservation parameters. Another reviewer agreed, remarking that major challenges remained for "all three application areas," and adding that the cost-effectiveness and accuracy of the project's building/system models were not discussed.

Regarding the project's collaboration and coordination efforts, reviewers expressed divergent opinions. One reviewer commented that the project was well-coordinated with other labs and its utility partners, but another reviewer had trouble identifying the stakeholder activities that the project team had undertaken, as well as determining whether or not these activities were core elements of the project. This reviewer commented on two occasions that the project would benefit from more stakeholder involvement in order to clarify future opportunities and validate whether the project's approach and findings are practical from various perspectives.

Weighted Average: 3.18 # of Reviewers: 3
Approach: 3.33 Impact: 3.67 Progress: 3.00 Collaboration/Coordination: 3.00 Remaining Work: 2.67

A. Approach

This project was rated **3.33** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- No further comment.

- The approach shown on page 5 and overall goals seem quite lofty and broad. While the framing of controllable loads as 'virtual batteries' brings a useful perspective for this and related projects, I suspect that a narrower implementation effort could be helpful. In any case, good luck gaining insights and experience on VBs!
- Some questions: Is the highly diverse mix of loads proving helpful for your gaining analysis and insights into the prospects for VBs? Home AC, small commercial HVAC, and supermarket refrigeration seem like sufficiently large and dissimilar loads to each merit separate consideration and technology development. I'm wondering if the complexity of addressing such different loads is justified at this somewhat early stage.
- Regarding the home AC, is the reason for exploring both "priority" and "predictive" control to compare which has better prospects for delivering grid benefits while not imposing on occupant comfort? It's hard to see what the case for the former control approach might be, other than being relatively simple.
- Is there is strong utility or manufacturer participation and interest in this project? It's not clear. Having ongoing stakeholder input would be good for ensuring that the approach is of practical interest, and the findings might be put to use. But in any case, your experience with this project should be very helpful in planning out a future approach and for interacting with stakeholders.

- Characterizing a building and its systems using terms similar as those used for a battery is interesting. The key issues, such as reliability and uncertainty, are identified. However, the proposed solutions do not seem to discuss how virtual battery's capacity, reliability, and uncertainty are identified from collected data. The proposed RC model for houses, and other models for commercial buildings, seem to be literature existing models. It is unclear how this project is different from other similar ones at ORNL and PNNL and from literature-reported approaches.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- This is based on my close observation, study and practice in this specific field for almost 30 years.

- The project goals seem quite broad. Achieving on the narrower subset of those that I think are the project's actual goals would be great, and may provide a credible solution to a real challenge and facilitate a highly attractive opportunity for consumer, reliability and environmental benefit. It's not entirely clear from a quick review such as this, and having clearer ongoing stakeholder interest and involvement would give a lot more confidence.
- Also, it is worth noting that unfortunately, BTO's Emerging Technologies Program goal (techs capable of 45% reduction in energy use /sqft by 2030) is not well-suited to the full range of responsive load beneficial opportunities that the VB approach seeks to deliver.
- I give this project a high rating on Q3 based on my sense of what would be a more useful BTO ET goal.

- The project-specific goals are significant. Buildings and the grid can be integrated more seamlessly, if a building and its systems are categorized as virtual battery with their capacity, liability, and uncertainty, cost-effectively learned from real data

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- No further comment.

- With such diverse and lofty project goals and approach elements, it's hard to tell which matter most.
- It seems like there's much left to be done, and not a lot of time. The home AC predictive control modeling approach seems relatively far from completion, at least in terms of assessment of the adequacy of modeling accuracy. Same for the assessment of the relative merits of the predictive and priority home AC control approaches.
- Regarding supermarket refrigeration, it also seems like there are some big questions to be addressed going beyond the immediate control technology goals and experimentation. E.g., it will be good to see the assessment of whether controls fall within the acceptable food preservation parameters.
- Stakeholder input could be helpful in clarifying priorities for future progress. To that end, integrating into the Southern Company connected neighborhood project should be a real plus for the home AC part of this project. Is there a plan for similar stakeholder input on the other loads (supermarket refrigeration and small commercial HVAC)?

- The project has made some progresses. However, many key issues, such as the cost-effectiveness and accuracy of developed building/system models, are not discussed. The developed models seem to have significant computational issues.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- No further comment.

- It's not clear what stakeholder collaboration and coordination is ongoing as a core element of this project. It's great that Southern Company will be involved via integration of the home AC element of this project into their connected neighborhood work. Hopefully there's already strong interaction, to help guide the project.
- Is there a stakeholder collaboration plan for the supermarket refrigeration and small commercial HVAC elements? That will be great.

- This project has good collaboration with other labs and the utility company.

E. Remaining Project Work

This project was rated **2.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- No further comment.

- I might be missing something, but it seems that the project goals and approach elements are quite broad and lofty, so it's set up to not fully deliver on the full suite.
- For the narrower elements as laid out, there seems like a lot of work left to be done, and it's spread across widely differing load types. Very ambitious!
- As mentioned in previous comments, more interaction with stakeholders could be useful in prioritizing effort and ensuring practical outcomes.

- The project has one remaining year. However, many major challenges still exist for all three application areas.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The actual promissing progress it has made so far.

- Framing responsive loads as VBs, and trying to work through the practicalities of operating them as such seems potentially very useful.
- Go Go GO!

- Using battery concepts (capacity, reliability, and uncertainty) to characterize buildings and their systems are innovative;
- Experimentally evaluate the proposed solutions.

2) **Project Weaknesses**

- Not much weakness as I could see yet.

- I wonder about a couple items, as mentioned several times in prior comments (and apologies for being redundant!):
- Trying to work on such dissimilar loads under the same umbrella (home AC, supermarket refrigeration, small commercial HVAC)
- Unclear stakeholder involvement to help ensure that approach and findings are practical.

- Proposed models/methods have nearly all reported in the literature. It is unclear how these existing models/methods contribute to the main objective – characterize buildings as virtual batteries. It is unclear how proposed solutions are different from literature reported MPC and/or DR strategies.
- The reliability and uncertainty are not discussed in the progresses.
- The cost-effectiveness, accuracy, and scalability of the proposed methods should be further examined.

3) **Recommendations**

- None.

- Follow your instincts. You're the expert on the topic, and if you find something that seems particularly useful, pursue it (with clear communication with sponsors and collaborators, of course).
- Engage more with stakeholders. Some will be very interested, and their insights and experience will be valuable.
- Narrow the focus if necessary.
- Go GO GO!

- Highlight major innovations of the proposed solutions, including both modeling and control innovations, when compared with other literature-reported strategies.
- Include cost-effectiveness, accuracy, and scalability as evaluation criteria for the propose solutions.

Project #32742: Improving Transformer Efficiency and Lifetime through Product Selection, Systems Integration and Dynamic Control

Presenter: Jianming Lian, Pacific Northwest National Laboratory and Klaehn Burkes, Savannah River National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Every reviewer credited this project's approach both with successfully finding the probable "bottleneck for optimization" of transformers, and with defining its challenges well enough for subsequent work to likely overcome them. One reviewer remarked, "we were always wondering about the transformer performance and limitations, and this project addressed it well." Reviewers were equally supportive of the project's potential impact on BTO's goals. Two reviewers agreed that the project's goals, if achieved, would significantly improve transformer efficiency and lifetime, with one also highlighting the project's simultaneous improvement of grid robustness and efficiency. This would help utilities and transformer manufacturers gain comfort with amorphous transformer longevity, one reviewer said, which would clearly advance BTO's overarching energy savings goals and its goal of demonstrating energy saving technologies.

Each reviewer was satisfied with the project team's progress to date, and expressed full confidence in their ability to complete the remaining project work, though one reviewer noted that much work still remained. Reviewers were similarly supportive of the project's collaborations and coordination efforts, and could not identify any further project weaknesses. Very few recommendations were made, save for one reviewer's proposal to test the repeatability of the project team's conclusions with different transformers.

Weighted Average: 3.95 # of Reviewers: 3
Approach: 4.00 Impact: 4.00 Progress: 4.00 Collaboration/Coordination: 4.00 Remaining Work: 3.67

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- It identified a potential bottleneck for optimization and achieved the results through a comprehensive study design.

- This is an absolutely fascinating project. Well done in ID-ing it, and framing it so practically. The individual elements are ambitious, but seem to be well tailored (and each necessary) to delivering an overall useful result.
- The strong interaction with key stakeholders seems like it's been a plus for your work - is that the case?

- The approaches adopted in this project include experimental studies, simulation model development, and control strategy development. These approaches are comprehensive and very likely to overcome the identified challenges/gaps.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- We were always wondering about the transformer performance and limitations, and this project well addressed it.
- This is based on my close observation, study and practice in this specific field for almost 30 years. In the last two decades, I personally walked through and assessed more than 600 buildings and campuses globally, and was the lead Principal Investigator for a comprehensive energy management program on the Texas A&M university campus, for which cumulative savings exceeded $90 million over a period of 16 years. I was also the PI or lead PI for numerous similar programs. In 2010, Dr. W. Dan Turner and I co-founded the Theory of Nodal Partners, which reflects our view of today's world, IT, energy and utility's supplies, transportation and consumption, smart grid of everything, interplay and readiness. We foresaw this was coming from the front seats.

- Great.
- To the extent that this project helps the utility sector and distribution transformer manufacturers gain comfort with amorphous transformer longevity, it could deliver energy savings well in line with BTO's overarching energy savings objective and Emerging Tech programs sub-goal of demonstrating energy saving tech.
- But even if it doesn't result in greater amorphous DT adoption, this project should deliver a credible new approach to optimizing distribution system DR and DERs, by including DT life and efficiency as part of the equation. That would be a highly attractive outcome for consumers, reliability and environmental benefit. The clear stakeholder interest seems to be a testament to that. Unfortunately, BTO's Emerging Technologies Program goal (techs capable of 45% reduction in energy use /sqft by 2030) is not well-suited to the full range of responsive load beneficial opportunities, but happily, this project also has the amorphous DT efficiency benefit to meet that goal.

- The identified goals, if achieved, will very likely and greatly increase the transformer's efficiency and life span, and hence improve the overall grid robustness and efficiency.

C. Progress

Based on current project efforts, the project was rated **4.00** for the degree to which the project has met ***project-specific goals*****.**

- Great progress and work is almost fully done.

- This project seems to be firing on all cylinders.
- Go GO GO!

- The project has made significant and satisfactory progresses.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Great team work and the team members really complement each other!

- Santee Cooper, NRECA, ERMCO.
- Fantastic stakeholder involvement. This brings great confidence in your approach, and on the likelihood that your results will be practical and put to use.
- Congrats.

- This project has demonstrated very good collaboration with other labs, university, and industrial partners.

E. Remaining Project Work

This project was rated **3.67** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- No further comment.

- Your project approach, stakeholder engagement, and progress to date give great confidence in your future project plan. And if you hit a snag, or discover something new and unexpected, it seems most likely that you'll prioritize and adapt well.

- There are still many remaining tasks and some challenges. But the team seems to be capable of achieving the overall goals within the project timeframe.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Clean, clear and straight-forward definition of task and speedy execution of work plan.

- Clear, focused opportunity, with clear, focused approach.
- Strong stakeholder engagement.
- Strong implementation of approach.
- Just great.

- Comprehensive approaches for the identified problem;
- Good collaborations with other partners;
- Experimental studies are well designed and solid.

2) **Project Weaknesses**

- Could not find any yet.

- The only weakness as I see it: that it can't be cloned!

- No major weakness identified.

3) **Recommendations**

- I would recommend a Co-PI system for such projects to well support young PIs and keep the methodology in check and progress on track for the future. In other words, some mentorship may be necessary for the PIs.

- Just keep going.
- Fantastic.

- If budget allows, testing the repeatability of some conclusions (with different transformers) will be interesting.

Project #32744: Transactive Signal Methodologies: Clean Energy and Transactive Campus (CETC) Project

Presenter: Srinivas Katipamula, Pacific Northwest National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Both reviewers were extremely supportive of this project's approach to designing, developing, and testing scalable technologies for transactive control of buildings, campuses and districts, calling the approach "splendid," "original," "foundational" for transactive controls, and executed thoughtfully with with-developed components and objectives. Each reviewer was equally optimistic about the project's potential impact on BTO's overall energy savings goals, as well as its goal of demonstrating energy saving technologies. One reviewer remarked further that its benefits "go far beyond the direct project outcomes themselves." Specifically, the automated fault detection and diagnosis, AIRCx, and auto-correct sub-elements of this project were expected by one reviewer to both advance the project's ability to deliver energy savings and provide a credible new approach to optimizing distributed energy resources.

Both reviewers were impressed with the project's progress to date, which one reviewer characterized as "enormous" and "delivering on concept and technology. Both reviewers were equally confident in the project team's ability to finish its remaining work, especially given the project's approach, stakeholder engagement, and "spectacular" progress. Each reviewer said that the project's partners were well-chosen and well-coordinated, and that the team had incorporated new project partners and sub-elements well. One reviewer suggested the addition of a stakeholder that influences utility regulations.

Weighted Average: 4.00 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 4.00 Collaboration/Coordination: 4.00 Remaining Work: 4.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Comprehensive but all necessary. Glad to see all the components and the integration are all there with logics to connect. Have been watching Dr. Katipamula's work from far and close through the years, and I'm very happy now the loop is closed by him to fully utilize his whole-life's pursuit in this broad field and turn it into something very "splendid" and "impactful" following the trend and senses DOE, BTO and the industry have realized and been leading the country and communities into.

- This ongoing, foundational transactive controls project continues to make great sense, providing core technology and approaches that inspire other projects, thinking and possible applications. It's great that this project recognizes and aims to facilitate both EE and DER opportunities.
- Well done overall, and congrats for both the original vision and for the steady, thoughtful development of objectives and approach elements.
- The only questions/suggestions regarding approach and framing are:
    - Is there a way to get some additional stakeholder input, particularly along the lines of the policymakers and policy influencers that will be so important in defining the electricity markets/rate design and DER program design that would be key to forming some of the values used in transactive operations? (The project's current stakeholder engagement seems to be strong, particularly with the foreshadowed establishment of a broader utility stakeholder advisory group)
    - Is it really necessary to presume that "EE is at the core", rather than more broadly recognizing that both EE and DER may be highly beneficial depending on grid conditions and consumer preferences? It doesn't appear to get in your way on this great project, but someday it might.
- Overall: Outstanding!!

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- This is based on my close observation, study and practice in this specific field for almost 30 years.

- This project plays an enormous role in developing the core concepts and technology of transactive operations, and proves that up with real implementation. Its benefits go far beyond the direct project outcomes in themselves. Just outstanding, inspired, and enormously valuable.
- The AFDD, AIRCx and Auto-correct sub elements of this project should certainly help deliver energy savings in line with BTO's overarching energy savings objective and Emerging Tech programs sub-goal of demonstrating energy saving tech.
- Going beyond that, this project is also delivering a credible new approach to optimizing DERs. That will be a highly attractive outcome consumers, with reliability and environmental benefit as well. The stakeholder interest seems to be a testament to that. Unfortunately, BTO's Emerging Technologies Program goal (techs capable of 45% reduction in energy use /sqft by 2030) is not well-suited to the full range of transactive DER beneficial opportunities, but happily, this project also has clear EE benefits as well.

C. Progress

Based on current project efforts, the project was rated **4.00** for the degree to which the project has met ***project-specific goals*.**

- Well done in parallel execution of quite a few sub-tasks and with integrations.

- This project just keeps delivering on both concept and technology, building out the transactive DER and EE opportunity in a very thoughtful and effective way.

- The successful incorporation of new project partners and new sub-elements continues to inspire confidence.
- Go Go GO!

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Well picked collaboration partners and well carried-out coordination from multiple tracks.

- Great to see engagement with utilities, manufacturers and other institutions.
- Going forward, the foreshadowed advisory panel will be a good step. It would be useful to also include other stakeholders (beyond manufacturers and utilities) who influence state and federal energy utility regulatory outcomes, as the ultimate application of this technology will involve utility rate and EE & DER program design regulations and legislation. Insights from policymakers and influencers will be helpful.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- No further comment.

- The project approach, stakeholder engagement (current and foreshadowed), and enormous continuous progress to date give great confidence in your future project plans. And if you hit a snag, or discover something new and unexpected, it seems most likely that you'll prioritize and adapt brilliantly.
- Go!

F. Additional Comments and Recommendations

1) **Project Strengths**

- Like I mentioned previously, solid foundation of scientific knowledge development plus years of field experience all paid back with this gigantic total solution package, which is a view from 30,000 feet above but also irons out all the details. It is amazing to witness national labs' scientists' lives from a historic standpoint and I have to admire them!

- Brilliant concept; smart approach building out the concepts; excellent implementation; good stakeholder engagement. All key to its continuing success.

2) **Project Weaknesses**

- None.

- The one area where this project's continuing spectacular performance could be enhanced: engaging utility industry policymakers more, to gain a better mutual understanding of what's possible and attractive from future regulatory and legislative developments that will guide/facilitate/drive the electricity markets & rate design and EE & DER program design. Those policy developments will be vital in unleashing the enormous potential of this project's transactive technology.

3) **Recommendations**

- None.

- GO Go GO!
- And engage more with utility policymakers and policy influencers, for reasons discussed in comments on project weaknesses.

Project #32745a: Virtual Batteries

Presenter: Di Wu, Pacific Northwest National Laboratory
DOE Manager: Sven Mumme

Brief Summary of Reviewer Comments

Both reviewers expressed confidence in this project's approach to enabling utilities and building owners to use flexible building loads as virtual batteries, with one reviewer saying that the framing of building loads as batteries is "useful for both analytic purposes and discussions with other stakeholders." In this reviewer's estimation, the approach's sub-elements were thoughtfully created, necessary, and "tractable." Given the number of communities nationwide, this project's outcomes could be truly impactful someday, one reviewer said, while the other reviewer elaborated on this point by saying that virtual batteries could deliver a credible solution for energy storage needs. Both reviewers expressed satisfaction with the project's progress to date and the team's plans for its remaining work. The project earned high marks and compliments from both reviewers for its collaborations with various stakeholders, with one reviewer praising the project for its strong involvement of manufacturers and utilities.

Weighted Average: 4.00 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 4.00 Collaboration/Coordination: 4.00 Remaining Work: 4.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The key is aggregate and bundle, which I learnt and concur.

- Brilliant.
- Framing responsive building loads as VBs is useful both for analytic purposes and for discussion with key stakeholders.
- All the approach sub-elements seem very well thought out, necessary, and tractable. Well done.
- Intensive involvement of utility stakeholders (NRECA and SCE) gives great confidence that your approach is on target, and that the results will have the best chance of being put into practice.
- Really brilliant.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Thinking of all the communities nationwide and the great potentials, it could be truly impactful one day.

- This VB project should deliver a credible solution and framing to deliver on a highly attractive opportunity of for consumer, reliability and environmental benefit, based on the need for energy storage, DR and ancillary services (as distinct from EE). The strong stakeholder interest is a testament to that. Unfortunately, BTO's Emerging Technologies Program goal (techs capable of 45% reduction in energy use /sqft by 2030) is not well-suited to the full range of responsive load beneficial opportunities.
- I give this project the top rating on Q3 based on my sense of what would be a more useful BTO ET goal.

C. Progress

Based on current project efforts, the project was rated **4.00** for the degree to which the project has met ***project-specific goals*****.**

- On track and great progress. No further comment.

- Seems to be going well.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Great engagement of collaboration and coordination.

- Super.
- Great to see the intensive engagement with utilities and manufacturers.
- Going forward, the foreshadowed advisory panel will be a good step. It would be useful to also include other stakeholders (beyond manufacturers and utilities) who influence state and federal energy utility regulatory outcomes, as the ultimate application of this technology will involve utility rate and EE & DER program design regulations and legislation. Insights from policymakers and influencers will be helpful.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Proceed as planned. Great potential also exists in commercial buildings, but could be much more complicated.

- The project approach, stakeholder engagement (current and foreshadowed), and progress to date give great confidence in the project plans for remaining work. And if the team hits a snag, or discovers something new and unexpected, it seems most likely that they'll prioritize and adapt brilliantly.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Great team work and penetration of electrical engineers and mechanical engineers, etc. Working to solve the problem from both sides.

- Great concept; smart approach building out the concepts; excellent implementation; very strong stakeholder engagement. All keys to its continuing success.
- Well done.

2) **Project Weaknesses**

- How to facilitate such transactions in a highly secured fashion.

- A major challenge for much of the work in this area will be ensuring a fit between capabilities developed and the regulatory and market structures under which they might be eventually deployed. EE/DR/storage program design and related rate/market design will need to evolve to un-tap the potential.
- That's not a criticism of this project by any means. Rather, it suggests that more and earlier interaction with utility regulators and policymakers will be valuable, going beyond the project's currently excellent efforts to interact with utilities and equipment manufacturers.

3) **Recommendations**

- I would recommend a Co-PI system for such projects to well support young PIs and keep the methodology in check and progress on track for the future. In other words, some mentorship may be necessary for the PIs.

- Go Go GO:
- And engage more with utility policymakers and policy influencers, for reasons discussed in comments on project weaknesses.

Commercial Buildings Integration
Energy Performance & Tools

Project #222101: Financial Management for Retail Energy Efficiency

Presenter: Eric Hiatt, Retail Industry Leaders Associations
DOE Manager: Priya Swamy

Brief Summary of Reviewer Comments

Nearly every reviewer applauded this project's approach to attacking a key market barrier that, according to one reviewer, had kept the retail industry from addressing its cost-effective energy conservation opportunities. Several reviewers underscored the importance of leveraging's RILA leadership, strong and diverse membership, and its reputation to reach the retail industry with energy information. Other reviewers called out the project's "clear and well-considered management structure" and its strong planning efforts. One reviewer's remarks stood in stark contrast their peers, however, claiming that the team's lack of engagement with retail finance professionals had created a "big risk of project failure," by not providing the right information in a manner those stakeholders need; the reviewer called this omission a "red flag," and the consequence of "poor planning and execution."

Despite this one reviewer's concern, all others did not doubt the potential impact of this project to advance BTO's energy efficiency goals. One reviewer claimed that the project's utilization of BTO's commercial building efforts provided a foundation for success, while another highlighted that the strength of RILA's systems could significantly reduce the energy use intensity of U.S. retail buildings. Even though reviewers praised RILA's role and its influence, however, they did not hold all of the project's other collaboration and coordination efforts in as high a regard. One reviewer was not convinced that the project's current momentum was organized enough to be sustained into the future. Another reviewer remarked that there was room to engage property owners, developers, and landlords, which the reviewer claimed were a missing element. As described above, a third reviewer questioned the lack of engagement with retail finance professionals. Not every reviewer was unsatisfied with the project's outreach, however. One reviewer characterized the project's partners as "unusually strong and diverse," describing their "impressive combination of financial expertise, advocacy, and business engagement."

Reviewers did not comment heavily on the project's progress. One reviewer found the number of the project's implementation models to be low, at least when compared to the number of stakeholders in RILA, but most reviewers did not have any significant reservations about the project team's progress or the work remaining. Two reviewers commented that having educated finance professionals in the final stages of this project would be beneficial, though one remarked that "it might be too late" at this current stage. A predominant theme that emerged from the reviewer's recommendations for improvement centered on institutionalizing the project's resources, materials, and partnerships to permanently influence and grow the retail market's energy optimization efforts. One reviewer remarked that creating a specialized industry group, or developing, "succinct, visual case studies based on adopted models" could, become useful testimonials for other businesses to learn from and copy.

Weighted Average: 2.76 # of Reviewers: 4
Approach: 3.25 Impact: 2.75 Progress: 2.50 Collaboration/Coordination: 2.25 Remaining Work: 2.75

A. Approach

This project was rated **3.25** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Collaborative approach using multiple entities to enhance finance EE is strong.
- With over 1,000 facilities within RILA's reach the program's impact could be significant.
- Excellent approach to characterizing initial corporate conditions within a defined market segment.
- The project has a clear and well-considered management structure and set of partners (e.g., Deloitte Finance, IMT, EDF, RILA, and retailers). Notably, the project team also thoughtfully engaged EDF Climate Corp fellows. This is great application of this resource.
- The project team gave significant consideration to planning for the end of the current funding cycle (e.g., turning workshop resources into durable materials such as financing guides).
- Focus on finance offices within retailers addresses a key barrier/opportunity to capturing all cost-effective energy opportunities.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.75** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Utilizing 1 of 3 prongs of BTO show's solid foundation for success.
- If the existing RILA systems are truly leveraged the impact could be significant on the reduction of EUI of US buildings.
- The project appears to have a significant, positive impact in line with expectations from the proposal.
- Not yet connecting directly to retail finance professionals during the first two years creates a big risk of project failure through not providing the right info in the right way that these professionals need.

C. Progress

Based on current project efforts, the project was rated **2.50** for the degree to which the project has met ***project-specific goals*****.**

- Suggest organizing financial education workshops for the future.
- It would seem that the amount of implementation models created is low compared to the amount of stakeholders in RILA.
- The project appears to be proceeding in line with expectations. Notably, the project is taking specific action to prepare for the end of the performance period by creating durable resources.
- Not yet connecting directly to retail finance professionals during the first two years creates a big risk of project failure through not providing the right info in the right way that these professionals need. This was poor planning and execution and failure to engage them immediately at the beginning of the project was a red flag.

D. Collaboration and Coordination

This project was rated **2.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Strong financial education implementation; however it appears that momentum in the future is not organized well to continue to make the project successful.

- The planned leveraging of relationships with other industry organizations will bolster collaborating and coordination.

- The project has an unusually strong and diverse set of partners and collaborators.
- The project has demonstrated an impressive combination of financial expertise, advocacy, and business engagement.
- It might be useful to have a more explicit role for engagement with property owners/developers/landlords. This appears to be a missing element in the project's otherwise complete and impressive set of partnerships and collaborations.

- Not yet connecting directly to retail finance professionals during the first two years creates a big risk of project failure through not providing the right info in the right way that these professionals need.

E. Remaining Project Work

This project was rated **2.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Collaboration is relatively strong to complete project work. Consider oversight of next steps to keep key stakeholders engaged.

- The education of Finance professionals/teams to better understand the long term operational savings is an important component to educating the industry.

- The team presented a clear plan for the completion of the proposed work.

- Engaging finance officers now is a good idea, but there is a risk that it is too late to provide what they need if their answers necessitate significant changes from the created materials/approach.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Excellent bridge of financial education linked with energy incentives.

- Activating the strong network RILA has created and informing key decision makers on the long term operational savings of energy conservation measures. Aggregating those cost savings over many locations such as the stakeholders have can be a powerful business case to incite action.

- Leadership by RILA is a valuable and distinctive aspect of this project. RILA's role provides credibility and opportunities for unusual partnerships.
- This is a model for future BTO projects with strong industry leadership and clear links to on-the-ground industry practice.

- Good conversion of 101/201 courses into e-learning courses.
- Good capturing of resources and promoting those in a campaign to get them to finance professionals.

2) **Project Weaknesses**

- Lack of seeing follow thru on continuing education.

- Perhaps not including educating the finance professionals concurrent with the energy managers to better facilitate cooperation and collaboration.

- This project has a great team.
- It seems notable that the project does not have explicit partnership with retail project owners/developers. This could be a limitation on the scalability of the work.

- Not yet connecting directly to retail finance professionals during the first two years creates a big risk of project failure through not providing the right info in the right way that these professionals need.

3) **Recommendations**

- Take action to continue education with assistance and money.

- Create succinct, visual case studies based on models adopted to serve as testimonials for like business to spur adoption of energy conservation measures.

- As the project comes to a conclusion, it would be useful to carefully consider how:
    - Resources and collaborations could be institutionalized in self-supporting industry groups or partnerships.
    - Information can remain accessible after the end of the performance period.
- Overall, it's an excellent project and a model for others.

- Focus on turning the program materials into a permanent large-scale change in the retail market dynamics with respect to implementing energy optimization projects. Given the lack of connection to date with finance professionals, be prepared to engage directly with them 1-on-1 about how they view the resources you've developed, and quickly pivot the resources if you get feedback the resources need to be different to address the CFO's real needs that you might not have heard yet.

Project #222109: Accelerate Performance

Presenter: Ben Heymer, Seventhwave
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Overall, reviewers regarded this project's approach as well-articulated and clearly structured. However, all reviewers also either implied or explicitly suggested that the project's approach should have been more strongly oriented toward building owners and developers instead of utilities, who one reviewer described as not likely being "the most effective partners to scale-up use of innovative procurement strategies." One reviewer "heard no mention" of coordination efforts with building representatives, whom the reviewer felt was a "crucial" stakeholder group when it came to writing requests for proposals in the commercial sector. Two more reviewers echoed this concern, while one added that the choice of energy utilities as an intermediary "seem[ed] removed from the actual decision makers the team is attempting to influence." Several reviewers remarked that the project team appeared to have begun realizing this perceived mistargeting of coordination efforts, commenting further that while the project team "should have" pivoted before, time still remained to do so.

Reviewers were comfortable with the project's progress on tool development, but disagreement among reviewers was evident regarding how impactful these tools were expected to be in the project's sample applications and proof-of-concept demonstrations. Several reviewers were also skeptical that the project's outcomes could be scaled up from its test niche to the wider market, recommending that a different approach—one that engaged a wider set of stakeholders—would be necessary to achieve the project's intended impacts.

Several reviewers left many suggestions for the project team to consider in regards to improving the project's approach and engagement of the commercial buildings industry. Several reviewers suggested that a more thorough market analysis of the procurement tools' intended users could improve the project's outreach efforts and eventual market diffusion. To expand the project's pool of stakeholders, this same reviewer suggested that the project team forge partnerships with non-utility partners like the Urban Land Institute, American Institute of Architects, U.S. Green Building Council, and other similar groups, all of who "have more direct access to the individuals [in the commercial building community] with responsibility for procurement."

Weighted Average: 2.98 # of Reviewers: 4
Approach: 3.25 Impact: 3.00 Progress: 3.00 Collaboration/Coordination: 2.50 Remaining Work: 3.00

A. Approach

This project was rated **3.25** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Performance based procurement has issues as each utility has unique regulatory goals - this is a known issue which can make implementation difficult.

- By setting absolute energy targets in the RFP, projects will realize lower EUI's.

- This project tackles an important issue and represents a timely effort to increase the use of performance-based procurement for high performance buildings.
- The project team clearly articulated a three part approach, including tool development, utility engagement, and demand creation
- Working with and through utilities was clearly essential element of the team's approach. However, the evidence presented suggests that utilities may not be the most effective partners to scale-up use of innovative procurement strategies. This part of the team's approach requires further review and, potentially, reconsideration.
- Additionally, the team's approach does not seem to have sufficient consideration for factors influencing market demand. There is a relative lack of information on factor such as prevailing attitudes and constraints on adoption of innovative procurement. In other words, what, exactly, is the potential audience and what are their motivations and constraints for adopting new procurement strategies. This is foundational information that can provide an evidence base to refine the project approach.

- The approach was strong in addressing the owner's and utilities barriers. Based on what the team learned, there should have been and still could be a pivot to reduce the focus on the utility pathway a bit and include an owner/developer focus.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Advanced energy guides are strong and used well. Would be beneficial to publish more tools.

- The performance based procurement process will be impactful in terms of developing pathways for energy performance.

- Generalizing, project's intended impact was a change in building procurement practices. The interventions include the development of new tools, sample applications, and proof-of-concept demonstrations.
- The team had clear positive impacts through tool development. They distilled and generalized NREL's performance-based procurement experience and created more generally applicable instruments.
- Impact from the applications and proof-of-concept seem harder to evaluate and, at best, limited to a few areas and small number of specific partners. These impacts are significant but modest given the potential of the idea and the scope of the challenge.
- Sufficient information was not provided to compare magnitude of observed/realized impacts with expectations at the inception of the project. In absolute terms, it seems that is possible to achieve much broader impacts with these important ideas.

- The team has developed a permanent utility program plus a couple more pilots. If these persist, that will be a useful toehold for this approach in the market. But scaling it up to capture most of the market will require a different approach outside of the utility program space. The team should begin this in its final year.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- Good progress.
- Considering NREL's location it would seem there should be more progress in surrounding states.
- The project seems to be on-track based information provided.
- Progress to date is good.

D. Collaboration and Coordination

This project was rated **2.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Would suggest having key people/stakeholders work on getting the word out on advancing publishing tools.
- I heard no mention of coordinating with owner's reps, which is crucial as they are many times the ones owners look at to write RFP's in the commercial sector.
- The team has a strong set of partnership and national collaborations.
- Unfortunately, these may not be the collaborations and partnerships with the greatest potential for positive impact. Debatably, this might have been recognized at the outset of the project. However, the project team's experience does seem to provide clear signs that different types of partnerships and collaborations are needed to scale up the impact of this important work.
- Specifically, the team emphasized collaboration with energy utilities. This choice of intermediary seems removed from the actual decision makers the team is attempting to influence, presumably property owners and developers. The presentation alluded to the team's growing awareness of this limitation. It is not less clear whether there are sufficient times and resources available to address this issue or simply to use it as the basis for future work.
- Good work to date. Team should do more to engage commercial real estate development community.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Success appears to need more publishing of tools.
- As noted before the outreach needs to be to owners' representatives as they are key to the RFP generation process.
- The project appears to be on-track based on the information provided.
- The team is likely to complete the rest of the work as planned, meeting the narrow plans of the award.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Strong knowledge from NREL labs and seventhwave.

- By creating a performance based procurement process the program has front loaded the energy conservation conversation and provided a path for all project participants to buy into project goals.

- The foundation of this project is very strong.
- The idea of generalizing and sharing NREL's innovative and demonstrably effective approaches to high performance procurement is excellent. NREL's approach has undeniably provided tangible, on-the-ground benefits.
- The project has distilled and generalized this experience into a set of practical tools.
- The project team has shown in a few instances that these tools can be successfully applied beyond NREL's context and circumstances.

- Project effectively worked with utility program administrator, laid the groundwork for this approach in the utility program space.

2) **Project Weaknesses**

- Further funding to publish more tools and have key people to educate on tools.

- Outreach to owner's reps and developers seems lacking.

- The project team is limited by its focus on utilities as an outreach and scaling partner and the lack of essential about market demand and barriers to adoption.
- As mentioned in earlier questions, there are better choices for partners. Utilities are removed from the procurements decisions that the team seeks to influence.

- The project fails to directly engage the commercial real estate development and owner communities nationally. The utility program channel is good, but indirect. Including the owners' developers is a must to accomplish the market transformation goal.

3) **Recommendations**

- Money to foster more tools and people to facilitate and educate on tools.

- Tackle this from the business case side by reaching out to institutional building owners and owners' reps.

- Based on the information provided, I would suggest two actions:
    - Study market demand and constraints on adoption. It would be useful to have a representative sample of information on the characteristics of the market of intended users for the procurement tools. Who are they? How do they make decisions today? What would attract them to this new toolkit? What are the barriers to adoption? Ideally, answers to these questions could be expressed as statistical distributions with the target market. This information would benefit the project team and others.
    - Partnerships. As mentioned in previous responses, the project would benefit from collaboration with non-utility partners, such as ULI, AIA, ICSC, or USGBC. These groups have more direct access to individual with responsibility for procurement. Raising awareness and skills in these national and international groups would create new opportunities to scale up impact.

- Directly engage with the Urban Land Institute or other similar group to go straight to the owner/developer community nationally and influence them.

- Develop a process for the utility to engage early in project planning process through direct engagement with real estate developers through BOMA, institutional owner trade groups etc. Document and create resources for some of the biggest market transformation needs in this space: getting engagement of owners/developers in early project planning phase; using utility program to educate local design community about how and why to use this approach; address any utility/regulator issues in approving and counting savings from a program whose cost-per-kWh-saved is less clearly-calculated than a typical widget incentive program. Document the process and opportunity for local/state governments to incentivize this requirement in their permitting processes or otherwise – outside the utility program context. Make an extra effort to get a few state/federal building projects into the program and document any findings specific to public buildings – state, local, and federal government are big building owners themselves and are the kind of long-term occupants of a building that can capture benefits over many years. Publicize this program approach widely through channels like the Consortium for Energy Efficiency and the Association of Energy Services Professionals. Document recommendations for any needs for a changed approach from broader market in the US, such as AIA, American Planning Association, ASHRAE, NASEO, etc. – there might be recommendation for some of these to change education of their members, licensure, any legal barriers to design/build, etc.

Project #24292: Boosting Energy Efficiency and Economic Development through Chambers of Commerce

Presenter: Lotte Schlegel, Institute for Market Transformation
DOE Manager: Priya Swamy

Brief Summary of Reviewer Comments

Comments made by reviewers about this project were notably more positive and supportive than the scores suggest. Every reviewer made notably supportive remarks about the project's approach to engaging chambers of commerce, which they collectively described as an innovative way to promote energy conservation measures across different jurisdictions throughout the country. Similarly, reviewers expressed that the project's impact could be significant, especially for small business owners, and two reviewers commented these efforts could and should be replicated around the country to advance BTO's larger goals. According to one reviewer, "the potential for self-sustaining replication is very high," but another reviewer doubted this claim because "there [was]n't more outreach to other chambers."

Reviewers expressed apparent satisfaction with the project's progress to date and remaining work, though one reviewer thought the leasing barrier would need to be overcome, while another reviewer wanted to hear more about efforts to reach even more chambers of commerce. As previously mentioned, reviewers commented that the project's collaborations were a significant project strength, but one remarked that the project's "door-to-door" approach of engagement might be time consuming, and that utilizing other avenues of engagement (e.g. the National Chamber Program) could be beneficial for securing additional partners. Several reviewers recommended that the team add a dedicated coordinator to oversee the chamber outreach, while another said the project team might consider presenting the program to a network of chambers to broaden outreach efforts.

Weighted Average: 3.05 # of Reviewers: 3
Approach: 3.33 Impact: 3.00 Progress: 2.67 Collaboration/Coordination: 3.00 Remaining Work: 3.00

A. Approach

This project was rated **3.33** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Chamber connections approach is excellent. Replicate with other chambers should be an ongoing effort.
- Pairing basic energy education with easy steps for improvement seems like a great way to approach promotion of energy conservation measures.
- This is an exceptionally innovative and smart combination of project leads and partners -- it illustrates a great combination of national, local, and regional expertise.
- This project is a nice evolution of the IMT-COSE Cleveland Pilot with a focus on 250+ small businesses (7 million sf) through green leaving, energy efficiency workshops, energy audit consulting, and energy improvement technical assistance.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Impact is to bring all chambers together using consistent information across chambers
- The program contributes to program goals by providing opportunities for identifying pathways for energy performance for small business owners.
- This project provides a very clear description of impact by phase based on businesses reached, energy assessments, green lease reviews, business complete energy improvements, plus supporting communication materials.
- The project appears to be important in two different ways:
    - The project has a direct and positive impact on the participating organizations.
    - The project can serve as a model for similar efforts that could be replicated across the country.
- The first category of impact is commendable. The second category is important.

C. Progress

Based on current project efforts, the project was rated **2.67** for the degree to which the project has met ***project-specific goals*****.**

- Progress still needs to overcome leasing barrier - currently an issue
- The progress towards reaching small businesses seems like it is tracking well but I didn't hear much about reaching additional chamber or membership organizations.
- Progress was clearly reported, and it seems to be on-track.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Collaboration is good. Door to door outreach though seems very time consuming. Utilize other avenues to create success

- There is a National Chamber Program is a network of over 1,500 chambers of commerce that works together to deliver greater member value; perhaps this might be an area for further collaboration.

- Outstanding use of non-traditional partnerships to increase awareness and support on-the-ground action.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Further logistics/organization is needed to take further action

- With a little over a year left in the project, the remaining goals seem attainable.

- The team appears on-track to complete remaining work as scheduled.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Chamber approach – excellent.

- The door-to-door engagement and in-person consultations seem to be working well for uptake.

- This project brings together an innovative set of partners to engage a non-traditional market.

2) **Project Weaknesses**

- Who will keep the momentum/oversight of the Chambers? Not clear.

- I am not sure how scalable the program is considering there isn't more outreach to other chambers.

- This is a very strong project, but there always opportunities for improvement. The project team could do more to:
    - create a reproducible model. This may involve complementing project-specific impacts with more effort on business model definition.
    - connect to conceptually similar organizations, such as Business Improvement Districts.
    - learn from/reference best practices from around the world. One example seems like the Sydney CitySwitch program (see http://cityswitch.net.au/)

3) **Recommendations**

- Get a coordinator to oversee chambers and create continuity.

- Teach the program to a network of chamber to broaden reach.

- The project has demonstrated the potential for engagement via Chambers of Commerce. The direct impacts are impressive. The potential for self-sustaining replication is very high.
- More than the impact of this project, it would be very useful to demonstrate that the approach could be institutionalized within Chambers of Commerce with self-sustaining business models. The success of the project suggests that it might be possible to create self-sustaining programs at Chambers of Commerce or larger industry associations (e.g., add-ons to membership fees, loan referrals, sales leads, etc.).
- As an example, the presentation materials indicated that the Energy Efficiency Symposium turned-out 15 organizations representing 55,000 businesses. Conceptually this is <$10 per member business. Is the project worth $10/member? Can it become self-sustaining for some organizations? Can the project team

assess willingness to pay? Can the project team identify reasons why the services may or may not be worth a nominal fee, such as $10/member? Are there other ways to design self-sustaining business models?

- It is important to keep in mind that these questions are relevant because of the underlying success and value of the project.

Project #25150: Building Energy Asset Score

Presenter: Nora Wang, Pacific Northwest National Laboratory
DOE Manager: Sarah Zaleski

Brief Summary of Reviewer Comments

All reviewers expressed confidence in this project's approach, but questions lingered about what the ultimate goal was of asset rating, and whether the project was optimally structured to achieve that mission. Specifically, nearly every reviewer suggested that, in their estimation, the project's progress had reached a crossroads between pursuing further tool development efforts or focusing more on the Asset Score's market uptake; one reviewer described their understanding that the "core project purpose" was to take the Asset Score to scale in the market. Reviewers uniformly agreed that the Asset Score had emerged as a relatively mature tool after "quite a bit of time," and that the project was progressing as intended. However, the tension between tool development and diffusion echoed throughout reviewers' remarks about the project's remaining work, its choice of partners, the scale of its intended impact, and whether the project was appropriately designed and defined to achieve what appeared to be joint missions.

Reviewers agreed that the Asset Score had already made a significant impact within its pilot niche of "discrete programs and local governments," wherein "key foundational research" had been undertaken to help the commercial building real estate sector "fully incorporate energy efficiency into [its] core business practices, including appraisal and underwriting." Reviewers remarked that these efforts align with BTO's commercial building goal of advancing net-zero buildings by filling long-existing gaps, providing the market with a tool that "effectively addresses a range of technical and design challenges [with] an impressive kit of analytical tools that are logically integrated with other [DOE] programs." There was more confusion, however, about the future of this project.

If this project was primarily oriented to develop a successful tool, than every reviewer seemed to agree that the project team mostly accomplished their objectives. However, several reviewers were less convinced that the project had made much progress on improving the market adoption of Asset Score. Even though one reviewer described the Asset Score as "a well-known tool," another reviewer disagreed entirely, saying that "general awareness of Asset Score remains relatively low across the building industry." Another reviewer wondered how people "would know it exists" and be incentivized to use it.

Consequently, several reviewers questioned the potential scope of this project's market impact, commenting that much of the project's remaining work and impact had already been realized if market deployment was not a significant project thrust area. One reviewer surmised that the national impact of Asset Score was "possible, but not inevitable or well documented at this time." Nearly every reviewer described the project's collaborations in very supportive terms, but a few expressed concern that the project's current partners could be pulling the project in too many directions, thereby enabling "scope creep" or causing the project team to overlook other stakeholders who might benefit from the Asset Score.

Reviewers generally focused their recommendations on ways to improve Asset Score's eventual market acceptance. One reviewer suggested that engaging more cities, utilities, states, the American Institute of Architects, LEED, and other similar partners could improve market diffusion. This reviewer continued by noting that the project team should continue work on the audit template and preview pathways to "increase the number of buildings that 'get in [Asset Score's] door.'" This reviewer also suggested integrating the Asset Score into federal practices for building energy audits. Another reviewer remarked that the project team may need to redefine their strategy according to whether they intended to encourage private sector activities that could ultimately produce a similar product that replaces Asset Score, or whether there was a compelling reason to operate Asset Score indefinitely as a publicly managed tool within DOE.

Weighted Average: 3.16 # of Reviewers: 4
Approach: 3.50 Impact: 3.25 Progress: 3.00 Collaboration/Coordination: 3.00 Remaining Work: 2.75

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Good approach.

- Creating a free standardized tool to inform investments and real estate transactions is a sound approach to get large portfolio owners interested in energy conservation.

- This is a big, ambitious, interconnected project. It is also clear that it has evolved significantly since its inception.
- Consequently, it is difficult for a reviewer to assess its "approach" in a discrete, bounded way. The Asset Score efforts appears to be technology infrastructure underpinning or connected to a number of BTO and DOE activities.
- The interconnected/interdependent nature of the project approach is simultaneously a strength and source of significant risk. The value of the "approach" is high dependent on progress and outcomes across multiple programs. Moreover, it's clear that the approach can change in response to circumstances. Again, this represents a strength, but also a weakness.
- The presentation did answer specific questions about the project team's approach to risk management. This should be documented in project materials.

- Core of project addresses compelling need for an ASSET RATING in the commercial building sector.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Good impacts to date.

- The program supports evaluation of a building’s integrated performance and encourages deep retrofits in alignment with the CBI goal of getting to net zero buildings.

- Asset Score has emerged as a very capable tool with the potential for significant positive impact on the industry.
- At this moment, it unless how much of the potential has been realized or will be realized in the near future. In part, this reflects the large number of applications, necessary dependencies involved in partnerships, and lag times between technology development and application.
- It is clear that Asset Score has had high impact in supporting discrete programs and local governments. This is a demonstrated strength.
- It is less clear how Asset Score will have national impact beyond early adopting programs and jurisdictions. This seems possible, but not inevitable or well documented at this time. In other words, how will the positive impact for early adopters translate into widespread positive impacts?

- If successful, the Asset Score will provide a pervasive asset rating in commercial real estate markets in the U.S. that can help the commercial real estate market fully incorporate energy efficiency into commercial real estate core business practices including appraisal and underwriting.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- Create more implementation efforts.

- Although it has taken quite a bit of time to get this far the project has made significant progress towards creating the tool. I didn't see much about how the tool will be more widely adopted, which seems like the point of development.

- Project development appears to be progressing as planned based on the documentation and presentation.

- Project has built a capable tool and supporting program infrastructure. There has been some scope creep in search of the best way to get to scale with the use of the score in the market.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Excellent collaboration with other entities.

- Perhaps if there was more collaboration with stakeholders that could benefit from this tool it would spread adoption.

- The Asset Score team has cultivated an exceptional network for partnerships and collaborators.
- This network is simultaneously a strength and a risk. It is a strength as it speaks to the efforts of the team and demand for Asset Score capabilities.
- It is a risk since this large group of stakeholders are likely to pull the platform in multiple directions. This creates challenges for the project's relatively small team and constrained budget. Incremental demand for Asset Score services will not be met with incremental revenue to support development. This creates a significant scaling challenge for this type of effort. This can result in a situation where development resources are "stretched" to the point where many stakeholders are dissatisfied. This is not inevitable, but it is a significant, foreseeable risk.
- Barring a change in the project's business model, it is not clear how the Asset Score team will meet and prioritize commitments to its impressive network of partners and collaborators -- most or all of whom receive Asset Score as a free service.

- The team has collaborated effectively with many related parties, including service providers, state and local governments, and commercial real estate owners and managers.

E. Remaining Project Work

This project was rated **2.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- In progress.

- As there is no end date for the program given it would seem the remaining project work would be more than what is listed. Specifically, how are they addressing market adoption and deployment of the tool?

- Project documentation and the presentation suggest that the project is on track to complete remaining work.
- However, the Asset Score project does not appear to have a discrete end-point. As a technology platform, it appears intended to be an open-ended commitment. Consequently, it is not clear how the concept of "remaining project work" should be evaluated.
- Based on experience, we can expect that the ratio of new development to maintenance will change over time. This means that the fraction of project budget allocated to fixing, refactoring, and upgrading current capabilities will increase, generally at the expense of new feature development. This is a widespread feature of software development, yet it is often difficult for R&D-oriented programs like BTO to accept. This is should be explicitly considered in planning for Asset Score and related information technologies (e.g., SEED).

- Keep focus on the core project purpose to ensure that the scoring is taken to scale in the market.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Asset score is a well-known tool.

- Simplified way for large portfolio owners to aggregate the performance and opportunities for their buildings.

- Asset Score is clearly offering an "in demand" set of capabilities. Market participants want the tools that Asset Score provides. The ability to get these in-demand services for "free" (i.e., subsidized) makes Asset Score very attractive.
- Asset Score has effectively addressed a range of technical and design challenges to provide an impressive toolkit of analytical tools that are logically integrated with other programs (e.g., SEED).
- Asset Score has attractive user interfaces and reports.

- The project provides the key foundational research that is necessary for the commercial buildings market to understand the asset-based performance of properties. This is a fundamentally technical need that requires the objective, fair, and scientifically rigorous execution that DOE and the Lab team have brought to bear.

2) **Project Weaknesses**

- Re-look at asset score merging with other companies in order to create streamlined tools.

- How will this tool become widely used? How will people know it exists and be incentivized to use it?

- Asset Score has a number of specific weaknesses, including:
    - General awareness of Asset Score remains relatively low across the building industry.
    - It is not clear (at this moment) whether Asset Score is a research and development project or an operational tool. If/when should stakeholders expect it to be available as a stable operational resource?
    - By design, Asset Score will inevitably have challenges balancing simplicity with complexity. For complex applications, Asset Score competes with established energy modeling tools. For "simple" applications, Asset Score must address knowledge, skill, and information gaps for users. The project team has clearly grappled with these issues internally. However, every new Asset Score user will need to understand and navigate this spectrum. This will require constant communication and user training.

- The project has undergone some scope creep, which increases the risk having a more costly system to maintain.

3) **Recommendations**

- Tweak asset score to entities that have different factors to contend with. Utilities are an example of having there on scoring and don't want to be bothered with using yet another tool.

- Address deployment and how this will be brought to market.

- Asset Score is an important piece of the Department of Energy's market transformation toolkit. It has successfully filled important gaps. Moving forward, it is possible several specific recommendations:
    - New Features. Asset Score needs a clear, well-documented plan laying out its feature development roadmap and providing a specific rationale to prioritize new features.

    - Maintenance and Operations. The transition from research and initial development to scaled operations will create new requirements for on-going maintenance and platform operations. These demands may not be entirely consistent with earlier research and development activities. The team can expect a greater emphasis on user support, day-to-day bug fixes, periodic refactoring, and increased expenses for servers and data storage. This requires a specific plan and management capabilities beyond the feature and development roadmap.
    - Market Interactions. Asset Score is a federally subsidized resource operating in the "prop tech" business space. To date, it has filled a specific market need. However, Asset Score provides its services for free, despite significant costs. This can make it difficult or impossible for private sector solutions to succeed in this space. Asset Score needs to define its intended relationship with private sector tools. Does it intend to encourage private sector activities that may ultimately replace Asset Score (i.e., Asset Score as a demonstration)? Or, is there a compelling public need for Asset Score to operate indefinitely with on-going public investment? The Asset Score team should clearly define its strategy with respect to these and related issues.

- Step back and ask what needs to happen for 100X-1000X increase in market uptake of the Score, then focus on those activities to reach the level of scale in the market. This is probably through channel partners such as cities, utilities, states, AIA, LEED, and similar. But it may also require some new thinking about the program.
- A few specific suggestions follow.
- Increase emphasis on audit template and preview pathways to increase the number of buildings that get "in the door" with the Asset Score. Work with federal sector to integrate the use of the Asset Score into federal practices for energy auditing buildings every four years. Integrating renewable energy and grid-interactive buildings are nice, and can be done to serve BTO needs, but should not distract from the core focus of scaling the Score in the market. Work with EPA to increase the integration between the Asset Score and Portfolio Manager. To best serve users, these two systems should provide a unified user interface or be brought together under one roof and combined into a single system. For design, develop an OpenStudio plugin (and maybe plugin for other design software like Revit) to run the Asset Score and ENERGY STAR Target Finder automatically for a model, to see updates rapidly during design phase. This embeds the score in the new construction market at the design phase. Link this project explicitly to the "Energy Factors in Commercial Mortgages" project to boil down both asset and operational data into a single score/metric for mortgage underwriting. Work with cities who are using Audit Template to refocus from gathering data in city databases to strategically injecting data into the market to motivate market activity to improve energy performance.

Project #25342: Energy Factors in Commercial Building Finance

Presenter: Paul Mathew, Lawrence Berkeley National Laboratory
DOE Manager: Holly Carr

Brief Summary of Reviewer Comments

Reviewers uniformly praised this project's approach for its clear and novel focus, which one reviewer framed as "a method of impacting owner behavior" that has been a "key, unmet need in the commercial real estate sector that no other research organization is funding." Several reviewers understood the preliminary nature of this project, calling it an "excellent example of applied, interdisciplinary economic research," which one reviewer expected would add to the body knowledge that fundamentally "underpins commercial lending." Several reviewers also expressed that the approach was appropriately refined to avoid scope-creep despite "the daunting scale of the commercial lending industry." However, one reviewer worried that the team had spent a lot of energy on lenders, at the expense of researching whether building owners would take action based on the lender's scoring.

Despite these assessments, reviewers disagreed somewhat on the magnitude of this project's potential impact. Most reviewers did not doubt the project's hypothesis that, if successful, it could contribute new information that could be useful for the commercial real estate market to "effectively internalize energy-related value into the mortgage underwriting process." As one reviewer pointed out, however, the ultimate impact of this projects rests on whether the information actually influences lenders "to make the investments necessary to reduce energy consumption."

All reviewers were encouraged by the project's progress to date, and most expressed confidence in the team's ability to complete the work ahead. However, one reviewer noted that a not-so-insignificant question remained unanswered: whether or not the team's pilot metric for energy in commercial/multifamily real estate energy could successfully be linked to commercial mortgage underwriting. A few reviewers implied that the answer to this question could come down to the project team's collaboration and coordination efforts, even though all reviewers agreed that the current efforts were strong. One reviewer expressed that by extending the current umbrella of stakeholders to include more building owners, the project team could observe if and how they responded to adjusted price signals. Another reviewer recommended about looking at institutions in the European Union and Australia, whom this reviewer felt were more advanced than the U.S. on considering energy performance in commercial lending.

Weighted Average: 3.30 # of Reviewers: 4
Approach: 3.50 Impact: 3.00 Progress: 3.25 Collaboration/Coordination: 3.00 Remaining Work: 3.75

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Good approach.
- Project team has done a good, and very systematic, job identifying barriers and developing/implementing plans to overcome them. My only concern is the extent to which a more systematic consideration of energy consumption will actually impact rates and owner behavior (e.g. motivate them to reduce consumption).
- This project has a clear approach and relatively narrow focus. This is commendable. No concerns.
- Project is performing fundamental economic research on real estate and energy. This project addresses a key unmet need in the commercial real estate sector that no other research organization is funding.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Using commercial mortgage as well as energy use data can have a strong impact on leveraging mortgage costs.
- The program goal is stated as improving (reducing) consumption by 35% relative to a typical building. In the case of this project it has not been clearly demonstrated that getting lenders to consider energy consumption in their risk analysis will directly influence owners to make the investments necessary to reduce energy consumption. It seems like the team is spending a good deal of time with lenders but not talking to owners to confirm that they would take action based on the lender's scoring. Even if the lender includes energy more correctly in the analysis will that evaluation rise to the point that the owner will spend money to reduce consumption?
- As the project team reports, this is a preliminary effort. It is intended as a coarse, preliminary effort to increase consideration for energy efficiency among providers of commercial debt.
- The project seems like to have the kind of constrained, preliminary impact that it set out to achieve. This is commendable given the daunting scale of the commercial lending industry, and its impact is commensurate with its approach and scale.
- If successful, this research will provide the fundamental economic science needed to help the commercial real estate market effectively internalize energy-related value into the mortgage underwriting process.

C. Progress

Based on current project efforts, the project was rated **3.25** for the degree to which the project has met ***project-specific goals*.**

- Much work has already been put in - including reviewing case studies and loan information.
- Project has clearly made excellent progress towards meeting its goals
- Process appears to be in line with expectations for the project.
- The team has made significant progress, providing new statistical insights that commercial mortgage underwriters have acknowledged as important.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Strong collaboration.

- Project has conducted good outreach and collaboration with external stakeholders. I would like to see this extended to building owners and how they would respond to the resulting price signal if the project succeeds.

- The project demonstrates strong interdisciplinary collaboration and partnerships.
- As always, there are opportunities for greater industry engagement and coordination.
- Notably, I think that the project team would benefit from greater exposure to on-going work in the European Union and Australia where consideration for energy performance in lending is more advanced than in the U.S. (e.g., work by Dutch banks like ABB AMBRO with use of Energy Performance Certifications in residential lending).
- One next step for the work would be to create opportunities for learning between advanced markets.

- The team has worked well with key stakeholders. The team should look for ways to continue broadcasting this information to other potential users.

E. Remaining Project Work

This project was rated **3.75** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Soon to launch – June.

- Project is well planned and has demonstrated that it is following a detailed and orderly process.

- The project appears to be making appropriate progress. No concerns.

- Team's plan to pilot test a "boiled down" metric for energy in commercial/multifamily real estate is the next important step in determining whether & how this energy economic insight can be linked to commercial mortgage underwriting.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Good knowledge of how commercial mortgages work and how energy use data can fit in.

- 1. Good team.
- 2. Investigation of a method of impacting owner behavior that has not been previously studied.
- 3. Good management of the program.

- The project is an excellent example of applied, interdisciplinary research.
- It addresses an important issue with a reasonable technical approach and a commendable set of partners.
- The project will add incrementally to the body of knowledge that underpins commercial lending.
- The timing and quality of the work may help it have a disproportionate positive impact on industry practice.

- The project address a key, underappreciate knowledge gap in the use of energy information in commercial real estate finance.

2) **Project Weaknesses**

- Challenge to provide energy scores - could be a risk factor.

- Needs to build a better linkage to owner behavior. Will owners actually take action to reduce consumption based on a slightly different price signal? In my mind it is a question of relative importance. Will a slightly higher interest rate motivate the owner to implement energy conservation measures?

- The project is relatively small and limited relative to scale of the issues it represents.
- The project team notes that methods are preliminary and very much data limited.
- Ideally, this project would be one element in a campaign. Again, ideally, this campaign would be informed by a systematic analysis of the barriers and opportunities to the use of energy performance data in lending. Such an analysis would provide the basis to prioritize knowledge gaps and interventions.
- The absence of a foundational review or priority-setting analysis for this specific (and highly complex) market limits the potential impact of this individual project.

- No significant weaknesses identified.

3) **Recommendations**

- Get lenders to understand energy factors as a part of a mortgage. Would like to suggest taking the next steps to conduct education on energy and mortgages.

- Build a better linkage to owner behavior. Will owners actually take action to reduce consumption based on a slightly different price signal? In my mind it is a question of relative importance. Will a slightly higher interest rate motivate the owner to implement energy conservation measures?

- As mentioned in the response to Question #13, I would like to see this project as one element of a coordinated campaign to improve the use of energy performance data in lending.
- Such a campaign might begin with a systematic review of opportunities and barriers. This review could help prioritize projects like this one.
- This project appears to represent one strong, initial effort. However, ideally, it should be followed by a coordinated set of activities to leverage the findings and have a tangible impact on practice.
- It is critical to be realistic about the scale of effort needed to drive significant change in a huge industry. This will take time and sustained commitment. This effort is likely to be justified by the potential for very large scale positive impact.

- Work with one or more cities to get the monthly EUI data for commercial projects (similar to WeGoWise data for multifamily) to try to integrate monthly data into the mortgage model and determine whether it is significantly more predictive than annual EUI data. Continue this project by piloting a simple unified metric (score) that mortgage underwriters can use to pilot the use of this energy information in underwriting. Look for second-order interests who might have a stake in this work and inform them of the meaning for them. E.g. CERES and other investor groups, regulators of lenders who ensure that underwriters are meeting fiduciary responsibilities, etc. Link this project explicitly to the Asset Score project to boil down both asset and operational data into a single score/metric for mortgage underwriting. Begin investigating whether this information will feed back into the appraisal process - i.e. if a building that is considered to be a higher default risk (and therefore likely has increased cost of capital) is therefore incrementally less valuable.

Project #94150a: CERC: Systems, Economic Analysis, and Modeling Project

Presenter: Carolyn Szum, Lawrence Berkeley National Laboratory
DOE Manager: Marc LaFrance

Brief Summary of Reviewer Comments

The two reviewers for this project offered divergent commentary on the project's approach, progress, collaborations, and remaining work. The first reviewer, for example, was complementary and supportive of the project's activities, remarking that the project had a clear and logical approach to U.S.-China cooperation and market transformation, and that it was supported by successful and high leverage public-private partnerships—highlighting the project's impressive ratio of partner investment to public commitment. They described that the project was proceeding as expected, that remaining project work appeared likely to meet expectations and milestones, and that the project featured excellent collaboration between partners in the U.S. and China.

The second reviewer, in contrast, was very critical of the project's approach to addressing market barriers in China versus market barriers in the U.S. This reviewer commented that the project team was clearly familiar with the China buildings market, but that it appeared as if they had not worked or coordinated with others in BTO to identify the needs of the U.S. market. It also was not clear to this reviewer that the project team had considered how the project's outputs would fit into the existing U.S. landscape of public and private resources. This reviewer acknowledged that the project had made "adequate" progress, and that plans for future work would likely meet project goals for impact in China. However, this reviewer felt that the project did not appear to be "calibrated" to achieve impact in the U.S.

It is important to note that the first reviewer's comments were not entirely supportive. They commented, for example, that the project team's stated metrics for impact measurement lacked clarity, and recommended that the project team do more to establish quantifiable impact measures. They also recommended that the project team better and more clearly articulate the criteria used to prioritize specific activities, as it was not clear why a specific activity was selected over other opportunities. Finally, they recommended collecting more foundational data about the status and trends of the Chinese market, in order to better track conditions and identify points of leverage and opportunity.

The second reviewer also flagged issues with the project beyond the project team's lack of engagement with the U.S. market. In regards to a specific project activity—the development of a retrofit targeting tool—this reviewer commented that it was not clear what the plan was for deploying the tool. The reviewer also questioned why the tool needed to exist in standalone format, recommending instead that the tool be integrated with other DOE building energy data analysis and simulation tools (e.g. the Commercial Building Asset Score).

Weighted Average: 2.50 # of Reviewers: 2
Approach: 2.50 Impact: 2.50 Progress: 2.50 Collaboration/Coordination: 2.50 Remaining Work: 2.50

A. Approach

This project was rated **2.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- LBNL-CERC has a clear and logical approach to cooperation and market transformation.
- The approach is supported by a successful and high leverage public-private partnership.

- Good use of existing tools (ASHRAE IMT and JCI Lean tool). It's not clear that the team has considered how the capability that they plan to develop fits into the landscape of existing public and private software tools available in the U.S. Good to see this project introducing the investor-ready EE certification to China. Try to make this an opportunity to increase its visibility in the US, too.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- LBNL-CERC is very clear about its research and development approach and priorities. It is somewhat less clear about specific measures of impact. For example:
    - NZEB. The materials emphasize "harmonization of Chinese ZNEB definitions with U.S. standard". In conversation, it became clear that this goal may be as simple as getting the Chinese government to adopt any specific, enforceable definition for ZNEB. These goals should be simplified and made more transparent.
    - Retrofit targeting tool. It's not clear what the specific impact measures are for the tool. Will impact be measured by the number of users? Floorspace? Energy saving?
    - Financing. The project team emphasized the launch of a "green financial product". What are the impact measures for this product? Investment value? Energy benefits? Environmental benefits?

- The project appears likely to have some impact in the China buildings market. It does not appear to have been calibrated for much benefit to the U.S. Market. It is not clear why Johnson Controls is choosing to make their IP open source through this project, and calls into question the value and validity of that IP.

C. Progress

Based on current project efforts, the project was rated **2.50** for the degree to which the project has met ***project-specific goals*.**

- The project is proceeding as expected based on the information provided.

- The project has made adequate progress. However, its failure to develop a deployment plan up front for the software tool is likely to limit the project's effectiveness.

D. Collaboration and Coordination

This project was rated **2.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The LBNL-CERC team clearly excels at collaboration and partnership. The project has an exceptionally strong track record of creating and sustaining effective working relationships between U.S. and China.

- The team does not appear to have worked with the rest of BTO to coordinate with the rest of the building energy data and analysis tools. This should have been done to determine what market needs were, how to address them, and how to work within the framework and overall strategy in this space.

E. Remaining Project Work

This project was rated **2.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The project appears to be meeting expectations and milestones based on information provided.

- The plans appear fairly likely to meet the project goals for impact in China. The team's failure to plan and coordinate will likely limit their ability to achieve planned impacts in the US.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The LBNL-CERC effort clearly excels in creating partnerships and exploring areas of mutual interest between academia and industry.
- The program has created and maintained professional lines of communication and helped make the Chinese market more accessible to U.S. companies.
- The program also has an impressive ratio of partner investment to public commitment -- conveyed as $3.50 to $1.00 in document provided. This is one indicator of the importance and relevance of the work.

- The project team is familiar with the China buildings market, its dynamics and needs, and the landscape of existing initiatives.

2) **Project Weaknesses**

- The LBNL-CERC effort has clear strengths in the establishment of long-term partnerships. It also has challenges with development of clear rationales for individual projects and establishing measurable impact measures. Documentation suggests challenges across several thematic areas:
    - NZEB. Partners in the effort appear to have different perspectives on the value and goal of the ZNE "harmonization" effort. The team could more clearly define specific success measures. For example, will success be defined by agreement on a shared definition? Presence of any enforceable definition for ZNE in the Chinese market? Use of a specific definition? Similarly, it is not clear why the project team has chosen to emphasize ILFI's rating as a "world standard". Equally rigorous and more widely used ZNE standards exist in the U.S., Australia, Europe, and Canada.
    - Retrofit Targeting. Similarly, it is not clear if the impact of the retrofit targeting tool will be measured in terms of users, floor space, and financial benefits. This was not articulated. It is also not entirely clear why public retrofit tool is needed for this market. In most markets, private sector entities create and compete on these tools. In this case, it would be useful have more detailed rationale for public subsidy and a clear expression of the end goal. Is this a technology demonstration? Is it proof of concept that is intended to jump start private action? It is a long-term operational solution?
    - Financing. This is an especially diverse category. It is not clear how impact will be measured and, critically, it is not clear actions are prioritized. In other words, project finance, preferential lending, etc. are all good things to do. However, it is not clear why any one of them should be prioritized at this moment in time. This may be clear to the project team, and it should be shared with supporting evidence.

- It’s not clear what is the plan is to deploy the retrofit targeting tool out to the market, or why it needs to exist as a standalone tool, as opposed to a stage integrated into existing tools. Waiting until late in the project to develop the deployment plan tends not to work. The lack of a clear deployment plan at this stage in the project raises a serious risk that the project will fail to meet its goals.

3) **Recommendations**

- LBNL-CERC is a national resource. It has a long-term track record of addressing critical issues and market barriers. It is possible to make several specific recommendations for improvement:
    - Outcome measures. The project can do more to clearly establish quantifiable impact measures. This could be an artifact of the document and presentation, but there are relatively few clear, quantitative measures of financial or environmental impact.
    - Prioritization. Related to the first recommendation, it is important for the program to be able to clearly articulate the criteria used to prioritize specific projects. The projects may be good or even excellent; however, it is not clear why a specific activity was selected above other opportunities. Information about the program's prioritization process will help make the effort more transparent and defensible.
    - Market conditions. It would be useful to have the program rooted in foundational data about the status and trends of the Chinese market. Related to the prioritization point above, one core element of the program should be tracking conditions and identifying points of leverage and opportunity. Often information about market trends stops with the simple observations that it is very big and growing fast. This is interesting, but not sufficient to prioritize interventions. More robust information about the state of the market would help LBNL-CERC prioritize its own efforts and serve as an exceptionally valuable resource to support U.S. companies and advocacy efforts in China.

- Increase integration of lean retrofit targeting tool with other DOE building energy data analysis and simulation tools. If possible, integrate it into an existing platform like the Asset Score.

Commercial Buildings Integration
Field Validation & Data Frameworks

Project #22291a: System Technology Research and Development Support (Software Motor Corp., Dynamic Water, Meazon)

Presenter: Michael Deru, National Renewable Energy Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers generally agreed that the project had a strong approach in leveraging existing field validation efforts to develop three technologies. One reviewer noted that the Peer Review presentation itself did not fully answer the scope of the project's approach, and the reviewer relied on the Q&A portion of the Peer Review session for clarification. Several reviewers noted that the technologies had potential to be "high impact technologies" if they could traverse the "technology valley of death" to broad commercialization, and two reviewers applauded the different technologies' potential to significantly impact markets. Critically, one reviewer commented that the projects would be more impactful if there was a focus on system efficiency and operations and maintenance, while others highlighted the projects' limited focus on the cost of ownership and baseline characterization.

Based on project milestones, a majority of the reviewers found the project to be on track and the remaining work to align with project goals. One reviewer expressed concern that dissemination of project findings may not be adequately funded, however, and recommended stronger dissemination efforts to get the technologies into the right markets more quickly. While most reviewers found these demonstration projects to be appropriately partnered, and to be collaborating with appropriate stakeholders, one reviewer suggested further engagement with utilities to facilitate transfer from research and development to market adoption.

Weighted Average: 3.28 # of Reviewers: 4
Approach: 3.50 Impact: 3.25 Progress: 3.00 Collaboration/Coordination: 3.00 Remaining Work: 3.50

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The presented approach is optimal to meet the project goals. Focuses on needs assessment and technology transfer.
- Leveraging multiple entities on development support is excellent.
- The outlined approach leverages existing in field validation efforts for all three of these technologies to fill in needed gaps.
- In the short time allowed for the presentation, it's challenging to provide in-depth insight into three separate research projects focused on three distinctly different technologies. At the conclusion of the presenter's time, it was unclear to this reviewer if sufficient technical rigor was applied in researching these technologies. However, during the Q&A session it became clear that there was a solid approach and methodology applied to each project. Each of these technologies present good opportunities to advance EE saving and measurement.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- A focus on system efficiency and O&M would be most preferable; a low efficiency system fitted with reduced water cycling will not generate the expected savings.
- Appears that this will have a strong impact given the collaboration and knowledge.
- All three of these are truly game changing "High Impact Technologies". The proposed scope will contribute to their effective translation across the "technology valley of death" to broad commercialization.
- All of the three technologies have significant potential to advance:
    - Electric motor energy efficiency savings
    - Cooling tower water savings and reduce chemical and maintenance costs
    - Cost effective metering

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*****.**

- Based on the established milestones, the project is at an appropriate stage.
- On track.
- These projects are all at their early stage of evaluation.
- The smart motor and water treatment projects are at or near conclusion and have demonstrated results in line with specific goals and outcomes. The Meazon wireless sub meter project is in field deployment phase, with no technology assessment results available.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- To facilitate transfer from R&D to market adoption, the project should reach out to utilities.
- Excellent collaboration and coordination.
- The presentation gives good confidence that the project team is undertaking effective collaboration / coordination with relevant stakeholders.
- These are technology demonstration projects. NREL has partnered with the appropriate partners and stakeholders for this type of technology demonstration and validation project.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The next steps outlined are appropriate for the goals.
- Will look forward to hearing from the teams upon "finalizing" this project.
- The presentation summarized next steps indicative of a work plan logically planned to meet the project-specific goals.
- The SMC and Water Treatment projects are in the Draft Results Reporting phase, with what appears to be solid positive results. The Meazon project is in the field demonstration phase and appears on track to meet project goals and timeline.

F. Additional Comments and Recommendations

1) **Project Strengths**

- The project team is the key strength of the project. Their experience will lend well to evaluate the benefits of these technologies.
- Collaboration with key companies.
- Project effort is well integrated and aligned with other efforts. Leverages these other investments. All three technologies represent potential step change improvement. Scope provides needed foundational steps for full commercialization of these technologies.
- All three project technologies represent advancements in savings and have potential to significantly impact their respective markets. This reviewer's opinion is that all three technologies demonstrate good value for the DOE financial investment.

2) **Project Weaknesses**

- From the presentation, there was limited focus on cost of ownership and baseline characterization.
- Potential that dissemination may not be funded enough.
- None of significance.

- None identified.

3) **Recommendations**

- Improve, highlight incumbent technology and their performance.
- Work with utilities as key partners to enable the transfer of knowledge/technologies to the market.
- Strong dissemination to get into the right markets quickly
- None of note.
- No recommendations for improvement

Project #22291b: System Technology Research and Development Support (Tech to Utilities)

Presenter: Greg Barker, Energy Solutions
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Generally, reviewers did not find this project's approach—streamlining measure development so that utilities across the country can use the process to evaluate new technologies for energy efficiency and demand-side management programs—to be effective. Though the project's concept was deemed strong, and the project's overall objective was perceived as valuable, reviewers found the project's approach to be flawed by its inability to capture details about regional markets, utility trends, or customer bases. One reviewer noted that a measure development process can be applicable nationally, but only at a very high level—where there is more commonality between utilities and technologies. Reviewers also described that the project's lack of funding for technology demonstrations, as well as its lack of stakeholder input, could pose significant barriers.

Given the perceived flaws in project approach, many reviewers did not feel that this project would have significant impact. One reviewer noted that that this project would have significant challenges delivering on its outlined project goals, while another felt that the project's impact would ultimately depend on the level of detail that could be achieved for a measure development process.

Reviewers did not agree on the project's progress to date: two reviewers commented that the project appeared to be on track, one reviewer thought the project was behind schedule, and the fourth felt that the project's deliverables and outcomes had not been articulated with enough clarity for the reviewer to pass judgement. There was also reviewer disagreement about the project's remaining work. Two reviewers felt the project was on track to complete its remaining work—with one specifically highlighting the potential value of the technology demonstrations—while one felt that the team was not tackling the correct problems, and that remaining project work was not addressing the key challenges impacting utility programs.

Reviewers similarly lacked consensus on the project's collaborations. Two reviewers noted strong collaboration with various entities and stakeholders, while one reviewer thought the opposite. One remarked that the utilities being engaged were not nationally representative, while another was not clear on how partners' input or contributions would be incorporated into the project work. As the project moves forward, one reviewer recommended that the project team engage with regulatory bodies to understand market trends to ease adoption.

Weighted Average: 2.56 # of Reviewers: 4
Approach: 2.50 Impact: 2.50 Progress: 2.25 Collaboration/Coordination: 3.00 Remaining Work: 2.50

A. Approach

This project was rated **2.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The barrier was poorly characterized as solely being attributed to data availability and transparency. Market barriers differ by region as do technology adoption rates and regulatory requirements.

- 50 percent completion to date; approach has strong success rate.

- The need is clear and articulated: improving the flow and consistency of information developed from technology demonstrations supported by federal agencies and other entities, administrators of rebate and incentive programs. The challenge: disaggregated utilities who are very much in the "not invented here" "doesn't apply to my unique situation" etc. is less clearly articulated, and the study is commensurately flawed.

- The concept of streamlining measure development is a good one. However, in practice it's difficult to create a nationwide process to address measure development. Here are a few thoughts:
    - Between utilities there is so much diversity and variability in the customer base, generation and transmission flexibility or constraints, rate structures, legal requirements….etc. This variability among utilities means similar measures may have different desired market impacts leading to different program structure, incentive payment, allocated savings and reporting requirements.
    - Between different technologies, there can be a lot of variability in the rigor and analysis needed to qualify for a measure.
    - Between the different regions of the USA, there are different measure development bodies, from individual utilities, to measure development bodies, such as the RTF in the Pacific Northwest. At a high level there is commonality between these entities for measure development process, but at a specific detail level, there can be a lot of differences in approach, rigor, and market impact needs.
- This reviewer agrees that at a high level there is commonality in the measure development process that is applicable nationally. At a more granular levels that commonality begins to breakdown. Where is that breakdown point?

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- The effort of developing technical reports for measures is loosely tied to the program's emerging technology goal.

- Consistency of rebates will help utilities.

- The rating is predicated on the "if project goals are met". This project is likely to have significant challenges in delivering on project goals, however.

- With large regional variability in measure development, as stated in my comments on approach, this reviewer questions the impact this project will have on improving the measure development process. It really depends on the level of detail that can be achieved for a measure development process that demonstrates national level commonality. The impact and outcome of this work may become more of a best practices document showing the minimum level of information needed to develop any measure to avoid common pitfalls, data analysis short falls, etc.

C. Progress

Based on current project efforts, the project was rated **2.25** for the degree to which the project has met ***project-specific goals*.**

- No data to assess how the utilities were performing prior to the process. Project is also behind schedule.
- Good progress to date.
- This project is moving at the expected pace and on track to deliver required deliverables.
- From the presentation, the project outcome and deliverable was not clearly articulated. Thus, it is hard to quantify the progress without firm milestones and deliverables.

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Project has identified and reached out to utilities and energy practitioners. However the participating utilities are not representative of the nation wide experience/challenges.
- Assume collaboration with entities will be strong.
- The team that has been assembled for this project includes all of the players that should make for a successful outcome. Presentation did not do a good job describing how their input has been / will be incorporated, particularly around the likely challenges to developing a consistent framework, the diversity of criteria to be considered, and the barriers to adoption of a consistent framework.
- There does not appear to be a significant engagement with utilities and measure development bodies. These are key stakeholders in this type of work product.

E. Remaining Project Work

This project was rated **2.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Incorrect "problem" identification. The key challenges impacting utility programs are not being addressed.
- Tech demonstrations across utilities and other entities will be key to success.
- Project seems well on track.
- None.

F. Additional Comments and Recommendations

1) **Project Strengths**

- This project can help markets where utilities have limited resources (internal and external) to conduct research and characterize technology benefits.
- Creating consistent and custom rebates, as well as educating customers on these new technologies, is a strong strength.

- This project couldn't be more needed. Currently, we have a multiple federal programs evaluating technologies that need a pathway to utility TRMS.

- Slide 9 titled, "Project Findings, Common Data Inputs Needed," lists input items routinely required in measure development. This high level measure development information is useful for researchers and other bodies that are developing technologies for measure deployment. However, this reviewer suspects that below this level, regional differentiation can become significant in the measure development process.

2) **Project Weaknesses**

- The barrier was poorly characterized as solely being attributed to data availability and transparency.

- Funding for tech demonstrations and training utilities.

- "Not invented here" is a significant barrier, and I believe there is an opportunity to better incorporate stakeholder feedback/input in developing framework.

- Poorly defined project deliverable and goal. Little to no acknowledgement for variability in regional measure development. The current project structure fails to acknowledge this variability and clearly define where the national level of commonalty and alignment is.

3) **Recommendations**

- Work with regulatory bodies to understand the actual process (i.e. barriers) and market participants (vendors, customers) to understand why technology X cannot be adopted despite a report saying it can generate high savings. Creating reports/data is only a starting point, not a true solution to low market adoption.

- Keep funding moving.

- All are incorporated in previous responses.

- This is a tough question to answer. It's not a large dollar project, and redefining project structure and goals at this stage may not produce better results than currently planned. It may be better to let the project run its course. A listed deliverable is to document and deliver a list of measure inputs agnostic of technology or region. Depending on the depth and scope of this deliverable, some of this reviewers more negative comments may not be as applicable as stated.

Project #22294: Systems Technology Research and Development Support (Evaporator Fan, Wireless Thermostatic Radiator Valves, Micro Combined Heat and Power)

Presenter: Brian Fricke, Oak Ridge National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers highlighted that this project uniquely tackled three, separate technologies or "widgets"—an evaporator fan motor, a micro combined heat and power system, and wireless radiator valves—that warranted separate evaluations. Most reviewers described the project's approach to measurement and verification as "sound," but half expressed concern about a variety of unaddressed barriers and uncertainties with regard to technology costs, markets, energy performance, and regulatory questions. One reviewer expressed that they could not adequately evaluate any of the technologies, because there was insufficient time during the Peer Review presentation "to focus on any particular project in-depth."

Most reviewers commented that the project's portfolio had made great strides, and that remaining project work was on-track for completion. Reviewers were equally supportive of the project's collaboration and coordination efforts. Reviewers offered mixed remarks, however, on these technologies' potential impacts on BTO's goals. One reviewer conjectured that these technologies' influence would center less on their ability to improve energy performance and more on other non-energy market factors. Several reviewers commented that, of the three technologies, the evaporator fan motor would have the greatest potential impact, while the other two would have more uncertain effects.

Weighted Average: 3.03 # of Reviewers: 4
Approach: 3.00 Impact: 2.75 Progress: 3.25 Collaboration/Coordination: 3.00 Remaining Work: 3.25

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Approach is sound - good description of existing market, baseline comparison, and plans to address non-technical barriers.

- Excellent ideation to target water savings using new technology.

- These are well thought through M&V evaluations of the physical performance of standalone "widgets". Presentation was silent, though responses were encouraging that qualitative measure will be included in study (how easy to install, operate, tenant engagement strategy, and acceptance in case of radiator valves). Presentation also leaves me concerned that cost and payback will not be adequately characterized. Ultimately, the success - or lack of success - of these technologies in realizing impact is less likely to be a result of their ability to deliver stated energy performance, but on other non-energy market drivers.

- This presentation is an overview of 3 separate and distinct technologies. In these multiple technology overview presentations, there is insufficient time to focus on any particular project in depth. The scope, approach, and execution for the evaporator fan motor and radiator valves appears solid and on track. The Micro CHP project is challenging. It is different than the other two presented projects. One can view the fan and radiator projects as "relatively" easy retrofit technologies. For Micro CHP, the technical feasibility and demonstration is only one component of this technology. There are a lot of market, regulatory, and other barriers which need to be considered. There was not enough time to present or discuss these issues; therefore, this reviewer cannot make a determination on whether the approach is correct and sufficient for the desired outcomes.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.75** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- EvapMotor Fans - the project outcome (35% to 80% energy savings) has potential to meet desired goals.
- MicroCHP - no data was provided on the actual project outcomes.
- WirelessTsat - N/A.

- Impact is not clear yet. Suggest outreach to other companies, in advance - contingency plan if QM Power does not work.

- As noted above, the impact of this project is going to hinge on market factors that need to be addressed via qualitative and cost/benefit analysis. Recommend adding that capability to the team.

- Evaporator Fan Motor - Market impact potential is significant. The product has good demonstrated efficiency over existing systems, and the retrofit application is national with a large energy efficiency potential.
- Wireless Radiator Valves - Market impact potential is good. If realized, the efficiency savings potential is good. National market potential is limited because this type of heating system is only found in certain regional markets.
- Micro CHP - Unable to make a determination on potential impact.

C. Progress

Based on current project efforts, the project was rated **3.25** for the degree to which the project has met ***project-specific goals*.**

- 2 out of the 3 projects are complete and recently completed reports. The 3rd project is likely to meet the intended goal of recruiting participant buildings.

- Good momentum on progress to date.

- Within the scope as identified, this project is fully on track.

- Evaporator Fan Motor - Motor is commercialized and UL listed. Project is in final report stage.
- Wireless Radiator Valves - Project is early in its life cycle, with a completion in Sept 2020. Equipment, instrumentation, and data acquisition installation is scheduled for summer 2018.Customer engagement activities are ongoing. Progress seems on track to meet intended goals
- Micro CHP - From the limited time to present, it's hard to determine if this project is on track to meet the intended goals. This reviewer has a number of questions. For example, payback calculation is listed as an outcome. Is the produced electricity part of the cost effectiveness calculation? For the current field installations, how is the surplus energy being utilized? Does the payback change if the electricity is used onsite vs fed back to the grid? Many questions……

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project team are working with the right industry contacts that will facilitate the demonstrations and knowledge transfer.

- Collaboration using one company has risk.

- All projects have a solid team, appear to be well coordinated. An ESCO partner for CHP project might strengthen.

- Collaboration and appropriate stakeholder partners are evident across all projects.

E. Remaining Project Work

This project was rated **3.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The next steps outlined are achievable and in line with expected delivery timelines. All projects are performing to a level that supports confidence in them meeting the milestones.

- Excellent effort to target water/energy savings. Risk is high with one company.

- Well characterized and on track.

- See comments on progress.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Identified start to finish barriers to the technologies under review. Effective project planning.
- Excellent to target efficient water heating - shows energy savings benefits immediately.
- All three technologies have well defined benefit to delivering significant energy savings. Documenting that they deliver in the field will be key to finalizing commercialization and market uptake.
- Evaporator Fan Motor - Good technology with large national EE potential. As the market adopts this technology, and energy savings are realized, the DOE will see a direct return on investment from this project
- Wireless Radiator Valves - Project is early in its life cycle. The identified EE need is solid and the potential return on savings is high.
- Micro CHP - This project focus is on demonstrating technical feasibility and payback. It appears there is good market potential and a solid justification for pursuing this work.

2) **Project Weaknesses**

- N/A
- One company.
- As noted above, qualitative and cost/benefit considerations will be critical to ultimately realize market uptake and final commercialization strategy for these technologies.
- Evaporator Fan Motor - None identified.
- Wireless Radiator Valves - The user interface is important for tenant participation and uptake. There was not much emphasis on this portion of the project. Granted there was not much time, and I hope that was the issue, rather than this project component being overlooked as non-essential.
- Micro CHP - Implementation of this technology is complex. Thru a systems thinking lens, there are many components involved in a T2M solution. This one project cannot address all the issues. The presenter did not clearly articulate the complexity of full implementation and how this project fits into an overall T2M plan. If the project focus is on technical feasibility and payback, then state that and define the parameters and goals. This reviewer was left with a fuzzy impression of what are this projects goals.

3) **Recommendations**

- N/A
- Reach out to other companies now - creates a backup in case QM power cannot implement.
- See above.
- Micro CHP - Clearly define technical feasibility and payback goals. That was not presented.

Project #24290: Scaling Energy Efficiency Retrofits for Small Commercial Apartment Properties (SCAPs)

Presenter: Ravi Malhotra, International Center for Appropriate and Sustainable Technology
DOE Manager: Priya Swamy

Brief Summary of Reviewer Comments

Reviewers agreed that this project's approach—documenting and improving its 'one-stop-shop' model for delivering energy efficiency retrofits for small commercial apartment buildings—was sound, directly addressing the main sources of reduced participation of multi-family properties retrofit programs. One reviewer praised the approach for identifying barriers, technical challenges, and project risks, and for developing strategies to overcome each.

Generally, reviewers were optimistic about the project's potential to make large contributions towards accelerating energy performance improvements in existing multifamily homes. One reviewer, however, cautioned about the potential scaling challenges associated with the franchise aspect of the project's service delivery model, adding that it would need strong business management and execution to be successful at a national scale. Reviewers applauded the project's progress to date, highlighting that it had exceeded its Phase 2 goals during Phase 1. The project's future work was also generally highly rated by reviewers, and was described as being on track and meeting project goals. One reviewer, however, recommended the project team hire additional staff to manage on-going work. Another reviewer also posed that future work should focus on national presence and sustainable value.

Reviewers noted a number of strengths of the project, including the project team's engagement with building owners, its integration of service delivery and financing, and its strong group of strategic partners and stakeholders. Another reviewer complemented the project team for pushing utilities to realize the savings of energy efficiency retrofits.

Two reviewers expressed concerns about the post-project franchise scaling, remarking that this effort needs to be well planned, managed, and not reliant on the current project leader. Another reviewer questioned whether the project team was attempting to replicate the model before determining its impacts on communities and building owners. Moving forward, reviewers recommend engaging with other companies and stakeholders to provide additional help, suggesting that this could lead to further outreach. Another reviewer suggested focusing on and understanding regional market needs, as well as rules on development and financing.

Weighted Average: 3.49 # of Reviewers: 4
Approach: 3.75 Impact: 3.50 Progress: 3.75 Collaboration/Coordination: 3.25 Remaining Work: 3.00

A. Approach

This project was rated **3.75** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project is directly addressing the main sources for reduced participation of multi-family properties - amongst many the top 3 being: access to financing, technical support, and split incentives. This is being done in a well-coordinated approach.
- Strong approach.
- This project is the very definition of an approach that identifies barriers, technical challenges, and project risks, and develops appropriate strategies to overcome/mitigate them.
- Excellent Novel Approach. Structurally, this multifamily sector is comprised of different stakeholders, who's financial and decision makers don't value stand-alone energy efficiency implementation. This in turn makes it very challenging to implement successful energy efficiency programs. This project takes into account the different stakeholders values and needs. It packages energy efficiency implementation into a larger financial package that is attractive to owners and operators of buildings in this sector.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The project is expected to make large contribution towards the residential goal to accelerate energy performance improvements in existing and new homes by integrating technologies and practices to optimize performance in buildings.
- Has sound technology that shows good impact.
- You can't beat being ahead of schedule, and exceeding your project goals - which gives great optimism that this project will exceed program goals as well.
- This business model and execution methodology appear sound. This reviewer's perception is that there will be scaling challenges associated with the franchise portion of this model. Not insurmountable, but will require strong business management and execution skill and structure to enable a successful large scale national deployment.

C. Progress

Based on current project efforts, the project was rated **3.75** for the degree to which the project has met ***project-specific goals*.**

- The project has gone beyond the expectations set. The established retrofit was of 170 properties - over 400 were retrofitted.
- Progress is strong for scaling energy efficiency retrofits.
- Doesn't get better than nearly meeting your Phase 2 goals in Phase 1....and moving forward with even greater velocity. "Exceeds expectations" in summary.
- Good progress demonstrating the "one Stop Shop" model through actual deployment and uptake results.

D. Collaboration and Coordination

This project was rated **3.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project team is working with a good set of partners to enable the retrofits. These have included utilities and financial entities to secure properties and off-balance sheet financing of projects.
- Has brought in multiple key companies that has made ICAST a sound company.
- The project lead gave a "textbook demonstration" of how to assemble strategic partners & stakeholders and leverage their contribution to overcome what could be seen by others at the outset of a project like this as potentially insurmountable barriers.
- Current project collaboration and stakeholder engagement are sufficient for demonstrating the validity of the business model.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Phase 2 goals are based on an affiliate model, which has not yet been fully established. The rate of growth is too fast. National presence should not be the priority. Focusing on perfecting and bringing sustainable value should be the primary focus.
- Suggest getting additional staff to manage on-going work.
- This project is on track to well exceed the project-specific goals established at the outset.
- Project appears to be on track to complete project goals and fulfil planned number of demonstration sites. Milestone is retrofit 170 SCAPS by March 2018. Presenter shows that current SCAP retrofits total 448 buildings in 24 months. The SCAP upgrade portion of this project appears ahead of schedule.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Integrated project delivery and in house financing services set this project apart from other service providers.
- Strong collaboration with multiple companies/entities.
- This project tackles a challenging market space - small commercial apartment properties - and has developed a scalable package of solutions as part of this effort that are highly likely to be successful in driving energy efficiency in this largely underserved/untapped market.
- A new and intelligent approach to engaging building owners. We know that the energy efficiency value proposition alone is not sufficient to generate uptake and adoption in this sector.
- The “One Stop Shop” Concept that imbeds energy upgrades into capital financing is a good business model and mechanism for realizing energy efficiency in this underserved market.
- Another novel and in this reviewers opinion strength of this approach, is the realization of savings by utilities. Savings are not realized thru the traditional utility UES measure model. But, rather, the “One Stop Shop” contracts with the utility to deliver X volume of energy savings. This reviewer believes this third party contract to deliver X savings model will become more common as we migrate towards a DER market

based approach to energy efficiency. This is an important shift in comparison to traditional Utility Energy Efficiency capture and delivery tools.

2) **Project Weaknesses**

- Attempting to replicate the model without fully understanding the impact to communities, owners, labor.
- Encourage reaching out to engage other companies/key people to provide additional help. Would lead to further outreach perhaps in other countries
- Despite excellent approach to building a durable, sustainable organization to deliver the package of solutions supported by this project, there is some doubt in my mind as to whether this effort would continue to survive/thrive if its sponsor/leader, Ravi Malhotra, were not involved.
- Nothing identified in the current project scope. As noted in my comments on impact, post-project franchise scaling needs to be well-planned and managed. This reviewer believes it's important to utilize leaders with business franchising skills to improve the success of national scale up.

3) **Recommendations**

- Each region has very different needs and rules on development and financing. The project should focus on understanding the market needs where they currently operate and get feedback on the process.
- Funding grants to offset costs.
- Clone Ravi Malhotra?
- None.

Project #24291: Building Tune-up Accelerator

Presenter: Nicole Ballinger, City of Seattle
DOE Manager: Priya Swamy

Brief Summary of Reviewer Comments

Most reviewers agreed with this project's approach—formulated in response to a City of Seattle mandate around "Building Tune-ups"—of developing a cohort of retro-commissioners, validating their training, and then finding the proper commercial buildings (i.e. 50,000-100,000 sq. ft.) for them to commence assessments. The approach was described as reasonable, and the project was complimented for having a strong set of stakeholders and addressing a critical need for effective retro-commissioning for smaller commercial buildings. One reviewer raised issues with the approach, however, describing it as well defined and appropriate for the project scope, but highlighting that no market assessment or characterization had been completed to identify needs and gaps in Seattle.

Reviewers were not confident about the impact that this project would have on BTO's commercial buildings goals. One reviewer noted the project's lack of tool development or building technologies integration—meaning that BTO goals were not directly addressed—but also highlighted the potential benefit for the City of Seattle regarding job training and creation. Multiple reviewers noted the possible monetary impacts of this project, especially for small buildings, and recommended a cost-benefit analysis be conducted to develop viable incentives, as well as possibly partnering with utilities to improve cost/savings tracking. Reviewers also noted a lack of clarity about comparison of the efficacy of virtual assessments to walkthrough assessments, the need to address implementation of energy conservation measures, compliance verification, and the impact of this project on the achievement of BTO's energy savings targets.

Most reviewers agreed that the project appeared to be making good progress, though multiple reviewers lamented a lack of project evaluation criteria. On the project's remaining work, however, reviewers had mixed reactions. One reviewer remarked that the project seemed on track to deliver within its project plan, but multiple reviewers suggested that the project team should ensure assessments are conducted before implementation, and another questioned the efficacy of the project's structure in enabling actionable policy and program recommendations.

Weighted Average: 2.64 # of Reviewers: 4
Approach: 2.75 Impact: 2.25 Progress: 2.50 Collaboration/Coordination: 3.25 Remaining Work: 2.25

A. Approach

This project was rated **2.75** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is well defined and appropriate for the project scope -developing the workforce necessary to meet the service needs associated with the incoming building assessment mandate. The issue is that there is no clear market assessment or characterization (i.e. what where the needs and gaps in Seattle?)

- Good to have a flexible mandate on building tune-ups.

- The hypothesis- that building tune-ups will drive 20% improvement in energy performance over a 2010 baseline is sound and well supported by previous studies. The City of Seattle's approach - adopting a policy mandating RCx is likely to deliver intended outcome. And the research question - can RCx be delivered effectively for the market segment 50-100k sf is important. Generally, the approach seems sound: enroll a cohort of RCx performers, validate their training, enroll a cohort of buildings to perform RCx, validate effectiveness of mandate.

- There is project-worthy energy efficiency savings potential in this project's target commercial market comprised of 50-100k sq. ft. buildings. The presenter highlighted a four prong approach of:
    - Service Provider Development
    - Building Owner Engagement
    - Building Assessment and Implementation
    - Evaluation and Retirement
- At a concept level, this appears to be a reasonable approach.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.25** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- For Commercial Buildings, the project is not developing tools nor enabling the integration of technology in buildings. BTO goals are not being directly addressed. City of Seattle may however benefit from job training/creation.

- Like the mandate impact; although it can cause people to have negative feelings towards Seattle, and may cause monetary issues (small builds).

- Persistence not addressed. Not looking at "high touch/high capability" "walk through/ typical capability" no touch (virtual) audits. Need to also address implementation of ECMs, compliance verification. Cost/benefit needs to be addressed to develop a viable incentive program. Utility partnership could be helpful to improve tracking of costs/savings metrics.

- Payback and market drivers could be better characterized.

- The initial driver for this project is the City of Seattle policy requirement that mandates for existing building energy savings tune ups. For this reviewer a key Impact outcome is a clear understanding how the project results will guide the future tune up program design to achieve tangible realized kWh savings. This reviewer has questions regarding the quality, detail, and actionable outcome from the tune-up walkthrough and Asset score assessment process. Will these assessments be sufficient to generate the target goal of 20% energy savings? The presenter mentioned comparing virtual assessments to walkthrough assessments. Virtual assessments are not mentioned in the slide materials. In addition, are there any planned variations in the walkthrough assessments to better guide success outcomes?

- From the presentation, it's unclear what the project evaluation criteria are. Do the project study parameters and goals align with and help quantify the project evaluation methods and outcomes? Will the study outcome evaluation clearly define the post project next step path?

C. Progress

Based on current project efforts, the project was rated **2.50** for the degree to which the project has met ***project-specific goals.***

- From the presentation there was no clear data to assess the status of the project outcome (20% average reduction over 100 buildings).
- Good efforts to date.
- This project appears on track to achieve the project-specific goals that have been identified.
- This project is about 50% complete. It appears on track to meet the presented project deliverables.

D. Collaboration and Coordination

This project was rated **3.25** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The team is working with a strong set of regional stakeholders (utility and service providers) to reach established goals within the city of Seattle.
- Employing many vendors to provide tune-ups is good.
- All key stakeholders have been engaged, and appear to be actively participating.
- Solid project partners.
- Service providers are well established companies with solid track records in the energy efficiency sector.

E. Remaining Project Work

This project was rated **2.25** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- A baseline analysis of market needs and resource gaps (tools and provider experience) should have occurred prior to training and building.
- Detail on the mandate should be the first place to begin owner engagement.
- Conduct assessments of buildings in advance, then do implementation.
- Project seems on track to deliver within its project plan.
- Slide 9 presents the remaining project work at a very high level. This reviewer cannot determine if there is sufficient study structure and rigor to enable solid results to enable realistic and actionable policy and program recommendations.

F. Additional Comments and Recommendations

1) **Project Strengths**

- N/A
- Mandate on tune-ups is good; flip side is issues with owners' perception of mandate and costs.
- This project serves to support a very well intentioned - and important - legislative initiative. It addresses a critical need - effective RCx for the challenging 50-100k sf segment. If executed successfully, this project could greatly contribute to the success of that mandate.
- The concept is good and the structure appears sound. However, in the short time allotted for the presentation there was insufficient time to create clarity into study details; which makes it difficult to determine if the study can produce solid results that enable meeting the 20% energy savings goal.

2) **Project Weaknesses**

- The speaker noted that the applicability of the mandate was STILL being developed by staff.
- Customer barriers have not been fully identified.
- No definition of workforce development occurred or existing providers used the channel to find more clients.
- M&V was not discussed. Suggest having M&V plans in place.
- I am unconvinced that the project's workplan will support the intended outcome of improving the effective delivery of mandated RCx for the 50-100k sf market segment in Seattle. Recommend proceeding with a change: evaluate differential value and cost/benefit of three types of audits - high touch/high capability, routine walk through / typical capability and low touch/no touch (virtual). Additional utility partnerships would be helpful in better crafting incentive programs.
- Unclear if different audit methods are being studied and how the evaluation process will optimize for program implementation
- Stated a 20% savings goal. How is this being measured? Is it based on AMI electric meter EUI pre post savings analysis, or….?
- Slide 6 states the incentive for basic tune up is .12/sf. This reviewer assumes that the evaluation will detail the success of which measures achieved high rates of return and whether the .12/sf incentive is sufficient to achieve the stated goals.

3) **Recommendations**

- Since the mandate was in place since 2016 - a survey on compliance and industry gaps should have been done to educate the 50,000sqft + building stock.
- Do M&V planning now.
- See comments above.
- The lack of clarity into project specifics does not mean that the project structure needs to be improved, if the underlying projects scope, tasks and goals exist and are sound. This was unclear from the presentation.

- However, if the project truly lacks clearly defined study goals, outcomes, and meaningful metrics from which to make comparisons and subsequent program recommendations, then this should be addressed before continuing this project to completion.

Project #25301: Assessment of Automated EM&V Methods ("M&V 2.0")

Presenter: Jessica Granderson, Lawrence Berkeley National Laboratory
DOE Manager: Sarah Zaleski

Brief Summary of Reviewer Comments

Reviewers generally found this project's approach to be sound for addressing tool and data quality challenges associated with evaluation, measurement, and verification (EM&V), although one reviewer noted that the specifics of the approach could have been more clearly presented during the Peer Review. Reviewers felt that this project addressed a critical need for low-cost, high-accuracy M&V—which could advance market models based on distributed energy resources and pay-for-performance—and they unanimously agreed that this project was critical to a broad array of BTO's goals for commercial buildings. One reviewer cautioned, however, that there were multiple market challenges that would need to be addressed before large-scale market deployment and adoption could be realized.

Reviewers agreed that the project was progressing according to its intended outcome and milestones, and reviewers also found the project's future work to be on track to reach its goals, particularly given that the project was nearing its end. One reviewer noted, however, that further progress on the project might be hindered by a lack of clear direction from DOE regarding future M&V initiatives. Another reviewer recommended developing a process to ensure feedback from pilots and testing to inform other related multi-year efforts.

Reviewers commented that the team had identified and collaborated with many key stakeholders, including utilities, public utility commissions, and non-profits. Two reviewers remarked, however, that this project needed to be integrated into a larger strategic systems plan in order to fully transition the technology to commercial applications for national deployment; to accomplish this post-project transition, one reviewer recommended further engagement with energy service companies (ESCO) other and end-user communities.

Weighted Average: 3.57 # of Reviewers: 3
Approach: 3.67 Impact: 4.00 Progress: 3.33 Collaboration/Coordination: 3.33 Remaining Work: 3.33

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project is squarely aimed at addressing tool and data quality challenges associated with EM&V. Increased confidence in method results will facilitate investment in sustainable projects and attribution of savings to utilities.

- The hypothesis - that meter based approaches to validate performance of ECMs will be lower cost, higher accuracy, and therefore facilitate greater uptake of ECMs - is sound. Based more on other presentations of this work, I know that this project is well designed to deliver the foundational research and in-field validation needed to transition this approach to market.

- From a project level, the approach is sound and project findings create a building block that moves the larger M&V 2.0 effort forward.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The project is directly addressing the call to action from the multiyear plan by leveraging data to develop automated EM&V and facilitating standardization.

- This project is critical to a broad array of program goals - particularly improved adoption, performance and persistence of ECMs, uptake of next generation technologies with uncertain field performance, and "beyond widgets" systems oriented approaches to energy efficiency.

- At a high level, meter based M&V is a key component to enabling a future Distributed Energy Resource (DER) business model. This M&V 2.0 work advances the knowledge required to realize a national level DER initiative. There are still multiple market challenges that need to be addressed in future DOE work, before we can realize a large scale market deployment and adoption.

C. Progress

Based on current project efforts, the project was rated **3.33** for the degree to which the project has met ***project-specific goals*.**

- The project has achieve the milestones listed (M&V 2.0 pilots) and initiated the transfer of knowledge (testing) to industry.

- Based on this presentation and others, this project has largely delivered on its intended outcomes.

- Project presenter demonstrated that the project is on track with meeting project goals and deliverables.
- DOE needs to consider where they want to go with M&V 2.XX initiatives. As stated earlier, this reviewer believes that meter based M&V 2.0 performance based savings validation is a key component to advancing DER. For a utility, M&V is core to validating energy efficiency savings with rate payer dollars. For utilities to adopt this methodology DOE should consider some form of a national M&V 2.XX standard that validates and verifies that the methodologies are sound and secure. This will open the market to allow different players to offer services in this arena, while giving utilities confidence that the underlying M&V methods are sound. Currently, M&V 2.0 services are available by several different vendors. One such vendor is Open EE meter. How does a utility choose which vendor? Today, most likely, before a utility will offer the service across its territory, it will want to run a pilot and verification project. The old utility saying of death by pilot is applicable. Something to think about.

D. Collaboration and Coordination

This project was rated **3.33** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Team has identified and working directly with key stakeholders - utilities, PUC, and building/energy performance practitioners.
- The extended project team includes key utility and NGO partners; via presentations and other participation, coordination / awareness among key industry stakeholders has begun. To fully transition this work, however, engagement with the ESCO and end user communities will be needed.
- Good coordination and collaboration for the scope of this project. Post-project transition to industry seems weak and lacks a larger planned systems approach to developing this technology for national deployment.

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The next steps include completion of pilots and knowledge transfer (testing) to EVO. Based on the established milestones, the project is at an appropriate stage.
- This project is "wrapping up" with the finish line well in view!
- Remaining project work appears on track to finish in the designated timeline.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Early collaboration with leading industry stakeholders.
- Addresses a critical need - low cost / high accuracy M&V that can take into account multiple systems, new technologies, and confounding factors/"non routine events".
- As stated, this reviewer feels that M&V 2.0, utility meter based savings verification, is a very important initiative for advancing DER and pay performance market models. This project helps further this initiative, but the end work product is not sufficient to enable market transformation. More work needs to be done as part of a larger strategy!

2) **Project Weaknesses**

- There is no clear feedback loop after the passing of testing to EVO or implementation of M&V 2.0 pilots.
- For a project this close to complete, it is unclear to me whether we have made sufficient progress to successfully transition this to industry/ commercial application.
- See earlier comments. Again, the main theme is what is the larger planned end state for the technology? How does this work plug into a larger strategic plan? Does the work product from this project fit into the next phase of “systems” plan?

3) **Recommendations**

- DOE should develop a process to ensure feedback from pilots and testing from EVO informs other related multi-year efforts.

- None.
- None. Project is solid.

Commercial Buildings Integration Technology Systems & Packages

Project #22230: Getting Beyond Widgets: Integrated Systems for Commercial Buildings

Presenter: Cindy Regnier, Lawrence Berkeley National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers found this project's approach was well thought out for demonstrating the energy savings of three system-based (versus 'widget'-based) commercial building retrofit packages that could be implemented as part of utility incentive programs. Reviewers praised this well-managed project for its ability to provide results demonstrating the potential of integrated design, which one reviewer felt was missing in the market.

Reviewers agreed that the project was on target to meet its goals, and also that it had significant opportunity for impact. One reviewer noted that the energy savings potentials highlighted by the project team did not meet BTO's goals for commercial buildings (i.e. 35% whole building reduction), but emphasized the strong potential for deployment of this project's retrofit solutions if payback was found to be four years or fewer. The other reviewer similarly lauded this project's development of "good data and hard facts" on the chosen retrofit technologies.

Although reviewers agreed that the project had strong partnerships with progressive utilities and engineering companies, one reviewer suggested collaborating more closely with building owners and facility managers—to test the acceptance of proposed solutions and respond to any concerns—while also devoting more resources to engaging with less forward-thinking utility providers.

Weighted Average: 3.65 # of Reviewers: 2
Approach: 3.50 Impact: 3.50 Progress: 4.00 Collaboration/Coordination: 3.50 Remaining Work: 4.00

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Approach is well thought out, focuses on retrofits that are not disruptive to tenants and has a good path to implementation via utility incentive programs.
- Good approach using different technologies to show different levels of savings.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- The project clearly supports CBI goals to investigate system integration, validate performance and develop analytical tools. Although savings are not likely to hit the CBI goals of 35% whole building reduction (5-20% was presented), the systems studied have strong potential for deployment if the economics show less than 4 year payback.
- Good data and hard facts on replacement options.

C. Progress

Based on current project efforts, the project was rated **4.00** for the degree to which the project has met ***project-specific goals.***

- The project appears to be on target to meeting its goals in accordance with the schedule that was presented. The work plan is logical and detailed.
- Just about done. On track to meet deadline.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project has shown deep collaboration with utility firms (incentive providers) and engineering companies (design and recommendation of solutions). They would benefit from collaborating with building owners/management firms to better understand if they have addressed all potential road blocks and to insure uptake of the recommended solutions.
- Good partners and efforts to meet.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Project is nearly complete and appears very likely to finish in accordance with the schedule that was presented. Work plan appears logical and the overall effort is nearly complete.
- Clearly defined goals and results are in line.

F. Additional Comments and Recommendations

1) **Project Strengths**

- 1. Study is well conceived and aligned with CBI goals
- 2. Demonstrating the potential of integrated design is a need.
- 3. Project appears to be well managed.

- Good data, proven results.

2) **Project Weaknesses**

- Project would benefit from engagement with building owners/management firms. Just because utilities offer incentives does not mean that there will be significant uptake.

- Getting other, less progressive utility providers to get onboard.

3) **Recommendations**

- The project is close to completion so there is little that can be done at this point. My only recommendation is engagement with owners/building managers to test acceptance of these solutions and respond to any concerns.

- DOE support to motivate less forward thinking utility providers.

Project #22291c: System Technology Research and Development Support (Streamlining IoT Plug Load Controls into BAS and EMIS Platforms)

Presenter: Rois Langer and Kim Trenbath, National Renewable Energy Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Both reviewers found that this project addressed an underserved area by focusing on the technical challenges of plug load control systems; however, one reviewer questioned whether the approach—conducting a landscaping study to identify the current state of the building automation system, energy management information system, and plug load controls market, and understand ways to better integrate plug load controls into these platforms—set up the project to overcome barriers and mitigate project risks. This reviewer recommended gaining a better understanding of the audience for the project's study, and how this audience would use the data. Another reviewer noted that the project did not address occupant concerns regarding the control of devices nor relevant cost barriers, and recommended future research should address these issues.

Both reviewers questioned the potential impact of the project, with one noting that tying plug load data to building management systems may not be helpful, and the other commenting that commercial building plug loads were a small, niche segment, so the overall reduction in energy use would be small. None-the-less, reviewers applauded the enthusiasm brought by the project team to this study of an underserved load segment. One reviewer noted how well the project team worked within a tight budget, though both reviewers found that that the project team had not adequately collaborated outside of the national labs and government research agencies. As the project progresses, reviewers noted that there was a clear plan, though also that the project had already fallen behind schedule and had not provided a completion date.

Weighted Average: 2.70 # of Reviewers: 2
Approach: 3.00 Impact: 2.00 Progress: 3.00 Collaboration/Coordination: 2.50 Remaining Work: 3.00

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Plug load control is an underserved area so any additional insight will be helpful.

- There is a very reasonable approach focused on the potential positive outcomes and dealing with the technical challenges. I am not clear on the level of focus that has been made to overcome barriers and mitigate project risks. Let me try to explain what I mean.
- Based on the presentation, the researchers have clearly looked at various plug load control systems. In addition, they have taken time to understand how those systems work as well as the kind of data that is currently available within those systems based on products that exist in the marketplace today. It was also very clear that the researchers took time to understand energy management information systems. The presentation included an explanation that the various data streams from building automation systems, plug load management systems and other sources of energy information are currently siloed and are not often (or easily) integrated into a standard platform that includes all the potential data. The researchers referred to the fact that there are many "widgets" that all exist and can be explored and utilized independent of one another, but that there is no "widget compiler" that pulls all the data together in one end-user interface. From that standpoint, and based on the current state of the research project, I would say that a strong to very strong analysis of the current state of the market is clear from research performed so far.
- Based of feedback presented at the Peer Review, the researchers are clearly soliciting input from reviewers regarding the possible barriers to be overcome. In my opinion, they are many. The technical barriers will just take time and money; there really is no reason for me to believe that the technology will not be able to be developed. My thought is that the primary barrier will understand the audience; by which I mean, who will want to look at this data and what will they do with it. I mean, let's assume for the sake of argument, that there is already a simple and easy connection that pulls the data from all the widgets into one place wherein an interested party might view plug loads and understand the character of the plug loads. Who will want (or need) to look at that data? What will those folks do with it? I think that that is the first question that remains largely unanswered. Once the determination is made regarding who the audience should be and what the goals of having the knowledge that could be provided should be, an individual could better understand what the hurdles and obstacles will be.
- In my current work, I find myself looking at many, many plug load items. I look at them in the "old fashioned" way of walking around and performing physical and visual inspections of what is plugged in. For the most part, plug loads are hard to manage. I do not think that the plug load management constraints that exist today will be significantly reduced by having better knowledge of what is out there. I suppose that a working energy manager such as I could determine areas to focus on if I knew that there was an abnormally large plug load at a specific facility. However, I am not sure there would be a lot of "actionable" information to be gained beyond that. To be fair, my experience is in K-12 schools, so it would be hard for me to comment on other industries. However, for schools, we are talking about computers and perhaps refrigeration when we talk about the major plug load consumers. In my district and in many others as well, the Technology Department only allows for minor interventions as far as computers are concerned. As far as refrigeration is concerned, we already address vacation and holiday periods with an institutionalized shut down process that requires all users of refrigeration to consolidate items in need of refrigeration into the fewest possible units and to turn all other refrigeration units off.
- It is true that there are other plug load items, such as lamps, charging devices, animal habitats (fish tanks, lizard and snake terrariums, etc.), laminators, clocks, and probably some others that are not coming to mind right now. However, there is nothing even close to 40% of whole building energy use as indicated by the cited EIA Energy Outlook data. In fact, I am not questioning the validity of the EIA data, but I am certain that it does not apply to K-12 schools.
- Anyway, my advice is to make sure this isn't a solution in search of a problem...

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **2.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The project seems to be well aligned with CBI goals for reducing the energy intensity of buildings and applying an integrated systems approach. My one concern is whether tying plug load data to the BMS or EMIS will actually be helpful. Personnel who work with the BMS (building engineers) are not typically trained or positioned to take plug load control actions. Also, plug load control will likely face significant occupant resistance, which there will need to be a good deal of focus to overcome.

- As I mentioned previously, I think the plug load portion of whole building energy use is "exaggerated" sectors of commercial buildings. In other words, this research will only appeal to certain niches of commercial sector buildings, I suspect those sectors that have heavy plug loads already have methods of addressing those loads. Although there may be impact towards the overall reduction of energy use, I do not think it will be huge. Even if the 40% number is perfectly accurate and plug load data allows for a 10% reduction... we are only looking at a potential 4% overall reduction. I think that is a very optimistic number and in actuality, it will be less.
- This is not bad research, but I think it is important to recognize that the focus here is on hunting squirrels, not elephants. I know that as a working energy manager, I will take every opportunity I can to reduce energy use, but I tend to focus my time and effort on the bigger payback items.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals.***

- This is a short term effort that is nearly complete. However, it was supposed to finish on 4/27 and the material provided does not make any projection of when the final task (Develop Plan to Address Research Needs) will be completed.

- The research is supposed to be an analysis of the landscape. It is worthy of analysis. Perhaps I will be proven wrong and the potential outcomes will be more vital to overall energy use reduction that I think.

D. Collaboration and Coordination

This project was rated **2.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Little in the way of collaboration is required in this type of literature review.

- There has been a lot of collaboration amongst the national labs and governmental research entities, but it appears that industry involvement has been largely deferred. BOMA, IFMA, AEE, ASHRAE, and other industry groups could (and should) be consulted. In addition, it would be helpful to see greater involvement from specific potential end users. The researchers have listed lots of potential future collaborators, but few specific target groups or individual entities outside of the governmental research community.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- This is a small relatively straightforward study that appears to be adequately planned. One concern is that the schedule for the remaining task was not presented.

- I believe the researchers are interested in making the right connections and will follow up on feedback to achieve the goals they have set out to accomplish.

F. Additional Comments and Recommendations

1) **Project Strengths**

- 1. Plug load control is an underserved load segment so the study is well targeted.
- 2. Identifying the research required to overcome barriers is an excellent first step.

- The greatest strength that I see is the enthusiasm of the research team. There is an honest desire portrayed by those involved to accomplish something of value here. I think that the end game will be very difficult to accomplish, but that does not mean it is worth focusing on. Another strength is that the overall budget for this project is very reasonable. There is not a whole lot of money being spent on anything yet. I am pleased to see that the basic research is going into taking a look at the actual value of integrating plug load data into EMIS, rather than jumping in too early before the potential impact is understood.

2) **Project Weaknesses**

- 1. The presentation and plan did not address potential occupant concerns around control of their devices, potential cost barriers and who would actually use the data generated by the integration.
- 2. The project is behind schedule and did not provide a completion date.

- I think the greatest weakness is that the potential impact of accomplishing the goal of integrating plug load data into EMIS will be (at least somewhat) smaller than the researchers may be hoping that it will be.

3) **Recommendations**

- Make sure that any future research looks into cost effectiveness, how savings would actually be generated (e.g. who will use the information) and potential occupant concerns.

- Really focus on what the potential actionable items will be. Look at existing facilities and make the case showing specific examples of plug loads that can and would be affected by having such data available. The data is available now- in widget form. How effective is the data now? Are there case studies showing a substantial and significant impact? Is the work being done here going to result in a materially significant difference being made? Let's consider those questions and explain the results of that research next.

Project #22292b: Technology Prioritization and Demonstration Support (Commissioning Study Update)

Presenter: Jessica Granderson, Lawrence Berkeley National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers overwhelmingly agreed with this project's approach to the meta-analysis of the costs and benefits of building commissioning in order to update previous studies. Reviewers commented that the project's efforts to gather current quantitative and qualitative data was likely to have a positive impact on building energy consumption, and will enable better benchmarking for others. At this midway point in the schedule, reviewers remarked that the project appeared to be on track to achieve towards its goals and featured effective and varied collaboration and outreach.

Reviewers praised the project for its ability to gather current data on commissioning projects and the impacts of these projects on facilities. One potential weakness noted by one of the reviewers, however, was the project's dependence on voluntary responses from commissioning service providers.

Weighted Average: 3.93 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 3.50 Collaboration/Coordination: 4.00 Remaining Work: 4.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- This update will keep a widely used reference up to date with current costs and benefits. As such, it is highly likely to have a positive impact on building energy consumption.
- Both quantitative and qualitative studies performed to best gather information that is current.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- Commissioning is one of the best ways to insure building performance and make progress towards CBI goals. By definition it is multi-system in nature and the update will gather valuable information on current costs and benefits.
- Should allow better benchmarking and historical data for others to use and verify their own efforts.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals.***

- The project has made good progress towards its goals and appears to be well positioned to meet them on schedule.
- About half way through the process and on track.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- I believe that the team's collaboration with the Building Commissioning Association is a highly effective approach for this work.
- Many different means of engagement. Newsletters, webinars, conferences, etc.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Project appears to be on target and well managed.
- Good plan and moving towards meeting the goal.

F. Additional Comments and Recommendations

1) **Project Strengths**

- 1. Addresses a current need and is likely to be effective.

- 2. Strong collaboration with BCxA.
- 3. Well managed. On target for budget and schedule.

- Ability to gather current data for commissioning projects and report out impact in facilities.

2) **Project Weaknesses**

- None that I can see.

- Dependent upon voluntary responses from commissioning service providers.

3) **Recommendations**

- No recommendations at this point.

- Good foundation and work will have a positive impact on the industry. Mandatory reporting of projects to a common agency for data collection.

Project #22293: Technology Prioritization and Demonstration Support (The State of Connected Lighting)

Presenter: Michael Myer, Pacific Northwest National Laboratory
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers found this project's approach to defining the capabilities of existing sensors and connectivity—for the purpose of helping determine if Internet of Things (IoT) lighting is a cost-effective energy saving solution in commercial buildings—to be well thought out, especially its assessment of the current industry, its collection of data from end users and manufacturers, and its efforts to answer all potentially relevant question from IoT adopters. Reviewers agreed that the ability to use lights for more than just illumination, and the development of IoT research roadmaps, will help meet BTO's commercial buildings goals around whole-building integration. Reviewers also commented that the project appeared to be progressing well, was on schedule to meet all stated goals, and was collaborating with leading stakeholders in all appropriate categories.

Reviewers felt the team was well managed, and featured great stakeholder engagement on this topic, which could have potentially large benefits for the private sector. As the project advances, reviewers recommended that the project team more clearly demonstrate the business case of IoT lighting to vendors, and counselled against defining any limits to what can or should be added to lighting fixtures.

Weighted Average: 3.93 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 3.50 Collaboration/Coordination: 4.00 Remaining Work: 4.00

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- IoT has the potential to transform the way buildings are operated but few understand how to approach it and the multiplicity of products/platforms is confusing to potential adopters. This study is very timely and appears to be addressing all of the more relevant questions.
- Good plan on getting an initial assessment of where the industry is and then interviewing end users and manufacturers.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Developing an IoT research roadmap will likely be highly valuable in helping leading firms reach the CBI goals. Also, IoT by its nature meets CBI goals of whole building integration.
- Ability to use lights for more than just a simple illumination device.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals*.**

- Project is on schedule and appears to be well managed.
- 3 months into an 11 month project. Good data collected and initial report out.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Project is collaborating with leading stakeholders in all appropriate categories.
- Picked well know, prominent vendors to review.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Project is on schedule and positioned to meet all stated goals.
- Study moving forward and will focus on a few additional technologies.

F. Additional Comments and Recommendations

1) **Project Strengths**

- 1. This is a timely topic that will provide potentially large benefits to the private sector.
- 2. Well managed and on target
- 3. Great stakeholder engagement.

- Ability to use lighting fixtures for more than just illumination.

2) **Project Weaknesses**

- None that I can see

- Showing the business case to have it make sense financially for the vendors to modify their products.

3) **Recommendations**

- None

- No ceiling on what can be added to the fixture. Keep it wide open.

Project #22295: High Impact Technology: Technology for Building Systems Integration and Optimization

Presenter: Matt Guernsey, Navigant Consulting
DOE Manager: Amy Jiron

Brief Summary of Reviewer Comments

Reviewers expressed divergent options on this project's approach and impact. One reviewer positively appraised this projects systems-replacement approach to maximizing energy efficiency, but the other reviewer found the Peer Review presentation to be confusing and commented that the project approach lacked a framework to evaluate technologies according to their costs, benefits, and potential disruption to tenants. This reviewer further remarked that without such a system for evaluating and prioritizing technologies, the results of the project would not be as significant, meaningful, or impactful.

Reviewers agreed that the project, despite its early stage, was on target for successful completion, and also that it was being well managed. Reviewers applauded the project's collaboration and timely project management, but noted that incorporating data generated by the project into the HIT catalyst program—at least in a way that is accurate and actionable—could be a future roadblock. As the project progresses, reviewers recommended ensuring that the outputs of this project are marketable and useable by different stakeholders across the country.

Weighted Average: 3.35 # of Reviewers: 2
Approach: 3.00 Impact: 3.00 Progress: 3.00 Collaboration/Coordination: 4.00 Remaining Work: 4.00

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- I found this presentation a bit confusing. As I understand it, the purpose of the project is to develop a framework for evaluating potential high impact technologies in 5 specific areas and my evaluation will be built around that assumption. What appears to be missing here is a framework to evaluate or score potential technologies according to their cost, potential benefit, and potential disruption of occupants and likelihood of adoption. To me, putting technology in buckets is fairly straightforward but ranking them for investment/investigation is both more complex and much more valuable.

- Systems replacement approach to maximize energy efficiency.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- On its surface this project should contribute significantly to the CBI goals of energy reduction and whole building system integration. However, without a system for evaluating and prioritizing the technologies that fit within the proposed matrix I do not think the results will be nearly as meaningful as they could be. Although the framework seems reasonable what is the point if we are not able to identify which technologies (on a cross topic/scale basis) are most likely to yield positive results.

- Good areas of interest relating to BTO mission.

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals.***

- The project appears to be on target and well managed.

- Still early on in the process. Interested to see where it goes.

D. Collaboration and Coordination

This project was rated **4.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- This is a real strength of the project.

- Interacting with many key players in the market.

E. Remaining Project Work

This project was rated **4.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The project is positioned to meet its goals, however I am not convinced that the goals will yield significant results.

- Good plan on implementing next phase with the HIT catalyst program.

F. Additional Comments and Recommendations

1) **Project Strengths**

- 1. Collaboration
- 2. On schedule and appears to be well managed.

- Amount of users they are dealing with should yield very good data.

2) **Project Weaknesses**

- Please see my earlier answers for concerns about this project. I understand the need to have a framework for evaluation but this appears to be an effort to put technologies into buckets. Without the next step of how to prioritize those technologies (which should not be a huge effort) the impact of this work will be limited.

- Getting the data into the HIT catalyst program and having it display accurate results.

3) **Recommendations**

- My recommendation is to develop specific criteria that will be used to evaluate and prioritize the technologies after they are put into the framework.

- Ensure the finished product is saleable and useable by different clients and areas of the country

Project #222114: Integrated Solutions for Optimized Performance (ISOP) Packages

Presenter: Abhijeet Pande, TRC Energy Services
DOE Manager: Priya Swamy

Brief Summary of Reviewer Comments

Reviewers agreed that this project's approach addressed real obstacles to deep retrofit projects in commercial buildings—particularly the issue of tenant disruption—commenting that the project not only aligned with the objectives of BTO's commercial buildings program, but also would demonstrate the different levels of energy savings that could be achieved through retrofit packages targeting the integration of different building system combinations. Reviewers did identify some weaknesses in the approach, however, including that the proposed test buildings might not be perceived as sufficiently representative of the wider market, and the risk that the program may not achieve wide-scale adoption by utility providers.

When evaluating the project's progress, one reviewer was content with the project team's efforts to date to collect data and develop a white paper. The other reviewer expressed concern, however, noting that four tasks had slipped despite being only a few months into the schedule. This reviewer remarked that the remaining project work would be difficult to finish on time, and recommended that DOE request a formal recovery plan from the project team.

While reviewers generally agreed that the project had good, collaborative partners, one recommendation was to engage further with commercial building owners and management firms.

Weighted Average: 3.38 # of Reviewers: 2
Approach: 3.50 Impact: 4.00 Progress: 2.50 Collaboration/Coordination: 3.50 Remaining Work: 3.00

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Project approach addresses real obstacles to deep retrofit projects. The keys to actually achieving results will be:
    - 1. The extent to which the team recognizes and addresses industry's perception that deep retrofits can only be achieved at the cost of major disruption to occupants.
    - 2. Developing and publishing targeting criteria to help project teams understand when and where this approach can yield paybacks of 5 years or less
    - 3. Outreach and wide publication of the results
- Good to use different types of combinations and different utility providers.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Project clearly aligns with CBI objectives. If successful it will demonstrate savings that achieve the goals of the program and is clearly targeted at system integration.

- Impact is good in that it showed different levels of savings for each type of combination.

C. Progress

Based on current project efforts, the project was rated **2.50** for the degree to which the project has met ***project-specific goals*****.**

- I am concerned about the progress of this project. Despite being only a few months into the work, 4 tasks have slipped. Most concerning is this includes the crucial Site Assessment and Selection step which has already slipped by 4 months. Based on current status I expect that the project will not meet its schedule, which could in turn impact costs. Strongly recommend that DOE look closely at status and request a formal recovery plan.

- Accomplished data collection and writing white paper.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Collaboration is appropriate to the project. My one recommendation is that the team reach out to commercial building owners and management firms outside the education market and discuss challenges those owners may see to these types of efforts.

- Good partners and effort to meet and disseminate information.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- The plan itself is detailed and logical however the team is well behind schedule and I doubt they will be able to finish the work on time without improved performance for the balance of the effort.

- Appears all work should be completed by summer 2018.

F. Additional Comments and Recommendations

1) **Project Strengths**

- 1. Well aligned with CBI goals
- 2. Good team
- 3. Logical plan that includes consideration of plug & play approach and how to keep from disrupting tenants
- 4. Technologies are proven but not typically integrated.

- Ability to quantify savings based on grouping of technologies.

2) **Project Weaknesses**

- 1. Project is 3-4 months behind schedule on key tasks including package definition and site assessment/selection.
- 2. Proposed test sites are both educational and will be perceived as not representative of the wider market.

- Wide scale adoption by other utility providers.

3) **Recommendations**

- 1. Develop a detailed schedule recovery plan.
- 2. Engage with commercial building owners and/or management firms

- Heavy DOE support in that they push the program to those providers who may be hesitant to participate.

Project #24150: Zero Energy Buildings Initiatives

Presenter: Shanti Pless, National Renewable Energy Laboratory
DOE Manager: Sarah Zaleski

Brief Summary of Reviewer Comments

Reviewers unanimously agreed that this project's analytical and research efforts around net zero energy buildings were prototypically supportive of BTO's commercial building goals, remarking that it was providing foundational information for future zero net energy projects, and posing the question: "what else could do more?" One reviewer remarked that it was difficult to discern from the Peer Review presentation whether the project was on track to reach its project-specific goals, but both reviewers were none-the-less pleased with the progress being made, especially with regards to K-12 schools. One reviewer described that the next step for net zero energy building was to find a way to reach higher market saturation, recommending that the project focus on accelerators to increase adoption.

Overall, reviewers found the project team's collaboration efforts to be exemplary. One of the reviewers, however, commented on the project's apparent lack of engagement with commercial owners or major facilities management firms, and recommended greater outreach to these stakeholders to better understand their views on barriers to zero net energy.

Weighted Average: 3.75 # of Reviewers: 2
Approach: 4.00 Impact: 4.00 Progress: 3.50 Collaboration/Coordination: 3.50 Remaining Work: 3.50

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- I believe that, for ZNE, it is all about education, guidance and showing potential adopters the art of the possible. In this realm the current study excels.

- The effects of this project are already beginning to be apparent. This is (in many ways) the culmination of years of work and research working towards proving that the concept of NET ZERO buildings is a real and technologically possible option. The next thing is to find a way to improve adoption and to allow the forces of market capitalism improve the cost-effectiveness of what is now technically possible, if not always economically feasible.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- This project is directly, and solely, focused on ZNE research. If it meets its goals, as I expect it will, it will be highly supportive of CBI.

- We are talking about NET ZERO buildings. What else could do more?

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals.***

- The presentation and slides make it a bit difficult to determine if the project is on target but there is enough benefit to give it the benefit of the doubt.

- The K-12 schools guide exists. There are existing schools that have met the goal of NET ZERO. The move towards other market sectors is very logical and clear.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The only reason I did not score this as outstanding is that the team, while they have engaged with school and district developers, has no apparent engagement with commercial owners or major FM firms.

- The list of collaborators is almost too long to even consider all of them. Collaboration (as a concept) could in many ways be defined by this project.

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- As mentioned earlier, it is a bit tough to tell from the material presented, but it is likely in good shape.

- There is a methodical, step-by step, approach that has been consistently "chipped away" at over the years. The process and the concept has been proven in one market sector. The move towards additional sectors continues in the same "eat the elephant one bite at a time" way.

F. Additional Comments and Recommendations

1) **Project Strengths**

- 1. Good team.
- 2. Integrated with prior work (AEDGs).
- 3. Good partners.
- 4. This project will provide much needed foundational information for those with ZNE aspirations.

- NET ZERO buildings. Is there really more that needs to be said?

2) **Project Weaknesses**

- No engagement with commercial building owners or operators.

- Market saturation efforts are the only potential weakness that I see. More could be done to focus on the accelerators and the push towards greater and more widespread adoption could be improved upon.

3) **Recommendations**

- Reach out to commercial owners and operators to understand their views on ZNE and what they see as the barriers.

- Focus additional effort on getting building owners and the architects and engineers that serve those owners to adopt Net Zero strategies. Don't focus on making it a policy or regulation issue, focus on making it a goal that makes so much sense that no one can avoid it. Find ways to improve the cost-effectiveness of strategies and make Net Zero a good economic investment right from day one

Residential Buildings Integration
Building America

Project #11102: Building America Envelope Research & Roadmap Support

Presenter: André Desjarlais, Oak Ridge National Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Multiple reviewers agreed that this project addresses a major goal of the Building America program: managing moisture risks associated with tight enclosures. All reviewers agreed that the moisture risks of tight enclosures are a key impediment to the adoption of enclosures with high R-values, and commented that the project would have a positive impact on this issue if the project's goals are met. They agreed that the web-based tool—which provides building professionals with guidance to minimize moisture-related risks in low energy, high performance homes—will be useful for users, disseminating unprecedented amounts of leading building science and expert knowledge in an easily understood manner. One reviewer remarked that the tool could even help show that high performance walls were safer than conventional construction practices. Another reviewer, however, was concerned that the tool may not address a key source of moisture problems in walls: the intersections between assemblies and penetrations.

Reviewers indicated that a significant amount of progress has been made on the project, highlighting in particular the incorporation of user feedback from beta testing as well as the use of detailed experiments for model verification. One reviewer, however, expressed concern about the value of limited hygrothermal lab testing, given the wide range of assemblies that could be conceived by the tool. Another reviewer was concerned about the potential for end users to misuse information (e.g. by skipping important steps in wall construction, such as rigorous quality control air tightness testing). A third reviewer noted that the current task seems larger than originally envisioned—potentially as a result of scope creep—and asserted that this enlargement of scope could compromise the project's impact by limiting its ability to meet specific Building America goals.

Reviewers agreed that the project team has done a good job overall with their strategic collaboration and coordination. One reviewer, however, recommended further collaboration with the Master Builder Association, while another reviewer was unclear about the extent of engagement with larger builders and wall component manufacturers and a third reviewer expressed confusion about the level of coordination between the project team and the Building America Solutions Center.

Looking forward, multiple reviewers agreed that the project was on track to finish on time, though one reviewer mentioned that scope creep would interfere with the timeline. Multiple reviewers also questioned what would happen after the target delivery date of summer 2018, as the tool will need continued updating and improvement, but it was unclear where those resources would come from. Reviewers offered a number of recommendations for the project, including initiating a Phase 2 project to address any issues that remain, conducting further beta testing with master builders in non-traditional markets (e.g. wood-frame multi-unit residential), marketing the tool beyond traditional outlets, and extending the tool to include roof and ceiling assemblies.

Weighted Average: 3.53 # of Reviewers: 4
Approach: 3.50 Impact: 4.00 Progress: 3.50 Collaboration/Coordination: 3.50 Remaining Work: 3.00

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project approach is squarely directed at providing usable and actionable content to users to mitigate their greatest concerns, i.e., what to do with moisture in, on, and around buildings, as delineated through stakeholder engagement surveys. By using the best information available, users will have unprecedented access to consensus guidance and analysis on nearly every type of wall assembly commonly used in residential construction, coupled with climate specific analysis of wall assembly performance.

- This project directly addresses one of the three thrusts articulated by the program manager, namely managing the moisture risks associated with enclosures with high R-values. The tool that is being developed will incorporate leading building science and expert knowledge to give guidance in a form that is easily understood by practitioners. The screenshots of the tool make it appear to be very professionally done, and one expects that it would be easy to use.

- The work appears to be both technically sound, but also responsive to user needs, which is an excellent combination. Their conduct of surveys to get feedback on their product, combined with acting on the feedback received is an excellent approach.

- The task seems to be larger than originally envisioned. This may lead to missing the program goals.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Concerns about moisture performance of high R-value wall assemblies in jurisdictions/climate zones across the country has limited the adoption of such assemblies en masse. Assuming project specific goals are met, one of the primary impediments to adoption of high R-value assemblies will no longer be an impediment, moreover, specific guidance on how to avoid moisture problems, or at least a risk assessment of the potential for moisture problems will be in the hands of the users to make their own, better informed decisions.

- As previously noted, the outcome of this project would directly address the program goal of mitigating moisture risk associated with highly insulated and airtight enclosures. The tool would provide easy to understand guidance that is backed by the best building science knowledge. The use of probabilistic modeling will help builders assess the performance of a wall system with the understanding that factors beyond ideal will lead to variations in performance.

- This project is doing an excellent job helping the program to meet its goals associated with getting builders to adopt energy efficient construction practices. Specifically, this project is helping address concerns about moisture problems in high-performance wall systems, and could show that high performance walls will actually be safer than conventional construction practices.

- Project deals with key impediment to the adoption of energy efficient technologies.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals*.**

- Beta testing and integration of feedback is ongoing and represents a significant step towards meeting project-specific goals. Beta testers are taking the web-based application to heart and providing cogent and appropriate feedback on usability and content and changes are being made based on this feedback.

- The version of the software tool presented appears to be rather polished. Feedback has been obtained from potential users, and a second (or later?) version has started to resolve some of the concerns expressed by users in the survey that was sent out.

- The project team seems to be well focused on meeting its stated goals.

- Although significant progress has been made, the scope appears to have expanded beyond the initial assessment of resources needed to complete the project.

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Strategic collaboration and coordination is indeed good, but the pool is somewhat limited to the "usual suspects". I would like to see outreach beyond the usual audiences at EEBA and RESNET to include Master Builder Association events in key cities across the country.

- The project team is comprised of a wide range of experts in the building science community. It is not clear what coordination is occurring between this team and the Building America Solution Center; it is anticipated that the software tool will integrate into that resource and not serve as a stand-alone tool apart from the other great resources of the program.

- The team has done an excellent job reaching out to industry experts and others. One thing that was not clear to me was the extent of engagement with large builders and wall component manufacturers.

- Excellent integration of "customer" feedback into program plan.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Remaining project work is achievable and feedback and response to feedback has been commendable. Beta 2 testing should be considered with a wider audience of Master Builder types in non-traditional markets, such as wood-frame multi-unit residential (3-5-stories).

- Team appears to be on track to finish, though model validation appears that it will be an ongoing process. It's not clear what sort of validation is needed on top of work already aimed at validating hygrothermal tools such as WUFI. A targeted delivery date of summer 2018 will be start; it is expected that the team will receive feedback and continue to modify the software.

- Their plan appears to be well thought out. One question in my mind is what happens after 2018. The tool that they developed will continue to need updating and improvement, and it is not clear how that will work. Is there any thought about getting relevant industries to provide maintenance support.

- Because the project goals seem to have expanded, I am not sure that there is enough resources to complete on the current timeline. I would recommend planning a Phase 2 project.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Project strengths include the caliber of the project team, and the unprecedented collection and usability of

the information in a point and click fashion.

- The project will result in a tangible product that should be very valuable to a range of building professionals.
- The project directly addresses a key challenge articulated by the program manager.
- The project will condense a tremendous amount of expert knowledge into actionable items by the building community and will give actionable guidance to those professionals.
- Strengths include:
- Excellent engagement with industry experts
- Very strong project team
- Good solicitation of user feedback, and incorporation of that feedback
- Use of detailed experiments for model verification
- The project objectives deal with a key need of the industry and the deployment of energy efficient technologies.

2) **Project Weaknesses**

- The project's main weakness will be in how the information is used or misused. While the quality of the information is top notch, the ancillary steps each project needs to take to ensure meeting performance expectations, such as rigorous quality control, air tightness testing, drainable wall assemblies, might not be fully appreciated by the end users unless they are already predisposed to such measures.
- No major weaknesses.
- It's not clear what value the limited hygrothermal lab testing will have considering the wide range of assemblies that could be conceived in the project.
- May not address the key area for moisture problems in walls, namely the intersections between different assemblies and penetrations.
- Project weaknesses are limited from my perspective, and may simply be due to a lack of information on my part. They might include:
    - Unclear plan for long-term strategy and business model for the service being provided by the website
    - Unclear engagement with large builders and manufacturers of wall components
- I think the project "bit off more than it could chew" -- overly optimistic.

3) **Recommendations**

- I don't really have any recommendations because I haven't had the opportunity to use the tool yet. In general, I would encourage wide advertising and promotion of the tool beyond traditional outlets.
- Would be great to extend this effort to roof and ceiling assemblies.
- Clearer plan for large-builder and component manufacturer engagement
- Clear business plan for the long-term survival of this effort
- I would plan on having a Phase 2 project to address issues which could not be handled in the existing project.

Project #11119: Healthy Efficient Homes

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

Brief Summary of Reviewer Comments

Reviewers agreed that the project team's approach is sound for meeting its goals of advancing adequate ventilation and improved indoor air quality (IAQ) in high performance homes. They also agreed that it addresses specific needs and gaps that have long challenged industry, including the development of related standards, tools, and other resources. One reviewer remarked that "there is always a concern about allocation of resources" when addressing a "gargantuan issue" like IAQ, and recommended that the project scope be narrowed slightly. But another reviewer mentioned that the project makes sense from an industry standpoint, as the fear of IAQ and ventilation issues is a major barrier to the adoption of more stringent energy codes. The project team was described by reviewers as being very effective at working and interacting with industry, and the team's collaboration and coordination with industry stakeholders was mentioned as one of the strongest aspects of the project; one reviewer identified the Leading Builders of America (LBA) as the only relevant missing stakeholder group, but they acknowledged that LBA may still be involved via the National Association of Homebuilders. Another reviewer was "very happy" to hear the presenter talk about the project's connection to public health, and mentioned public health stakeholders as suggested future partners.

Reviewers by-and-large agreed that the project's impact is significant, specifically highlighting the minimization of IAQ risks associated with tightening envelopes, the development of RESNET and ASTM standards and updates to existing standards (e.g. RESNET Standard 380 and ASHRAE 62.2), the development of new IAQ metrics and methods (e.g. a range hood test method), education and outreach, an industry-accepted definition of smart ventilation, and the evaluation of existing products. According to one reviewer, RESNET Standard 380 and ASHRAE 62.2 are the most widely used and referenced industry standards, and this reviewer described the project's influence on these standards as its most important success. Another reviewer commented that the project's work is critical to moving the industry forward and getting it comfortable with building tighter homes. That said, one reviewer remarked that "work remains on the product development side" (e.g. the development of reliable consumer IAQ monitors), but this reviewer was confident that most project targets would be reached by virtue of the project's wide stakeholder engagement, as well as "market forces that will rally around and push forward the work started by this project." One reviewer did caution that RBI's primary goal is to reduce home energy use by 40%, and that energy savings are a secondary goal of this project due to its focus on IAQ. However, the reviewer also highlighted that the project is critical to removing barriers to the adoption of energy efficient technologies, and that it also addresses other Building America program priorities, including comfort risks in low load homes.

Reviewers remarked that the project was well planned, has made solid progress toward its goals, and is on track to meet future goals in line with the project timeline. One reviewer specifically highlighted progress made on the project's test method development, commenting that it "institutionalizes metrics that matter and [will] enable lower energy use and better IAQ." Another reviewer commented that progress on the effectiveness of the project's IAQ monitors is encouraging, but that more work needs to be done to produce reliable tools that would allow the baselining of home IAQ. Similarly, another reviewer described that plans for some project elements (e.g. IAQ Score Beta) appeared a little optimistic relative to the project timeline, and counseled that some project efforts may not be completed by the end of the project cycle, while others (e.g. further activity around ASHRAE 62.2) would be an ongoing process.

Weighted Average: 3.52 # of Reviewers: 6
Approach: 3.50 Impact: 3.50 Progress: 3.50 Collaboration/Coordination: 3.83 Remaining Work: 3.17

A. Approach

This project was rated **3.50** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach is tailored to the specific needs identified by industry stakeholders - namely, developing standards, tools, and resources designed to address the needs and gaps that have long challenged industry advancement toward adequate ventilation and improved IAQ in homes.

- This project has taken on one of the more gargantuan issues related to lowering energy use in buildings: IAQ in low energy homes. The approach has been successful at filling in the many gaps in data and analysis relating to what defines and good IAQ, how to measure it, and how to control it, despite the industry's historically difficult ability to find common ground an agreement on even the need for ventilation.

- The project appears to be well conducted. There are many diverse aspects, so there is always a concern about allocation of resources to address the key technical areas.

- The approach that the team is using makes sense from an industry standpoint. The industry fear of building of too tight of homes and dealing with IAQ and ventilation issues is a major barrier to adoption of more stringent energy codes. The outreach approach that this team is taking is very effective as far as working and interacting with industry that reaches residential builders.

- The approach is sound and was clearly communicated. Dr. Walker clearly laid out how the IAQ work fits across many BTO areas and the challenges with the buildings industry typically not considering IAQ with energy. Very happy to hear the presenter talk about the connection to public health.

- *In previous years, BTO peer review also scored Project Relevance, but was not included in weighted average. This project would have scored well on project relevance, and is an opportunity to dig deeper into NEBs.

- Very well thought-out. I think the inclusion of standards development is very important to increasing industry adoption. Good stakeholder involvement.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- Project impacts to date suggest a high likelihood that the project will contribute to overall program goals. Important and significant impacts include:
    - 1) Development of new RESNET and ASTM standards as well as updates to existing standards. Standards help to establish operating and/or performance parameters for industry as a whole with benefits/impacts spread across the industry. It is often not in any industry actors particular interest to fund and support all of the work needed for standards development and revision. As a result, standards development activity is an important function of government and government-funded activity.
    - 2) Significant education and outreach through research publications, journal articles, presentations and workshops
    - 3) Industry-accepted definition of smart ventilation with international partners.
    - 4) Evaluation of existing products.

- Project impact is excellent and far reaching. Development of the new range hood capture efficiency metric and new metrics for IAQ, as well as informing other IAQ studies in other programs squarely addresses gaps in knowledge that existed before this project and prevented further product development and hindered industry action on this topic. Industry is now able to use common standards and develop tools and products

to begin meeting desired performance goals of improving IAQ and reducing energy use through smart ventilation controls. This reviewer recognizes work remains on the product development side, especially with respect to development of reliable consumer IAQ monitors, but is confident most targets will be reached by virtue of the wide stakeholder engagement and market forces that will rally around and push forward the work started by this project.

- The project addresses one of the three key technical challenges articulated by the program manager, namely the minimization of indoor air quality risk associated with tightening envelopes.

- Assuming that project specific goals are met this should have an impact on the industry if the standards that were moving forward are adopted into building codes and then adopted. This type of research is critical to moving the residential construction industry in the right direction and getting builders to comfortably build tighter homes

- Because RBI's primary goal is to reduce energy 40%, this project's impact is important, but less impactful on program goals by nature of focus on IAQ impacts primarily, and energy savings secondary. Still very important. This project does address DOE Building America program priorities for Comfort risks in low load homes, and IAQ risks in tight homes. Also impactful for codes and standards - other BTO program priorities.

- Critical to removing barriers to the adoption of energy efficient technologies.

C. Progress

Based on current project efforts, the project was rated **3.50** for the degree to which the project has met ***project-specific goals*.**

- The project has made solid progress toward all project goals and is on track to meet goals in 2018 in line with project timeline.

- Most impressive is progress of test method development portion of the project because it institutionalizes metrics that matter and enable lower energy use and better IAQ. Progress on effectiveness of IAQ monitors is encouraging, but clearly more work needs to be performed in this arena to have reliable tools. Smart ventilation progress is also encouraging and rationally focused on measured humidity and cooling system operation, though these parameters may need alternates metrics in hot dry climates. Baselining home IAQ puts the industry on the right path to addressing IAQ with data rather than anecdotes.

- As previously noted, this project has a diverse set of efforts, and there appears to be work to be done on all of those aspects in the short time left for the project. Some aspects appear to have had more progress; e.g. test method for range hoods is in good shape, 62.2 efforts, RESNET standard. Good progress made on others.

- Seeing research results being integrated into standards that can be implemented in the field is definitely outstanding. RESNET Standard 380 and ASHRAE 62.2 are the two most widely used and referenced industry standards and the success of this program in influencing those documents, not considering any other successes from the program, are the two most important successes of the program.

- Many of the key milestones are forthcoming. Most project progress on standards, codes (title 24), and evaluation test methods for Building America.

- The IAQ Score Beta version seems a little optimistic vs. the timeline.

D. Collaboration and Coordination

This project was rated **3.83** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project team has identified a well-rounded list of relevant stakeholders and has demonstrated significant effort in engaging strategically with this wide range of actors to advance project activities to meet project goals.
- Collaboration and coordination with stakeholders and industry is one of the strongest aspects of this project. Buy in and action from industry and trade organizations is key and well-used in this project to produce actionable results.
- Strong collaborations with Standard Development Organizations and other industry groups. Good coordination with the State of California.
- The partners that are involved in this project are outstanding. I did not see NAHB listed but when questioned the team was definitely coordinating with them. The only other team member that I saw that was missing was the Leading Builders of America but this collaboration could have been through NAHB.
- Since focus was on producing technologies (sensors & controls, smart ventilation), industry guidance and codes and standards, this project's outreach and collaboration is good. Peer reviews, presentations, etc. demonstrate.
- For future, would like to see this work expand with public health stakeholders, and the IAQ index application in existing homes.
- Wide range of stakeholders included. Excellent outreach to the trade.

E. Remaining Project Work

This project was rated **3.17** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Next steps identified align well with schedule for project completion in 2018.
- Remaining project work rationally builds on outcomes and successes to date to advance the state of the art and program goals.
- No major concerns, but it appears that some of these efforts cannot realistically be completed on a 3-year project cycle. For example, efforts with 62.2 will be ongoing, and movement of test methods for range hoods to an appropriate SDO will take effort. The capture of more IAQ data will be an ongoing process as will the promulgation of smart ventilation strategies.
- This project was well planned out and the remaining work looks to meet the project goals.
- Several milestones are at the end of the project, and the CEC portions of the work, especially are likely to move forward after 2018.
- Well planned and task-oriented timeline.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Engaging and keeping stakeholders informed over course of project through a variety of methods including papers, presentations, workshops, etc. This is a critical step in getting stakeholder support and buy-in as well as keeping abreast of evolving industry/stakeholder needs.

- Project strengths include the focused effort to fill data gaps that have prevented the industry from squarely addressing the relationship between IAQ, low energy buildings, and ventilation. Other strengths include the development and adoption of consensus standards to move the industry forward.

- Excellent engagement with user community through conferences, webinars, etc.

- Addressing the key issue of IAQ in residential buildings.

- Excellent outputs in terms of standards.

- From my perspective the project specific strengths were:
    - 1. Influencing RESNET Standard 380
    - 2. Influencing and interaction with ASHRAE Standard 62.2
    - 3. Outreach to key stakeholders

- It's one thing to perform research on issues but providing the information to where the research can be applied is a critical piece.

- Experienced project team, co-funding. Significant funding in FY 2019-21.

- Stake-holder interaction.

- The orientation to have research adopted into standards.

2) **Project Weaknesses**

- None identified

- To the extent that ultimate success for providing good IAQ in low energy buildings relies on either human intervention and/or non-human interventions, I feel these two areas represent the greatest risk to ultimate success: lack of user education or usability and adoption of appropriate systems to deliver good IAQ and low energy usage, and the development of long-term reliable sensor technology.

- No major weaknesses, but there appear to be a number of distinct aspects of the project that might make management of the project in terms of focus areas challenging.

- It would have been good to see NAHB as an active funding partner listed with the other project partners. Leading Builders of America would have been another strong partner in this effort since the research will directly impact their projects.

- No technical project specific weaknesses identified.

- Scope may be should be narrowed slightly.

3) **Recommendations**

- No specific recommendations come to mind

- Maintain focus on smart ventilation and IAQ.

- The work on IAQ metrics is very important. It is hoped that the team can focus on this effort and make some progress to quantify IAQ benefits so that it can be better considered in home performance.

- I think that this project is well planned and is having the desired results. I don't have any recommendations for improving the program.

- Consider how you can integrate this work to produce non-energy benefits that will be valued in utility funded programs. See previous comments re IAQ and public health, but these may be outside the scope of current project and directed for future work.

- Continue with Phase 2 with some of the future work mentioned in the proposal.

Project #11150a: Durability of Windows In Walls with Continuous Insulation

Presenter: Vladimir Kochkin, Home Innovation Research Labs
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers expressed mixed feelings about this project's approach to providing objective performance information for windows installed in walls with continuous insulation. The project's strength was seen as its collaboration and coordination efforts to convene stakeholders from the continuous insulation and windows industries as part of its Advisory Group. Reviewers saw this convening as helping to ensure that the project addressed key questions and mitigated the risks posed by a lack of industry acceptance. However, overreliance on this Advisory Group to disseminate information was mentioned by reviewers as a potential project weakness.

The project's careful experimental protocols were another strength highlighted by reviewers. However, multiple reviewers expressed concerns over certain technical details of the project. One reviewer was concerned that window installation methods developed by the project team may not have considered the continuity of all critical barriers through a window opening (i.e. thermal, air, water, vapor) nor allowed for drainage from the rough opening. Other reviewers highlighted the lack of interior wall finishes in the setups and the lack of control experiments. Reviewers were also concerned that the use of uninsulated, unfinished stud bays could be used to question the applicability of project outputs, though industry buy-in was referenced as a possible mitigation for this last concern.

Reviewers were mixed regarding this project's impact. Some reviewers highlighted the project's significance in settling longstanding questions regarding the subject matter. Others remarked that the project meets Building America's goal to "research, validate, and facilitate learning…that results in new strategies and practices in residential energy efficiency," specifically citing the need to reduce risks associated with high R-value enclosures. One reviewer recommended incorporating this project's findings into guidance documents that could be posted to the Building America Solution Center. Critically, some reviewers questioned whether the results of the project would be sufficiently applicable to a wide range of envelope and window types, given the limited number of window/wall assemblies being examined. Another reviewer commented that they were not sure what the project's impact would be, explaining that they did not actually know if (or to what extent) current window standards even limited the use of continuous insulation.

Despite the concerns highlighted above, reviewers agreed the project was making good progress and was on target to meet remaining project goals. Two reviewers raised concerns, however, about amount of funds remaining relative to the amount of work that was left to do, and another suggested developing numerical targets to clarify the project's objectives (e.g. increasing the market share of continuous insulation to X%).

Weighted Average: 3.23 # of Reviewers: 3
Approach: 3.00 Impact: 3.00 Progress: 3.33 Collaboration/Coordination: 3.67 Remaining Work: 3.33

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project is uniquely positioned to address a conundrum of sorts that has been plaguing the home building industry and pitting high-R value wall assemblies with continuous exterior insulation against manufacturers' right to dictate how their windows are installed to maintain warranties and meet performance expectations. My principle concern is whether the window installation methods developed and tested consider continuity of all critical barriers through a window opening (thermal, air, water, and vapor) and allow for drainage from the rough opening as well.

- The project team has done an excellent job of mitigating a major project risk, that the results would not be accepted by a key group, by convening the important players prior to conducting experiments. The demonstration of window attachment methods and the collection of data will hopefully help address the concerns with installing windows over continuous insulation. With stakeholder buy-in early on to the test approach, fewer challenges should be brought up by those in position to implement the solutions.

- There are slight concerns about the lack of interior wall finishes in the setups, as anything that will cause concern by stakeholders may be magnified even if the project team is convinced that the factor will not have an impact on the final results .

- I think the team did an excellent job engaging the key manufacturers, and getting their buy-in at the beginning of the process. One concern I have is that the decision to use uninsulated, unfinished stud bays could be used by some folks in the future to question the applicability of the procedure. This may not be a critical point if enough of the industry has already bought in.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- The research project squarely falls within the "research, validate, and facilitate learning . . . that results in new strategies and practices in residential energy efficiency," as well as supporting research needed for zero energy buildings. The impact is significant to settle longstanding questions surrounding the installation of windows in walls with continuous exterior insulation.

- The project directly addresses one of the needs of expressed by the program manager, the need to reduce risks associated with high R-value enclosures. Continuous insulation presents an outstanding opportunity to achieve high R-values, but the building industry obviously has a major question related to the installation of windows. This project has a very direct target, and the development of a guideline or sound knowledge will greatly encourage adoption of this approach.

- It is not clear how widespread the results will be in terms of envelope and window types.

- I was difficult to determine how much benefit this project will provide to the accomplishment of program goals. It could be a significant contribution, but it was not clear from the materials presented (i.e. exactly how much of an impediment to continuous insulation are the current window standards?).

C. Progress

Based on current project efforts, the project was rated **3.33** for the degree to which the project has met ***project-specific goals.***

- Progress of research is on target and producing preliminary actionable results and data.

- Project has spent a good deal of funds to date with still more time to go, but it is thought that much of the expense for the project would be in convening the stakeholders and setting up experiments. It is believed that the team is on its way to meeting project deadlines.

- The project appears to be doing a good job meeting its project specific goals, although it would be good to have the goals spelled out in a numerical manner (e.g. increasing the market share of continuous integration to XX%)

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Collaboration and coordination is good and impressive, given the magnitude of the task. My primary concern is that it is not clear to me who the critical barrier continuity and rough opening drainage champions are on the Advisory Group. Still, all in all, an impressive coordination and collaboration effort.

- The project team has convened the key stakeholders in continuous insulation and windows. The effort to bring these parties together to resolve the challenge of installing windows over continuous insulation is to be commended, and it should result in a product that is accepted by the key people who can implement the solutions.

- The team appears to be doing an outstanding job with respect to collaboration with stakeholders.

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Given the buy in from advisory group members and the breadth of testing, this reviewer has every confidence that the remaining work will meet project specific goals and produce actionable information for the industry to adopt.

- The key project work will involve continuous monitoring of the experiments. Assuming no catastrophic failures, the team appears to be well on its way to completion of that effort. Promulgation of the results to the appropriate venues will be the next challenge.

- The planned next steps all appear to be appropriate and reasonable. My one concern is whether the remaining funds match the remaining tasks.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Project's strengths lie mainly in the coming together of manufacturers and industry to address a pressing issue, the resolution of which will have direct and immediate benefits to the industry.

- A very focused project to address a specific challenge.

- The assembly of the Advisory Group has helped to ensure project is addressing the key questions.

- Technically sound.

- Strengths include:
    - early buy in by manufacturers into the process
    - careful experimental protocol

2) **Project Weaknesses**

- Uncertain the extent to which critical barrier continuity and rough opening drainage will be address in the final product.
- It is not clear that the results will be widely accepted since the team has been forced to only examine a limited number of window/wall assemblies. It is hoped that the window industry will be accepting of the results even for slightly different window types.
- Slides indicate that the team will rely on the Advisory group to disseminate information...it is hoped that this effort will be sufficient.
- Not a project weakness, but it would have been good to better explain the problem and concerns at the beginning.
- It would have been good to have some control experiments to assure that the procedure would give the same answers if the interior walls had been insulated and finished.

3) **Recommendations**

- Make sure critical barrier continuity and rough opening drainage is addressed.
- Identify means of incorporating results into guidance documents that would be made available through the Building America Solution Center.
- Consider how results can be extended to a wider range of window types, or whether the results are indeed applicable to a range of fenestration.
- Some control experiments
- More numerical metrics of success (e.g. % increase in Continuous Insulation market share)

Project #11150b: Aerosol Sealing in New Construction

Presenter: Dave Bohac, Center for Energy and Environment
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed with this project's approach to developing an aerosol sealing solution for improved air barriers in new construction. Reviewers also agreed the project could have a significant impact on BTO's goals to improve home energy savings, with one reviewer commenting that anything that "facilitates air sealing in the hard to reach nooks and crannies is useful," and another reviewer opining that "this approach can truly be a game changer if proven to be effective and safe." Regarding this project's specific technology, however, reviewers expressed some concerns. For example, multiple reviewers commented on the durability of the approach, suggesting that some durability assessment be conducted (e.g. follow-up airtightness tests in homes). One reviewer questioned whether this technology would disincentivize designers or contractors from properly ensuring the continuity of the air barrier, because these actors could get "close enough" airtightness with this sealing technology. Another reviewer recommended emphasizing that aerosol sealing should be a supplementary step in creating airtightness, rather than used in lieu of installing a "proper" air barrier. Multiple reviewers also noted the need for a larger, statistically significant, sample size to counter skeptics' concerns.

Reviewers agreed that the project was making good progress, was on track to complete remaining project work, and had done a good job collaborating with stakeholders. One reviewer, however, suggested expanding the number of stakeholders, including builders and field installers/contractors, particularly those specializing in air sealing. Another reviewer expressed doubt about the number of options available for expanded collaboration, in part because the project was testing a proprietary product from a single manufacturer, limiting outreach options.

Reviewers used adjectives such as "disruptive" and "game-changing" when describing the strengths of the project. Other strengths highlighted by reviewers included the technology's ease of use and the demonstration of immediate results. According to one reviewer, however, the project's main weaknesses came from holes created in enclosures after the sealing technology has been used, as well as the integration of this technology with other possible air barrier strategies.

Weighted Average: 3.23 # of Reviewers: 3
Approach: 3.00 Impact: 4.00 Progress: 3.67 Collaboration/Coordination: 2.67 Remaining Work: 3.00

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Project approach is logical, iterative, and repeatable. More importantly, it has demonstrated effectiveness at addressing initial technical challenges and barriers. Long-term risk mitigation remains somewhat unclear as longevity of products used for this air sealing technology and ability to move with buildings as they shrink and seat themselves is not fully known yet. Also, integration of the AeroSeal technology with an identified air barrier and the importance of purposefully designing continuity of the air barrier through the building enclosure are elements that can't be replaced by a sealing technology, but are at risk of not being taken seriously if a designer or contractor can get "close enough" airtightness with the aerosol sealing technology. In other words, the air barrier still needs to be design and installed correctly; aerosol sealing technology does not solve that problem.

- It is believed that demonstration of this technology is the best approach to showing its effectiveness in sealing homes. By conducting air-tightness tests before and after sealing, both with spray foam applied and not applied, the team will develop data to show the effectiveness. It will be harder to address the durability of the air sealing solutions in the short time frame of the project. Additionally, a challenge will be in gathering enough data to make statistically significant conclusions accepted by a range of skeptics.

- Good work with builders, but somewhat anecdotal. I would like to see a larger sample. Also no durability studies included.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **4.00** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- Improving airtightness in buildings is a well-established tool for improving energy savings. Any new tool or technology that makes facilitates air sealing in the hard to reach nooks and crannies is useful, so long as the importance of designing the air barrier is not forgotten.

- The technology being investigated in this project will help achieve the airtightness levels that will be required to make residential buildings more energy efficient. It is believed that this approach can truly be a game changer if proven to be effective and safe. Demonstration of that effectiveness as being done in this project is very important, and results to date show the promise.

- Air leakage key contributor to energy use. Controlling air leakage is critical to achieving to program goals.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals.***

- Implementation and early results are showing clear advantages to using the product, and lessons learned are providing confidence to contractors considering use of the new technology.

- The data presented by the team show great promise in the technology to date. It will always be valuable to have more data points, but the progress to this point and the methods used to collect the data are sound.

- Good progress but need more builders to get the range of performance.

D. Collaboration and Coordination

This project was rated **2.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Collaboration and coordination are good for this stage of the project and are expected to improve in the final stages of the project. While a small number of contractors are on board for the project, some players in the market have already adopted the technology with stellar results, consistent with results achieved in the study cohort.

- The team includes the main investigator, a company attempting to market the air-sealing technology, and a university that can provide other technical support in the use of the project. Additionally. it seems like at least one homebuilder has adopted the technology. It would be good to continue to engage those groups that would be in position to use the technology (e.g., builders).

- Seems to be an extension of applications research for a proprietary product from a single manufacturer. Therefore, there is limited options to expand beyond that one provider.

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Remaining project work is logical and on target to address most remaining installation challenges. This reviewer's main concern is with the small sample size represented in the project, however, the data thus far appears solid, defensible, and more importantly, the results are repeatable.

- The remaining tasks involve tests on more homes. The procedures set forth to date appear to be very sound to capture the data of interest, so there is no concern that the project goals will be met. Collection of more data will be the only way to get a better understanding of the product performance.

- No durability assessment included.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Disruptive technology that is easy to use and demonstrates immediate results.

- Investigating a game-changing technology for making homes more energy efficient

- Sound technical approach to make firm conclusions.

- The demonstration aspect is the only way to convince builders to use this project.

- Demonstration of a new technology.

- Involvement of builders and field installers.

2) **Project Weaknesses**

- The main weakness stems from holes that are punched in enclosures after the sealing technology has been installed. Additional weakness lies in the integration of the technology with whatever air barrier strategy is employed throughout a construction project.

- Challenging to make firm conclusions on the durability of the air-sealing approach in the limited time for the project.
- Could use better integration with builders or firms specializing in air sealing.
- Proprietary product, limiting outreach.
- Too small a builder sample.

3) **Recommendations**

- Be sure to maintain a focus on designing and installing an air barrier throughout each project and that aerosol sealing is a supplementary step to creating an airtight building, not in lieu of designing and installing the air barrier.
- Consider follow-up airtightness tests of homes should funding and logistics allow.
- Include some assessment of durability.

Project #11150f: Affordable, Solid Panel "Perfect Wall" System

Presenter: Pat Huelman, University of Minnesota
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers approved of this project's approach to refining and demonstrating a solid-panel "perfect wall" system. One reviewer expected the demonstration of this system on Habitat for Humanity homes, combined with the unskilled labor used to build these homes, would pay dividends in terms of convincing professional builders of the viability of the approach. Another reviewer commented that the use of modeling for energy analysis—combined with actual construction experience and field monitoring—seemed excellent, and was a strength of the project. Other strengths noted by reviewers were the project team and its leadership, the alignment of project outcomes with existing market platforms (e.g. DOE Zero Energy Ready Home, Minnesota code, etc.), and the project approach's innovativeness.

One reviewer commented that the wall system's novelty could actually be considered a weakness in terms of builder uptake, but highlighted that the system's short learning curve could overcome this issue. More critically, a different reviewer pointed out that the sensitivity of a specific system component—the peal-and-stick moisture barrier and its inability to be redone—was also a weakness, and asserted that there may be value in experimenting with other materials. Other reviewers commented on the challenges of assessing either the durability of the system or the scalability of the entire concept, due to its use of cranes and the risks associated with on-site construction quality (e.g. cutting the window hole incorrectly) and logistics issues; reviewers consequently recommended long term durability monitoring. Other weaknesses flagged by reviewers were the project's reliance on partners' timelines, a lack of clarity on the types of homes the system is recommended for, and the failure to identify a cost analysis methodology. Other reviewer recommendations included maintaining the focus on production building methods and constructing the wall assemblies in a factory.

According to one reviewer, the project has the potential to contribute significantly to the goals of the Building America program, with its demonstration of an affordable approach to residential construction and its potential to reduce labor costs, materials use, and construction time, all while improving energy performance, moisture-control, and durability. Another reviewer commented that the wall system makes "achieving Passive House-level air tightness targets almost easy[,] and providing robust thermal and moisture managed enclosures almost an afterthought." Several reviewers were unconvinced about the impact of this project on program goals, citing market uptake as an issue because of increasingly complicated architectural styles and because the wall system necessitates a "fairly major shift" in home construction. In contrast, one reviewer saw significant market interest as one of the project's strengths. In part due to this disparity, reviewers recommended conducting a more serious market analysis.

Most reviewers agreed that the project is currently on schedule and making progress to achieve its project goals. However, one reviewer questioned whether all of the research questions—mostly related to durability—would be answered in the time allotted, while another reviewer commented on the limited time remaining to complete many of the tasks.

Most reviewers complimented the collaborative efforts of the project, remarking that a good cross section of the industry was represented through the academic, construction, and design project components. One reviewer also complimented the project team for making adjustments based on feedback from collaborators, and remarked that the direct involvement of the builder community for evaluation was a strength of the project. In direct contrast to the rest, however, one reviewer commented that the "degree of stakeholder engagement is not as high as other projects, and does not seem to be a major focus within the effort."

Weighted Average: 3.32 # of Reviewers: 5
Approach: 3.20 Impact: 3.20 Progress: 3.60 Collaboration/Coordination: 3.20 Remaining Work: 3.60

A. Approach

This project was rated **3.20** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project approach is well-designed for refining and demonstrating a solid-panel "perfect wall" system to address several challenges to affordable, energy-efficient, durable performance in residential construction. It appears one of the biggest challenges and risks in meeting project objectives is working with housing providers that have been slow to move and/or have dropped out of the project.

- The project approach has clearly demonstrated the ability to address barriers, technical challenges, and mitigate project risks through the many example structures that have been built to date and are continuing to be planned. Refinement of the system and how to build with it are ongoing with good progress being made, and its competitiveness as compared to stick framing appears to be on track, but is not definitively there yet.

- The proposed approach, of demonstrating the construction of the "Perfect Wall" in a more cost- and time-effective manner, will demonstrate the feasibility of constructing such assemblies to the building community. One would expect that demonstration on Habitat for Humanity homes, where the labor is unskilled, should help in convincing the viability of the approach in more widespread installations, though the Habitat process is different from that of commercial home builders. One challenge will be in assessing the durability of the solutions.

- The approach of using modeling for energy analysis, combined with actual construction experience and field monitoring seems to be excellent. I am not sure about the scalability of the entire technical concept, as it requires the use of cranes, and appears to have some non-trivial risk associated with on-site construction quality and logistics issues.

- Excellent understanding on what is needed in field evaluation.

- Combined energy analysis with moisture (durability) analysis

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.20** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- By demonstrating an affordable approach to residential construction with the potential to reduce labor costs, materials use, and construction time while improving energy performance, moisture-control, and durability, the project has the potential to contribute significantly to the goals of the Building America program. This has been an enormous challenge to advanced energy performance in residential new construction.

- From a risk management and building science perspective, solid panel wall systems are extremely promising, making achieving Passive House-level air tightness targets almost easy and providing robust thermal and moisture managed enclosures almost an afterthought.

- The project directly addresses the program manager's articulated goal of reducing moisture-related risks associated with high-R-value assemblies. The perfect wall is one that has been touted for years, but challenges in cost-effectively implementing the approach has stood in the way of it being implemented in a more widespread manner. It is not clear how this approach can be used in a widespread manner, with homes having more complicated architectural styles, and whether the attention to the "seams" of the panels will still be the weak link in the assembly.

- It is a bit difficult to know how much impact this project will have relative to the program goals, as it involves a fairly major shift in the way that houses are constructed, and it does not seem like an obvious "no-brainer" change for builders to embrace.

- Will give another option for energy efficient construction. It is unknown at this time what the industry uptake will be.

C. Progress

Based on current project efforts, the project was rated **3.60** for the degree to which the project has met ***project-specific goals*.**

- The project has made significant progress with construction and monitoring of research and control homes. They are successfully working with builders on designs to meet their specifications and needs. Work is underway toward all significant project goals.

- Project progress is excellent for this stage of the project and seeing construction of several more examples and designs as compared to last year is good. Also good to see uptake in the marketplace by early adopters. Will look to see results from monitored homes in the near future.

- The team appears to be on track to meeting its goals. They have done some energy modeling, but it is not clear that that accomplishment is as significant as the measured data considering the general acceptance of the perfect wall concept for durable assemblies. Preliminary designs of the homes is an important step.

- Within the goals set out by the project, the team appears to be doing all the right things.

- Timeline of the project is proceeding on schedule.

D. Collaboration and Coordination

This project was rated **3.20** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project team is working with relevant stakeholders to ensure project success. The team is demonstrating to homebuilders, trades, and others the benefits of their wall system in terms of cost, time, and performance.

- Collaboration and coordination represents a good cross section of the design, construction, and academic sides of the industry to make sure all issues are identified and address early and thoughtfully. Team has also demonstrated and excellent knack for learning and making adjustments along the way to facilitate ease of use and adoption in the market.

- Team has put together a team to model the home and construct the home. Team has significant experience with residential construction. It's not clear how these concepts can be extended to have a more widespread reach through other collaborators.

- The degree of stakeholder engagement is not as high as other projects, and does not seem to be a major focus within the effort.

- Good stakeholder involvement in evaluation of technology.

E. Remaining Project Work

This project was rated **3.60** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- The team presents a reasonable plan for completing remaining project work within project timeline and has adjusted for some setbacks stemming from delays related to some project partner lags, etc.

- Remaining project work thoughtfully and logically builds in previous work to develop in service performance

data and system optimization.

- There will still be a significant amount of work, and it is not clear that some of the research questions will be able to be answered in the time allotted for the project. Questions on the time and cost required to assemble a home using these approaches should be addressed in the time, but questions on the durability of the solutions could take longer to resolve .

- It appears that they are right on track to meet their project objectives.

- There are still a lot of tasks to be completed in a limited time span.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Strong approach to technology demonstration and evaluation. Aligning project outcomes to existing market platforms (DOE Zero Energy Ready Homes, MN code, etc.). Expanding efforts beyond MN.

- Project strengths include the project team and implementation of the "perfect wall" a production quality scale/fashion, and to see that there is significant interest in the market.

- Innovative approach to implementing a well-accepted practice for construction durable and energy efficient wall assemblies.

- Directly addressing cost concerns as well as concerns of availability of skilled laborers.

- Demonstration is important to show viability of a new approach such as this one.

- Good combination of modeling and implementation.

- Strengths include:
    - Strong technical leadership
    - Clever idea
    - Complete approach, including modeling, demonstration and modeling

- Direct involvement with builder community for evaluation.

- Excellent building science background.

2) **Project Weaknesses**

- Reliance on other partner's timelines.

- One minor thing -- presenter mentioned that the installation of the peel and stick moisture barrier is very sensitive and can't be redone, this seems to run somewhat counter to ensuring that the wall system can be constructed and assembled by laborers with uneven skills. Would be value in experimenting with other materials that may be less sensitive to installer error.

- Novelty of the system could be considered a weakness, but a relatively short learning curve can overcome that. More clarity on the types of homes the building method is recommended for would be good too, e.g. suitability for single story homes, or better suited for 2-stories.

- Not clear that all questions will be answered in the allotted timeframe for project. (durability)

- Not clear how these simple wall constructions can be applied to a wider range of architectural styles (may

not have had time during the presentation to address)

- Most significant potential weakness is the practical market size that is likely to be addressed. More focus on stakeholder and market-actor engagement is needed (e.g. a business plan and business partners that will be ready to run with the technology at scale). Some more legwork to find the barriers to acceptance in the major markets would really help.

- Two potential weaknesses on the technical side are the need for cranes and precision installation, and the robustness of the design to on-site mishaps (e.g. cutting the window hole incorrectly)

- Cost analysis methodology not identified

3) **Recommendations**

- Maintain the focus on production building methods and time and efficiency of construction.

- Can any of the assemblies be assembled in a factory? While transportation would be complicated, there is still a need to transport large sheets, so perhaps it's not an issue. The presenter alluded to challenges with cranes, but it's not clear that it would be much different from what is needed in the method that was discussed.

- I would want to see a more serious market analysis (perhaps done by someone not on the team)

- I would want to see stronger engagement with serious builders, and a detailed analysis of niche that this technology is likely to be able to address.

- Add long term monitoring of performance to get an idea of durability.

Project #12104: Residential Building Comfort System Research

Presenter: Jon Winkler, National Renewable Energy Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project's approach—developing and utilizing physics-based computer models to create the knowledge needed to overcome technical risks in high-performance homes—was a good one. The concurrent incorporation of methods for addressing these risks (e.g. improved moisture modeling, home zoning research, installation quality analysis, and installation quality experiments) was seen by reviewers as a project strength. One reviewer commented that this project would help solve the "chicken and egg problem" of, on one hand, manufacturers not producing equipment for high performance homes because of a perceived lack of market, and, on the other hand, high performance home builders being concerned with the lack of appropriate equipment for their markets. Critically, one reviewer questioned whether Energy Plus was the best mechanism for some of the project's modeling studies (versus other software like TRNSYS CFD), particularly studies involving zoning.

Reviewers agreed this project will have a positive impact on filling the knowledge gap around mechanical system operation in energy efficient buildings, with one reviewer calling the project the only coordinated effort to identify and develop tools and methods for industry use in this area. Another reviewer highlighted that the majority of outputs would be in journal papers, calling this a necessary step to establish scientific fundamentals, but counseled that follow on work would need to be completed to ensure that the building industry implements the research findings.

Reviewers agreed the project is on track, especially in its development of modeling tools. One reviewer described a significant project hurdle as being the leap from modeling to installation and equipment production, but also acknowledged that the project has and is pursuing development of the necessary information to help solve this issue. Another reviewer expressed some concern about the project's remaining experimental efforts, given the limited time left, but multiple reviewers remarked that project work appears to be logical to meet project goals.

Reviewers mostly agreed that the project had done a good job coordinating with national labs like NREL and ORNL, as well as leveraging tools created by other BTO programs. One reviewer identified some collaboration with RESNET and ASHRAE, but pointed out that interactions with these groups did not yet appear to be very significant; project team collaboration with other Building America teams was also questioned. One reviewer mentioned that project team presentations represented the majority of stakeholder involvement, rather than active engagement, and there was universal agreement among reviewers that the lack of industry participation was a weakness of the project. One reviewer expected industry engagement to increase in later phases of the project—as the models and tools developed by the project begin to be used—and another reviewer recommended development of standards or guidelines as one way to engage industry in the use of project knowledge.

Weighted Average: 3.42 # of Reviewers: 3
Approach: 3.67 Impact: 3.67 Progress: 3.67 Collaboration/Coordination: 2.67 Remaining Work: 3.33

A. Approach

This project was rated **3.67** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- High performance, low load homes and properly supplied and installed HVAC systems are a frustrating chicken and egg problem: manufacturers aren't producing equipment for high performance, low load homes because there isn't a market; low load home builders and HVAC system installers complain there isn't equipment appropriate to serve their market. Manufacturers aren't investing in R&D to supply the emerging market because they don't have the data to design equipment around. The project approach aims to squarely fill this data gap using physics-based computer models to develop and create the knowledge to overcome the technical risks facing manufacturers, suppliers, and builders of high performance, low load homes. The approach combines 4 key research activities that utilize current available models and data generated through previous RBI and DOE funded programs to help industry push through barriers to developing next generation equipment and devices to enable high performance, low load homes to proliferate more broadly and achieve their performance targets with greater certainty.

- Project combines modeling of moisture, zoning, and installation quality along with a smaller amount of experimental studies. The modeling should help extend findings to a wider range of use cases around the United States. Challenge will always fall in ensuring that the model is correct; data for validation will be needed for all studies. I do have a question whether Energy Plus is the best mechanism for conducting some of these studies. Some have indicated that TRNSYS handles the transients, particularly in the zoning aspects, much better than Energy Plus.

- Excellent suite of projects.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.67** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Project directly impacts support research needed for zero energy buildings to become the norm. Due to the lack of industry R&D focused in this area, this project represents the only coordinated effort to identify and develop tools and methods for the industry to take advantage of to fill this burgeoning niche.

- This project directly addresses one of the three key focus areas of the program, namely the best approaches for implementing low-load HVAC in energy efficient homes. The project is still in the research stages, meaning that most of the outputs will be in journal papers. This step is necessary, to establish the scientific fundamentals. The work in implementing these solutions in the field will need to continue after this project is done to see the building industry implement the research findings.

- Critical to understanding mechanical systems in energy efficient buildings.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals*.**

- The project has demonstrated significant progress in key areas critical to the overall project success. The leap from computer modeling to installation and equipment production remains a significant hurdle, but the project has and is pursuing development of appropriate information and tools to begin to move the needle firmly in the direction solving the problem of a lack of good information and data to reliably predict performance and begin building equipment to address the need.

- Project has developed a number of tools for modeling, and work has resulted in a number of publications in

respected journals. Project appears to be on track.

- High impact technology that will aid other projects

D. Collaboration and Coordination

This project was rated **2.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project demonstrates significant internal national lab coordination and leveraging of tools created by BTO programs over the years to produce new and novel work to lead the industry toward meeting RBI goals.

- Project team at NREL involves a number of leading researchers; one member of team is from ORNL. There was a bit of mention of work with RESNET and ASHRAE, but it doesn't appear that those interactions are very significant at this time. It's not clear what sort of collaboration the team is having with other BA teams, including the work being done at FSEC.

- Most of the stakeholder involvement is being presented to rather than involvement in the projects themselves.

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Remaining work planned to meet project specific goals are logical and designed to lead into the next stages of needed research and development, all nicely set up for greater industry participation in the R&D effort due to the efforts expended early in the work. Remaining work continues to build on and leverage tools and assets within the BTO-RBI portfolio.

- Team still has a bit of work in modeling and experiments; experimental efforts are a bit of a concern given the limited time left in project. Work appears to be logical to meet project goals.

- Work is logically planned. Needs a little more focus on industry deployment.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Project strength includes attacking problems facing development of systems for high performance, low load homes on several fronts at once, recognizing that working on models in the 4 target areas was not mutually exclusive and advances in each area alone are good, but together are greater.

- Project is addressing a key issue for BA, namely the operation of low-load HVAC systems.

- Modeling aspect should lead to broad conclusions.

- Value are in the tools being developed

2) **Project Weaknesses**

- Underlying weakness of the project is the lack of manufacturer participation, but that is expected to change in later phases as models are rolled out and users begin to use the tools to develop new equipment.

- While it is understood that the basis of this work should be journal articles, there is still a need to translate that work into knowledge usable by the building community, whether it be standards or guidelines or other

information. It's not clear how that will be done in the project.

- Specific plan for industry deployment.

3) **Recommendations**

- Engage manufacturers sooner than later.
- Identify how EnergyPlus/Open Studio will be able to answer questions as opposed to some other software (e.g., TRNSYS, CFD), particularly with the zoning studies.

Project #15116: Residential Building Energy Modeling & Data Analytics

Presenter: Scott Horowitz, National Renewable Energy Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers generally agreed that this project's approach to developing a common, open-source residential energy modeling platform was good. Reviewers agreed that the project, if successful, would have a large impact on BTO's goal to "research, validate, and facilitate...opportunities that result in new strategies and practices in residential energy efficiency." Multiple reviewers mentioned the importance of building energy modeling (BEM) to expanding understanding of how different approaches will contribute to high performance housing, as well as to speeding up the research-to-market pipeline. One reviewer further described that "standardizing simulation engines" to get consistent results—as this project aims to do—has been an issue affecting most efficiency programs that utilize performance modeling. The project was therefore summed up by one reviewer as an "enabling technology needed by new technology developments."

Reviewers identified a number of potential hurdles to the project's success, including the need to gain acceptance of the project's model by private sector software vendors, as well as to encourage adoption of a common modeling engine by efficiency programs. Reviewers also highlighted the significant effort that is required to maintain modeling tools over time with upgrades and updates. Reviewers identified this need to provide ongoing maintenance as a weakness of the project, and recommended developing a plan for how this continuous support will be provided or to pass it off to the private sector. Reviewers also recommended considering other software (e.g. TRYNSYS) that might be able to provide better modeling predictions than EnergyPlus, as well as continuing to emphasize not just technical enhancements to modeling capabilities, but also the broadening of applicability of tools and analysis in the market.

A majority of reviewers agreed that the project was making good progress in meeting its goals along several different "thrusts," including ResStock and Home Energy Score/RESNET conversions. Furthermore, all reviewers agreed that the project team would successfully complete the remaining project work, as it was well-defined and closely aligned with both industry needs and BTO's emerging Grid-interactive Efficient Buildings (GEB) initiative. One reviewer attributed much of the project's progress to its positive engagements with stakeholders, which the majority of reviewers agreed had been well done. One reviewer, however, was not clear on how much coordination was happening between the project team and other National Labs contributing to the Building America program, or with BTO's BEM sub-program. Another reviewer questioned why RESNET was not an active partner while HERS software developers were, and noted that the state of California was a good candidate for collaboration. Other recommendations were to further broaden the project's partnerships to include municipalities, utilities, and affordable housing developers, as well as to target outreach to groups that question the value of energy efficiency and the accuracy of modeling tools.

Weighted Average: 3.57 # of Reviewers: 5
Approach: 3.60 Impact: 3.60 Progress: 3.40 Collaboration/Coordination: 3.60 Remaining Work: 3.60

A. Approach

This project was rated **3.60** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The project approach leverages BTO and industry investments to develop a common, open-source residential energy modeling platform suitable for research and industry use. This approach will ultimately significantly reduce the time needed for adoption of new technology within the available and most used modeling programs, speeding up implementation of Research 2 Market opportunities and allowing for greater granularity that can lead to targeted opportunities within the housing stock.

- Modeling is critical to extend lessons learned from laboratory and field studies to the wide range of housing across the US. The combination of efforts related to home scoring, ResStock, and OpenStudio development is key to expanding the understanding of how different approaches will contribute to high performance housing. With modeling tools, if they are not maintained, they end up dying a slow death, so it is important to continue to support upgrades and updates to keep the effort relevant. It would be great if the entire effort could be handed off to the private sector, but this reviewer cannot envision that as a possibility in the near term.

- Standardizing simulation engines to try and get results that are consistent have been an issue across efficiency programs that utilize performance modeling. California is about the only state that has managed to standardize approaches so that the results from different software are consistent. If successful this project should provide consistent results for programs e.g. HERS, performance based energy code compliance and any other performance based efficiency programs.

- This project presentation seemed rapid fire because multiple tools were presented. The format and number of tools made an in depth evaluation difficult. (i.e. I don't have many notes on GEB roadmap approach) And it assumed a level of familiarity with multiple DOE tools supporting many programs across EERE. I'm fortunate to have familiarity with most of the components discussed.

- Scott did frame the presentation well; that this group has a historic research challenge, as well as an industry challenge: How does the BTO prioritize investments and priorities (hvac, etc)? What is our role? Who is the end user of these software tools? The large team, many who have been working in this space for a long time, have a deep history an understanding of both historical uses, needs, trends, and constraints of these tools in the marketplace, both public and private. Additionally, they are very up to date and responsive to industry needs and solutions.

- Previous DOE peer reviews included a non-weighted question on relevance. This project would have scored high on relevance. The importance of DOE's work in this area is crucial.

- Will produce technology that will improve industry standards and transparency of technology evaluation.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s).***

- Program squarely addresses the RBI strategy to "research, validate, and facilitate . . . opportunities that result in new strategies and practices in residential energy efficiency." As the program's impact statements note, energy modeling software is used pervasively and at scale to drive efficient buildings and technologies and BTO's energy modeling capabilities are targeted at the largest programs pursuing energy efficiency targets. The faster the modeling programs can implement proven new technology, the faster they can be analyzed and implemented. In addition, the more granular the analysis, the more targeted and tailored the outreach and approaches can be.

- As previously stated, modeling is key towards extending valuable but limited laboratory and field data. Engaging with home scoring efforts will bring the best modeling approaches to those applications. The use of ResStock enables strong conclusions across the entire building stock.

- If the goals of the project specific goals are met there should be no reason why the program goals cannot be met. Some of this will hinge on the acceptance of private sector software venders for this approach in addition to efficiency program acceptance of a common engine.

- The buildings analysis and analytics tools are crucial for validating energy performance of technologies and strategies in homes. Additionally necessary for zero energy buildings. Of course, modeling calibrated to real world energy use in buildings is also vital. Continue to emphasize validation of these tools for use in the existing home market, including multifamily. This task is more difficult than new construction, but it is essential to meet DOE impact goals, and this group seems well suited to do it.

- Enabling technology needed by new technology developments.

C. Progress

Based on current project efforts, the project was rated **3.40** for the degree to which the project has met ***project-specific goals.***

- Project is well on its way to meeting its goals.

- The team appears to have several different thrusts, all of which appear to be moving along well. Continuous maintenance by adding and amending code for challenging situations will be a long effort. Good progress appears with both ResStock and the Home Energy Score/RESNET conversions.

- Based on the information provided the project seems to be on track and on schedule to meet the project specific goals which is not easy for software specific projects.

- Seems to have a clear outline of next steps and priorities. Ongoing work....

- Excellent progress to date.

D. Collaboration and Coordination

This project was rated **3.60** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The team has done an excellent job of engaging stakeholders along the way - project is indeed an outcome of this constant and high level engagement.

- Team has listed many different stakeholders. It is not clear how much the team coordinates with other national labs in the BA program or those funded through Amir Roth's program.

- I did not see RESNET referenced as an active partner even though the HERS software developers were. Also - is California interested in this platform? Other than that the collaborators seem strong.

- I'm impressed at the breadth and depth of collaboration and coordination this team provides to a range of stakeholders. This is not easy task and could overwhelm, but the project seems focused and coordination appears to be strategic. They are also very accessible (the people and the tools.) It's clear that the team is driven by creating tools and analyses that are used in the market, valid, and accessible to a wide range of stakeholders. Kudos. Please continue to broaden your outreach and accessibility. Municipalities, other utilities, etc. Consider affordable housing developers/managers, CDFIs, etc.

- Related tangentially, there is also a need for external stakeholder engagement (by this group, maybe not - others?) for those that question the value of energy efficiency (and the accuracy of modeling tools) in real world application in existing homes.

- Excellent outreach to standard / rating system stakeholders.

E. Remaining Project Work

This project was rated **3.60** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Remaining project work is well-defined and closely aligned with identified needs in the industry and the GEB Roadmap.

- The team appears to have adequate staffing and skills to complete the remaining efforts.

- This project has been well planned and is moving forward on schedule. Platform development projects tend to be very difficult to keep on schedule and plan for and this project appears to have done a great job on planning.

- Seems to have a clear focus on near and long term project work.

- Some of the future work could have improved specificity in the timeline.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Project strength lies in the reducing the Research 2 Market timeline and leveraging previous investments in energy modeling software.

- The results are very important to enable all stakeholders to make conclusions, whether those stakeholders are researchers, auditors, or policy people.

- Strong technical team.

- There are several strengths to this project including:
    - 1. The consideration of all of the efficiency programs and how they will be incorporated into the software
    - 2. Working with interested and affected stakeholder groups
    - 3. Accounting for GEB

- Technical rigor, breadth, depth, and accessibility of both analyses and tools. Strong project team. Clear strategic focus. Transparency is tremendous strength.

- Much needed to support transparency and uniformity in industry ratings and certifications.

2) **Project Weaknesses**

- Version control and keeping up to date, as with all software programs.

- No major weaknesses; always challenging to understand when a project such as this one reaches diminishing returns, where it should be downsized into a maintenance effort instead of a development effort.

- I don't see any weaknesses to this program. The only partner that I didn't see on the list was the California Energy Commission but they may have been contacted and were not interested.

3) **Recommendations**

- Continue the close coordination and collaboration and leveraging previous investments in software.
- Consider other software such as TRNSYS that might be able to provide better predictions than E+.
- A plan for version control will be critical for this project and I would recommend including that to improve the program.
- Per earlier comments, continue focus on the existing housing stock, including multifamily (for ResStock). Continue to emphasize not just the technical enhancements, but applicability of tools and analyses in the market.

Project #15275: Building America Research Dissemination

Presenter: Chrissi Antonopoulos, Pacific Northwest National Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers overwhelmingly agreed that this project's approach to disseminating Building America (BA) research was good. One reviewer commented that "knowledge is power and [the Building America Solution Center (BASC)] is where all of the knowledge resides," and another described the BASC as a very user-friendly website. Reviewers generally agreed that the project has had a positive impact on BTO's residential building goals, and that the BASC is key to the BA program's strategy of getting technology to market. While overwhelmingly praising the availability of such a complete library of knowledge in a single location, some reviewers questioned the project's impact due to the lack of information on how many users actually implement lessons learned from the BASC. Another area of concern raised by reviewers was the work being done to drive users to the site (e.g. social media marketing).

A majority of reviewers agreed that the project was making good progress, with website traffic continuously building and exponential growth seen as likely. The incorporation of existing building resources and an expansion of user demographics (e.g. architects) were seen as positive indicators of this progress. One reviewer noted, however, that there were no numerical targets for user growth to evaluate against, and that it would require research to see how similar efforts of knowledge dissemination are judged. Reviewers agreed that the project had a clear and reasonable plan for completing its work, although multiple reviewers commented on the need for continuous maintenance of the BASC. One reviewer even mentioned the volume of information available on the BASC—normally a strength—as a potential weakness, given the need to provide ongoing support to the website.

The project was generally seen as having strong collaborations with a wide variety of stakeholders, both public and private, but there was some disagreement regarding the project team's level coordination with other DOE programs, including other BA research teams. One reviewer highlighted the need for the project team to gain an understanding of the needs of its customers (i.e. those who implement solutions at the design stage and in the field). Teaming with the National Association of Homebuilders was seen by reviewers as a good idea, and reviewers also suggested collaborations with the code enforcement and regulatory community, as these domains have been identified as barriers to technology deployment. Additionally, disaster resistance was mentioned as another new domain that should be included in the BASC. The need for a wider scope in stakeholder outreach was seen as a project weakness, and more marketing was recommended to address the deficit. One reviewer suggested a "sort of Wikipedia interface," or a campaign within Wikipedia, to drive users to the BASC. Another reviewer suggested ensuring that research from non-DOE organizations (e.g. foreign research and research from other federal agencies) is also included.

Weighted Average: 3.64 # of Reviewers: 5
Approach: 3.80 Impact: 3.40 Progress: 3.80 Collaboration/Coordination: 3.40 Remaining Work: 3.80

A. Approach

This project was rated **3.80** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Strong approach designed to ensure that the overall Building America program can maximize the impact of its research investments
- Knowledge is power, and this is where all of the knowledge resides.
- This project has resulted in an incredibly valuable source of information for the residential building community. Their approach to making results of research available to the public has resulted in a very user-friendly site. They are obviously doing something right.
- Information curation is not my specialty, however the approach appears to be a good one, namely getting all of the information in one place.
- Needed enabling technology to share Building America results.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.40** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- As noted, the Solutions Center is a cornerstone of Building America's strategy for getting technology developments to market. For researchers, industry, policy makers, and others having a single location to find data on proven technologies and construction techniques, what research is underway, etc. is invaluable. Who has time to dig through multiple sites to find information catalogued and presented in very different ways?
- Because knowledge is power, and the Building America Solutions Center is where all the knowledge resides, the growth in users of the repository is key to meeting RBI goals. The jump from users of the information to action taken on projects is not clearly known, but certainly can be assumed at some level. Though I rate the impact as fair, mainly because of the difficulty of assessing the impact, having all of the Building America program information at the ready and from one central repository/website, is essential to making sure the information is accessible for all time.
- This project is key to conveying DOE research to those who will implement the solutions in a manner that they can digest.
- The value of this project to meeting program goals is very high. I am not sure about what is being done to drive potential users to the site (e.g. social media marketing)
- Contribution to program goals is based on making results from other projects accessible. Enables use.

C. Progress

Based on current project efforts, the project was rated **3.80** for the degree to which the project has met ***project-specific goals*.**

- The project team has identified a number of priority improvements for the Solutions Center and is making solid progress toward implementation. I would particularly point out work toward incorporating of resources related to existing buildings - this is an extremely valuable addition!
- BASC website traffic continues to build, and will likely experience exponential growth in the coming years. Very encouraging to hear that program demographics are picking up more architects - energy efficiency

begins with design.

- Team has progressed well on their project plans, completing the milestones that were planned.
- The project appears to be doing well, however there were no numerical targets against which progress could be evaluated. This would take some research on how similar efforts are judged.
- Excellent progress, but this needs to be an evergreen project as new technologies are constantly being developed.

D. Collaboration and Coordination

This project was rated **3.40** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Strong collaboration with other DOE programs, private industry, and other research institutions/funders has made the Solutions Center a much richer and comprehensive resource. This helps leverage even greater opportunities for collaboration and coordination between and among private and public sector actors.
- Strong ongoing stakeholder engagement. Wide and varied audience, so might be difficult to find the right appeal for every potential user.
- To make this project work as well as it has, the team needs to coordinate with all BA teams as well as gain an understanding of the needs of its customers, the people who will implement the solutions at the design stage and in the field.
- Teaming with NAHB is a good idea.
- I would like to see some direct linkages with code enforcement and regulatory community as codes have been identified as a significant barrier to new technology deployment.

E. Remaining Project Work

This project was rated **3.80** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals.***

- Clear and reasonable plan for completing remaining project activities in project term.
- Project has proven track record of success and growing family of users. Remaining work only builds on this past success in logical and useful fashion.
- The site will require continuous maintenance, but it seems like much of the work to continue to reach project goals will be finished shortly. Movement into disaster resistance is an interesting new field that should be tied into other information included in the Solution Center.
- Plan looks good
- Very logical work plan

F. Additional Comments and Recommendations

1) **Project Strengths**

- Focus on meeting needs of industry for information and findings from government supported research and getting information into hands of those who need it

- All of the right building science/Building America knowledge easily accessible from one location.
- The result of this project has been the ultimate go-to source for information on energy-efficient, durable homes with good IEQ.
- One-stop shopping for information
- Organization of project

2) **Project Weaknesses**

- The volume of information is the BASC's strength and potential weakness. Ongoing maintenance of the platform is essential.
- Needs a wider scope in stakeholder outreach

3) **Recommendations**

- More marketing to expand audience and overall awareness of the extent of information and resources available. Make materials available to others so they can readily spread the word about the Solutions Center.
- Continue focus on outreach.
- While I haven't checked closely, the team should ensure that research results from non-DOE organizations are also captured in the information provided to stakeholders. (e.g., Canadian and European work, other US Federal agencies such as EPA, HUD, NIST).
- Perhaps some sort of Wikipedia interface, or perhaps a campaign within Wikipedia to drive people to Building America resources.
- Continue project by funding future work identified in presentation

Project #19119: Building Science Technical Quality

Presenter: Stacey Rothgeb, National Renewable Energy Laboratory
DOE Manager: Eric Werling

Brief Summary of Reviewer Comments

Reviewers agreed that this project's approach—providing scientific leadership to ensure high quality, impactful results from Building America's (BA) building science research program—was good, necessary to enable technology, and essential to ensure continuous operation of the BA program. One reviewer lauded the project for leveraging resources from across the national labs to ensure the best use of previously invested resources and assets. One reviewer commented that the "project is basically the entire [BA] program, which appears to be working well," while also noting uncertainties about program impacts and questioning program evaluation methodologies. Reviewers suggested comparing the BA program with other market transformation efforts to evaluate the success of this project.

Reviewers had mixed feelings regarding the project's impact. One reviewer remarked that it is important to remember that this project's management and support of BA's research portfolio are keys to the success of the overall BA program. Multiple reviewers, however, expressed that it was difficult to measure this specific project's impact, as other BA projects that are funded and overseen by this one get the credit for their individual project's impacts. Despite these difficulties, reviewers agreed the project team had made good progress in achieving its project-specific goals, and had done a good job collaborating with relevant stakeholders. This collaboration with all BA activities overseen by the project team was perceived by reviewers to be key to ensuring that remaining project goals are met.

Reviewers identified a myriad of project strengths, including the project team's requisite expertise to support each BA research effort, the project's focus on system performance over component performance, and its focus on market transformation. Project weaknesses were also diverse. One reviewer stated that as an overhead program, there may be a desire to limit involvement, while another reviewer questioned the size of the budget in comparison to the research budgets this project oversees. One reviewer wasn't sure if the project's technical expertise was utilized by other BA teams, and recommended that the project team better highlight the technical support it has provided. Other recommendations were to focus the project on in-field performance by making use of Internet of Things and smart meter technologies for data collection, and also to conduct builder interviews to determine what parts of this project this stakeholder groups values most.

Weighted Average: 3.39 # of Reviewers: 4
Approach: 3.25 Impact: 3.50 Progress: 3.25 Collaboration/Coordination: 3.50 Remaining Work: 3.50

A. Approach

This project was rated **3.25** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The RBI science research technical quality management program is essential to ensuring Building America research programs remain useful and relevant, and assists with leveraging resources throughout the National Lab network to ensure the highest and best use of previous resource investments and assets. There are no guarantees that the program approach is be successful all the time, but past history suggests a successful track record.

- This project is necessary to ensure continuous operation of the BA program. It appears that systems are in place to support the DOE funding opportunities and to track the progress of projects that are awarded.

- This project is basically the entire program, which appears to be working well. It is always difficult to determine what would have happened if the program did not exist, and therefore to what extent it can take credit for the savings achieved. I am not an expert in evaluating Market Transformation programs, but I think that comparison with other market transformation programs is how the success of this approach should be evaluated.

- Necessary enabling technology

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.50** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*****.**

- As an overhead program charged with supporting all other projects, impact is difficult to assess other than to note that the general success of the BA program, of which SRTQM is also a part of.

- It is hard to quantify the impact of this project, as much will be attributed to the projects that are funded and overseen here. It is important, though, that management and support of the research portfolio are key to success of the overall program.

- This project is the program, and it appears to be working well. I think more measurable goals would be good. It is hard to say how well the stated goal (By 2025, market leaders will achieve in their buildings an improvement in energy consumption per square foot of at least 35% relative to typical commercial buildings in 2010.) has been achieved.

- Necessary enabling technology

C. Progress

Based on current project efforts, the project was rated **3.25** for the degree to which the project has met ***project-specific goals*****.**

- Based on the success of the BA program, the SRTQM program shares in the success and project progress.

- No concerns, as most projects appear to be on schedule and it appears that the support provided to those projects is sound.

- It is hard to distinguish project-specific goals from program goals

- To date, the project has accomplished its goals

D. Collaboration and Coordination

This project was rated **3.50** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- SRTQM being part and parcel of each Building America research project means each project must practice and engage in significant collaboration and coordination efforts.
- Project provides support to projects throughout the RBI portfolio.
- There appears to be significant and broad stakeholder engagement. A strategic analysis of this engagement would be good to see.
- Broad range of stakeholder involvement

E. Remaining Project Work

This project was rated **3.50** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- SRTQM is only as good as the projects it participates on, which is all of them. It would be hard to know how well the BA research programs could get along without professional assistance, guidance, and some oversight from SRTQM to help insure lines of communication across labs and across disciplines remain open and available to appropriate project teams.
- Project needs to continuously monitor ongoing projects and provide support for upcoming FOA's.
- The planning work seems to be to stay the course, which seems fine, assuming that a deep dive strategic analysis has been performed.
- Clear pathway to accomplishing project goals

F. Additional Comments and Recommendations

1) **Project Strengths**

- Expertise to support each BA research program.
- A necessary effort to ensure that the program remains relevant, that the right things are being done and that each project is delivering on its potential.
- The technical support provided, e.g. experimental design and measurement expertise, is invaluable to the program.
- Various initiatives spread around the country
- Focus on actual system performance rather than component performance
- Focus on market transformation

2) **Project Weaknesses**

- As an overhead program, there may always be the lingering desire to limit involvement.
- While the previous question on strengths highlights the technical assistance that the project provides to all

BA teams, I do not recall hearing much in the other presentations about how those projects made use of that available expertise. It seemed like much of those aspects of projects (e.g., experimental design) were carried out by individual project team.

- The project budget is relatively large. While the importance of program support is acknowledged, the budget is much greater than most of the projects discussed. Is such a large outlay needed for program support?

- It is always difficult to decide what is the best market transformation strategy

3) **Recommendations**

- Continue focusing on collaborate resources and leveraging previous works.

- Find ways to highlight specific technical support provided to other teams.

- Even more focus on in-field performance, perhaps making use of IoT and smart meter technologies to collect performance data at reduced costs

- Conduct a review by medium and large builders to see what they value (perhaps this has been done)

- Refine metrics for success, perhaps based upon other Market Transformation programs

Residential Buildings Integration
Other RBI Initiatives

Project #14202: Race to Zero Student Design Competition

Presenter: Stacey Rothgeb, National Renewable Energy Laboratory
DOE Manager: Sam Rashkin

Brief Summary of Reviewer Comments

Reviewers agreed with this project's approach of holding an annual competition for college teams to design zero energy ready homes. Multiple reviewers complimented the project's positive influence on developing a future-focused STEM workforce, as well as the project's efficient, effective, and unique ability to generate interest in building science at the undergraduate level, especially at a time when there was no national building science curriculum. Reviewers also agreed on the project's positive impact in helping meet BTO's residential building goals, by helping to develop a better talent pipeline for the building community in a more robust, cheaper, and safer manner than its counterpart, the Solar Decathlon. One reviewer, lamented the lack of an actual house being built at the end of the competition, describing that this possibly left educational opportunities on the table. Multiple reviewers also pointed out the possibility that not enough students will be exposed to Race to Zero to meet the timeline of program goals, but expressed interest in seeing how many student ended up in the high-performance building field. To quote one reviewer: "If this effort could be shown to lead to hiring by homebuilders who previously didn't put much thought into building science, that would be a great story."

Reviewers agreed that the project had been making good progress, having conducted several competitions with increasing student participation each year, and having engaged in successful collaborations with both industry partners and educational institutions. One reviewer, however, highlighted a lack of numerical goals against which progress could be measured, and suggested more direct collaboration with builders and contractors rather than just the National Association of Home Builders.

By leveraging increased industry participation and funding, reviewers expected the project to complete its remaining work and continue growing. However, reviewers did express budgetary concerns, notably about the project team's ability to utilize current funding efficiently enough to reach the desired number of students. Assuming budgets aren't a concern, one reviewer recommended that the competition add more multifamily and commercial buildings to the competition, as well as existing building retrofits. Another reviewer suggested a slow approach to expanding the competition, so as not to dilute the amount of time students spend with judges and professionals in the field.

Weighted Average: 3.65 # of Reviewers: 3
Approach: 4.00 Impact: 3.33 Progress: 3.67 Collaboration/Coordination: 3.67 Remaining Work: 3.33

A. Approach

This project was rated **4.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Absent a nationalized curriculum and requirement for building science training and developing a future focused workforce, this reviewer is not aware of any programs in existence that have been as efficient and effective at generating positive interest in building science at the earliest collegiate levels.

- This project is a unique one to evaluate. If one considers the goal to expand the workforce trained in the science, architecture, and engineering of residential building systems, then this approach is excellent. The development of a design competition enables building science to be spread to a large contingent of college students who wouldn't otherwise get such training. The project team is going about the effort in a logical manner.

- Within the project's stated goals, the selected approach is excellent, balancing cost and engagement requirements with technical rigor, and with employment opportunities.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.33** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Without knowledgeable professionals in the field, and programs to expose young minds to the possibilities, RBI program goals could not be achieved without the leaders such programs as this create.

- This project has done an excellent job of extending building science to college students to build a better pipeline for the building community. The design competition has the possibility of engaging many more students than does its accompanying project, the Solar Decathlon.

- The only reason this project did not get outstanding in this category is the timing of education and engagement provided relative to the timing of the on-the-ground goals.

C. Progress

Based on current project efforts, the project was rated **3.67** for the degree to which the project has met ***project-specific goals*.**

- Project specific goals have been met and exceeded.

- The project team has managed to successfully conduct several Race to Zero Design competitions, with interest increasing every year.

- The only reason this did not get outstanding is that there were no numerical goals to which the actual performance could be compared.

D. Collaboration and Coordination

This project was rated **3.67** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Collaboration and coordination with industry partners and educational institutions is evident and clearly demonstrated in the growth of the program.

- To carry out such a large endeavor, the team had to coordinate with academic departments and building

professionals to ensure that the competition was representative of what would be seen in the residential building sector while contributing to the educational direction of the students.

- Collaboration looks good, however I would suggest expanding to include actual builders and contractors (not just NAHB)

E. Remaining Project Work

This project was rated **3.33** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Remaining project work includes growing and learning to cope with success. Will need to leverage industry funding more in the future and continue to build on the commercial race to zero program.

- The only questions remain as to how to tweak to process to ensure that it remains fresh and how to reach the desired number of students within the budget available and the staff allocated to the effort.

- The plans seems to be to expand the number of students, which is good, but there is not much detail beyond that. Perhaps this is due to uncertain funding.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Focusing on undergraduate programs and stakeholder engagement in the program.

- Reaching a great deal of students to expand the workforce for delivering high performance homes.

- Provides real-world experience without the costs and safety concerns of the Solar Decathlon.

- Excellent idea for getting students to engage and train our future workforce/leaders, balancing cost and engagement requirements with technical rigor, and including employment opportunities.

2) **Project Weaknesses**

- Adding more multifamily and commercial building typologies, as well as existing building retrofit competition.

- While stated as a positive, the fact that the team does not actually build a house may leave educational opportunities on the table.

- I did not notice any particular weaknesses

3) **Recommendations**

- There was discussion at the review about expanding the competition. I would do so slowly, as I am sure that there is some benefit to the teams in a competition in which they have more face-to-face interactions with judges and other professionals in the field. While we all applaud the increase in building science education, it would be interesting to continue to understand how many of the students end up staying in this field. If this effort could be shown to lead to hiring by homebuilders who previously didn't put much thought into building science, that would be a great story.

- Provide clear targets against which progress can be measured.

- Increase number and scope of sponsors

Project #15148: Home Energy Score Gateway

Presenter: Dave Millard, Pacific Northwest National Laboratory and Noel Merket, National Renewable Energy Laboratory
DOE Manager: Joan Glickman

Brief Summary of Reviewer Comments

Reviewers found the approaches taken by these two complementary Home Energy Score (the Score) projects to be sound. One reviewer described the first project—which was focused on setting up the web-based infrastructure to support home energy scoring—to be a "required" activity if the home energy score was to become an established tool for the home performance industry. This reviewer also commented that the second project—which was attempting to harmonize different scoring approaches by using EnergyPlus as a common simulation engine—could help decrease confusion and provide a more robust approach to developing an energy score. Two other reviewers agreed with these assessments, with one commenting that web-based infrastructure for the Score should improve the accessibility and usability of Home Energy Score platforms, and another affirmed the need for common energy score metrics. One reviewer applauded the project team for considering not just technical approaches to energy scoring, but also issues related to market uptake around financing, consumer motivation, and policy adoption. However, another reviewer warned that if these efforts were successful, they would result in yet another platform for which DOE must provide continuous support, limiting its flexibility to address new areas. One reviewer expressed a desire to see how this work fit with commercial energy scoring applications.

Reviewers agreed that these projects squarely addressed BTO's residential buildings goals by validating the energy performance of targeted building technologies and improvements in real-world homes. They also agreed that these projects directly improved the usefulness of information collected by Home Energy Score raters, enabling them to develop implementable and useful real-world measures. Commenting further, reviewers flagged that these projects could (1) result in energy performance metrics that would be used by the real estate and home performance industries, (2) open doors to valuing the impacts of related efficiency programs, and (3) help measure progress towards reducing home energy consumption. One reviewer noted that scoring tools are inherently an enabling technology, but others highlighted that these projects' tools could have a huge impact on the existing homes market, which represents the vast majority of opportunity for improving energy efficiency in the marketplace.

According to most reviewers, both of these projects appeared to be on track and were making progress towards project goals. One reviewer described that the initial Home Energy Score gateway was operational at the time of the presentation, and that on the modeling side the project team had both completed a good amount of work related to HPXML, and had produced good comparisons of existing tools with EnergyPlus predictions.

Reviewers agreed that the projects featured excellent collaboration and coordination across the country, including with interested jurisdictions, utilities, and national labs. Reviewers remarked that both projects appeared to be coordinating with key players in the home performance industry, which would help ensure that project results would address the needs of end users. The project was also lauded by one reviewer for its work with key EnergyPlus developers as well as a range of Building America teams. Another reviewer, however, flagged the lack of collaboration with RESNET as a key omission.

According to most reviewers, remaining project work was well organized, logical, and tailored to meet the projects' targets and goals. One reviewer described the remaining project work as "ambitious," however, referring specifically to the transitioning of residential data to downstream consumer. Another reviewer remarked that a lot of the task seemed to be left to the projects' final year. Moving forward, reviewers offered a number of recommendations for the project, including that the project team should facilitate access to data generated by the project to help publicize its findings and impacts; make sure that all aspects of the technology are scalable; research ways to lower the cost of producing Scores; and find ways to mitigate the risk of human error during data entry and simplify quality assurance steps.

Weighted Average: 3.39 # of Reviewers: 5
Approach: 3.00 Impact: 3.60 Progress: 3.60 Collaboration/Coordination: 3.60 Remaining Work: 3.40

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- Development of the HES Gateway using coding formats and inputs commonly found in HES platforms should improve the accessibility and usability of HES platforms, which ultimately leads to identification of focused efforts and low hanging fruit to spur energy savings and better targeted utility programs.

- A simple and transparent approach to rating a homes' efficiency is essential to incorporating efficiency and energy costs into the home's value. The home energy score approach is sound in that it simplifies and creates consistency around a number of steps in the home audit process. Key is getting greater distribution of the score.

- These two projects are (a) setting up the web-based infrastructure to support home energy scoring, and (b) attempting to harmonize different scoring approaches by using Energy Plus as a common simulation engine. The first part is required if the home energy score is to become an established tool for the home performance industry. The second aspect will help decrease confusion and will hopefully provide a more robust approach to developing these scores. The development of HPXML is also a necessary building block towards improving the ability to get consistent scores.

- Project approach is sound, and the team is strong.
- Good to hear that the team is not just considering technical approach but reference Market uptake re financing, consumer motivation, and policy uptake.

- Common metric needed.

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.60** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- Any program that can focus on existing buildings, which is the vast majority of opportunity in the marketplace for improving energy efficiency, can be successful. The project squarely addresses the RBI strategy to validate energy performance of targeted building technologies and improvements in real-world homes. Without the common platform or common tools to collect and assess data, this strategy would be difficult to achieve. The HES projects directly improve the field and usefulness of the information collected by HES raters to lead to implementable and useful real-world measures.

- Having an easy to understand energy score for homes and increasing transparency on home energy efficiency and costs has a very high impact on related efficiency programs. The score can open doors to valuing the impacts of a number of related efficiency programs and help measure progress towards the goal of reducing home energy consumption.

- If the projects are able to set up the infrastructure to enable more cost-effective and accurate scoring of home energy performance, then one could envision that this work will result in metrics that could be used by the real estate industry and home performance industry.

- These technical projects directly have impact on BTO program goals. Supports systems integration, validates energy performance, and produced products that are gaining market traction, such as Portland. Over 90k homes scored is impressive. Huge impact on existing home market, and Per earlier comment regarding the approach, great that the technical team is involved in thinking though the applications for expanded use. ex Gateway to get the rebate.

- Scoring tools are enabling technologies

C. Progress

Based on current project efforts, the project was rated **3.60** for the degree to which the project has met ***project-specific goals*.**

- Project is well on its way to meeting project goals. Program use is starting to be mandated by jurisdictions. Will start to see impacts no financing and hopefully expansion of qualified raters.

- The score has progressed to being an established metric for a number of programs.

- Both aspects of the projects appear to be making progress towards their goals. The Gateway project has a long timeline. It appears that the initial gateway is operational at this time; it is envisioned that continuous maintenance will be needed, and further modifications may be required if more users make use of the portal.
- The modeling aspect of the project also appears to be going well. They have completed a good amount of work related to HPXML, and they have done good comparisons of existing tools with Energy Plus predictions.

- The timing of this session forced reviewers to share and split time. I would have liked more information on the Gateway's transition to commercial entities. Also, many of the questions from the audience seemed to indicate the need more information on the Home Energy Score program.

- Project on track, with interim goals completed

D. Collaboration and Coordination

This project was rated **3.60** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- Excellent collaboration and coordination across the country by interested jurisdictions, utilities, and National Labs.

- By its nature, the project is a collaborative effort of many stakeholders, both internal and external. This is true from the technology piece to the dissemination of the scores.

- Both aspects of the project appear to be coordinating with the key players in the Home Performance industry to ensure that the results of their work will address needs of end users. The key EnergyPlus developers are on the team, and the gateway involves a range of BA members.

- Presenters have significant collaboration with real estate data services providers, developers, as well as contractors, assessors, and local policymakers. Also significant internal stakeholder coordination with Open Studio and Energy Plus migration, as well as Home Performance with Energy Star use of the tools. Good investment.

- Good stakeholder outreach, but I would like to see RESNET included in stakeholders.

E. Remaining Project Work

This project was rated **3.40** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Remaining project work is well organized, logical, and tailored to meet its targets/goals. Good leveraging of ongoing work in other labs as well to complement completion of project, e.g. Residential Building Energy Modeling and Data Analytics project run by Scott Horowitz.

- The team will need to be flexible to accommodate a number of possible scenarios, from incremental to very rapid growth.

- It appears that both aspects of the project will have plenty of time to complete the project objectives. While I do not fully appreciate the challenges in setting up a Gateway for the Scoring, it appears that the team has a number of years left but has already completed most of the work. It also appears that the modeling component has completed a good amount of work but has several years left.

- Ambitious remaining project work for transitioning residential data to downstream consumers. A lot of success depends on local data registers. Would love to learn more about ANSI standards down the line a few years out.

- Seems a lot of task is left to final year of project.

F. Additional Comments and Recommendations

1) **Project Strengths**

- Recognition of the confusion in the market around HERS and HES scoring and developing a methodology to combine data sets for each tool; Mandated use of HES Score in some jurisdictions, web-based interface.

- The project's strength is the inherent simplicity and intuitiveness of a 1-10 scale score and the ability easily compare homes which it offers

- Will result in a usable tool by the Home Performance Industry
- Addresses the supporting details that are challenging but critical.
- Will help to make the HEScore more accepted.
- Technically sound.

- Strong project team. Huge impact on existing homes and relevance for other BTO initiatives.

- Excellent goals to improve uniformity of rating systems.

2) **Project Weaknesses**

- Potential long lead to adoption by users in the marketplace and not achieving expansion of the program as hoped.

- Costs associated with the production of the score are still high and may prevent rapid distribution. The technology underlying the score is also quite complex, which is not an issue at the current scale at which scores are generated but could be if those numbers were multiplied by 10 or more.

- I don't know if it's a weakness, but if this effort is successful, it will result in yet another platform to which DOE will need to provide continuous support, limiting flexibility to address new areas.
- Is E+ definitely the correct solution for this problem? I appreciate that E+ has had a lot of work put into it, but it doesn't work well in all situations. I am not sure if other tools work better (e.g., TRNSYS), but it would be nice to be convinced that porting everything to E+ is the best option.

- Not project specific, but more stakeholders need to be aware of these resources. Many BTO peer review attendees did not know about this work.

- Lack of involvement with RESNET which publishes the standard for the most widely used rating system.

3) **Recommendations**

- Make sure to address items noted in question 12 - having robust plans in place to facilitate rollout.

- Facilitate academic and other access to data generated by the project to help publicize its findings and impacts (for example Portland).
- Make sure all aspects of the technology is scalable.
- Research ways to lower cost of producing scores.

- Find ways to mitigate risk of human error at point of data entry, simplify QA steps and make them interactive where possible, or add API method to provide QA feedback on inputs before score is generated.

- Be very clear about an end point for the Gateway effort.

- Would like to see how this work fits with Commercial Energy Score applications, and roll out.

Project #19120: Residential PACE Energy Savings

Presenter: Lisa Schwartz and Jeff Deason, Lawrence Berkeley National Laboratory
DOE Manager: Steven Dunn

Brief Summary of Reviewer Comments

Reviewers described this project's approach to its research on the deployment and energy impacts of residential Property Assessed Clean Energy (R-PACE) programs as sound, clearly communicated, and possessing both a reasonable scope of work and a clear project plan. The only major criticism of the project approach was offered by one reviewer who strongly questioned why California (CA) was selected as the focus point for the study—rather than a less progressive state whose experience might be more generalizable. Another reviewer, however, noted that the project team had clearly communicated that it was the availability of data in CA that made this project viable.

Reviewers agreed that this project contributed to a variety of BTO's residential buildings goals, including validating the energy performance of building technologies; researching, validating, and facilitating learning and leadership opportunities; and supporting research needed for zero energy buildings. One reviewer noted that these types of program evaluations are necessary to see how much energy has been saved per dollar spent, while another flagged that the California Energy Commission's (CEC) involvement was indicative of the project's impact, as other states, public utility commissions, and utilities were observing CA's experience. Critically, however, one reviewer expressed that while data collection and analysis were useful, it was not clear how widely the project would influence the market.

Based on its schedule, reviewers agreed that the project appeared to be on track and had made good progress to date. One reviewer highlighted, however, that while the project had answered its first research question (i.e. whether R-PACE programs are driving deployment of energy efficiency and solar), it would be important for the project team to differentiate and report on the impacts of energy efficiency versus solar. This reviewer also expressed a desire to see longer term studies addressing the overall costs for R-PACE; the consumer experience; and the quantification of non-energy benefits such as increased home value, increased comfort, resiliency, reduced energy costs, and impacts on low-to-moderate income communities. Looking forward, two reviewers warned of the problematic nature of any effort to collect and clean billing data—flagging that unforeseen issues could delay completion of the project—while another reviewer was concerned that there were no milestones listed for during the project's final 18 months. One reviewer repeatedly encouraged expanding the project team's analysis outside CA.

Reviewers described excellent CA-based stakeholder involvement in the project, including the CEC and major investor-owned utilities. One reviewer commented on the lack of stakeholder involvement outside of CA, however, while another recommended additional outreach to contractors—whom the project team had described as the primary drivers of adoption—and to the real estate community and consumer protection groups.

Weighted Average: 3.07 # of Reviewers: 3
Approach: 3.00 Impact: 3.33 Progress: 3.00 Collaboration/Coordination: 3.00 Remaining Work: 3.00

A. Approach

This project was rated **3.00** for the degree to which the project's approach contributes to overcoming barriers, technical challenges, and mitigating project risks.

- The approach that was selected makes sense but I am questioning why California was selected for the study and not a less progressive state or states that may have come up with different results.

- The project team's approach is sound, and clearly communicated. The milestone deliverable by Deason and Murphy was also helpful to review. The project team clearly communicated that the increase in data availability makes this project viable, as well as relevant for California Energy Commission and other states interested in learning from CA. The majority of the comments and discussion were related to the PACE program, and a few on the research scope, rather than the project approach.
- The approach is sound and was clearly communicated. Jeff clearly laid out the timeliness and rationale for conducting this analysis. The data now exists in large enough volume to do this type of analysis. And other stakeholders are looking to CA for precedent. Some of the review time was spend discussing program items, rather than research approach, but that is necessary context. Some of the questions re how R-PACE works is relevant, though, because they could inform research questions*. Additionally, more time was spent on research question #1, than on the energy use analysis, which will come later. His supplemental report, one of the milestones, released at the time of BTO provided additional context, and was helpful.
- *In previous years, BTO peer review also scored Project Relevance, but was not included in weighted average. This project would have scored well on project relevance, and is an opportunity to discuss consumer protection.

- While data and analysis useful, it is not clear how widely it can influence market

B. Impact

Assuming that the ***project-specific goals*** are met, this project was rated **3.33** for the degree to which the project is ***expected to*** contribute to ***program goal(s)*.**

- The project specific goals will contribute to the program goals and, as with utility incentive programs, these types of program evaluations are necessary to see how much energy has been saved per dollar spent.

- In addition to project goals, this project directly contributes to BTO's program goals. Specifically, the project supports 3 of the BTO strategies, including: 1) Validate energy performance of targeted building technologies and improvements in real-world homes 2) Research, validate, and facilitate learning and leadership opportunities that result in new strategies and practices in residential energy efficiency 3)Support research needed for zero energy buildings.
- Additionally, California Energy Commission's involvement is indicative of project impact. Other states, PUCs and utilities are watching CA.

- Focuses on existing home improvement which is necessary to achieve program goals

C. Progress

Based on current project efforts, the project was rated **3.00** for the degree to which the project has met ***project-specific goals*.**

- Based on the project schedule and the progress to date the project seems to be on track.

- The project has completed its milestone deliverable of report released assessing solar deployment. The project summarized results toward answering its first research question re whether R-PACE programs are driving deployment of energy efficiency and solar. It will be important to report energy efficiency impacts vs solar.

- Good progress to date

D. Collaboration and Coordination

This project was rated **3.00** for the degree to which the project staff demonstrates strategic collaboration or coordination with relevant stakeholders.

- The project has the cooperation from the CEC and also the major IOUs in the state in addition to an energy independence program.

- Jeff mentioned that contractors are the primary drivers of adoption. Therefore, contractors should also be an important stakeholder to engage. One reviewer asked about stakeholder engagement to the real estate community: REALTORS and appraisers. Another reviewer inquired about consumer protection. Recommend future additional stakeholder engagement to address consumer protection and risk.

- Excellent California-based stakeholder involvement, but little stakeholder involvement outside of California

E. Remaining Project Work

This project was rated **3.00** for the degree to which the project has logically planned remaining work to meet the ***project-specific goals*.**

- Collecting billing data is always problematic for these studies and can extend the time line for completion of the project. Hopefully this is accounted for in the project time line.

- Data collection & cleaning is time consuming with energy use data. The researchers laid out their progress with data collection and their approach for analysis. I'll be interested in the results of efficiency v solar.
- For future, I am particularly interested in seeing longer term studies of overall costs for R-PACE, consumer experience, and the quantification of NEBs thru increased home value, increased comfort, resiliency, stabilization of household expenses thru reduced energy costs, and particularly the impacts on low-to-moderate income communities.

- Clear plan, but no milestones in last 18 months of project

F. Additional Comments and Recommendations

1) **Project Strengths**

- Assessing program impact is necessary for finance programs because there is really no way to determine impact. If I understand the program correctly I believe that reviewing before and after billing data makes the most sense as this would provide a consistent method of comparison.

- Experienced project team, reasonable scope of work, clear project plan, and has met project milestones/deliverables. The involvement of CEC is also good. These studies should be relevant for other PUCs and utilities.

- Focus on existing home improvement financing

2) **Project Weaknesses**

- The weaknesses that I see in this program are:
    - 1. The state that this is being conducted in that may not provide a true representation of the impact of the program

  - 2. How the data will be normalized, or if it will, to account for occupants living in the house. If the sample size is the 90,000 pace participants this may be a non-issue but I think should be addressed in the reporting.

- No technical project specific weaknesses identified.
- This reviewer does not have history with the project scoping work done prior. Consider stakeholder engagement with real estate community to understand what research questions their constituency would need in order to build support for R-PACE.

- Too California centric.

3) **Recommendations**

- Would recommend replicating the study in other less progressive states where there the program financed several upgrades. For the future you could also make providing utility bills a program requirement so that you could have ongoing evaluation of the program.

- See previous comments re consumer protection and stakeholder engagement. Addressing consumer protection issues could be outside the scope of this project, and subject of future research. Broadened stakeholder engagement could be included.
- I'm looking forward to more work in this area because there's not much data and evidence available yet.

- Expand energy usage data analysis outside of California.

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DOE/EE-1874A • October 2018