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Building Technologies Office

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

2019 National Laboratory Call for Core and Competed Activities
DE-LC-000L070

Table 1. Dates for National Laboratory Call

Key Dates	
Lab Call Released	4/5/2019
Informational Webinar	4/11/19
Full Proposals Due	5/10/2019
Presentations/Rebuttals Due	5/31/2019
Merit Review Meetings	Week of 6/3/2019
Notification of Decisions	Summer 2019

Table 2. Summary Information for the Call

Summary Information	
Purpose	Seeking submission of proposals from specific DOE/NNSA Federally Funded Research and Development Centers (FFRDCs), and specific National Laboratories to receive funding for projects under the Building Technologies Office (BTO) multiyear lab funding plan for fiscal years 2020, 2021, and 2022
Means of Submission	Proposals to this lab call must be submitted to EERE Exchange by the dates listed above
Questions	Questions about the lab call and the submission process may be directed to: BTOCoreLabCall@ee.doe.gov

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Informational Webinar:

The Building Technologies Office (BTO) will be hosting a webinar on Thursday, April 11, beginning at 3:00 PM (EDT). Please use the following link to register for attendance: https://doe.webex.com/doe/onstage/g.php?MTID=e37ce8d209d9cdd5f9822c47d63c61c98

After your request has been approved, you'll receive instructions for joining the meeting. The webinar will be recorded and made available on the BTO website.

Merit Review Meetings:

Merit Review panels will take place on the week of June 3, 2019. Panels for the Sensors & Controls and Solid State Lighting topics will take place in Washington, DC. Applicants for these topics are expected to present to reviewers in person. Panels for the Indoor Air Quality, Advanced Residential Ventilation Technologies and Building Energy Modeling topics will be held via webinar.

Modifications:

Mod. No.	Date	Description of Modification
001	4-15-2019	a) Provided additional guidance for proposal submission in Appendix B.3

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Introduction

This Lab Call is being issued by the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office (BTO). This section describes the overall goals of BTO and the types of projects that are being solicited for funding support through this Lab Call.

The DOE mission is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions. Powering our homes, offices, schools, hospitals, restaurants, and stores consumes a lot of energy. Residential and commercial buildings account for approximately 40% of the nation's total energy demand – greater than that for either industry (32%) or transportation (29%) – and about 75% of all electricity use (and even more of peak power demand). The resulting annual national energy bill for buildings totals more than $380 billion.

Improving the energy efficiency of buildings reduces energy costs in homes and commercial buildings. Many of the nation's more than 118 million homes and 5.6 million commercial buildings were constructed before 1980—prior to the existence of today's efficient products and building construction practices. By saving money on energy costs there is more money available to flow into other sectors of the economy. Unlocking the energy savings of these buildings through efficiency improvements represents a significant economic opportunity.

Improving the energy efficiency of buildings alleviates pressure on our electric grid and extends our energy resources as we diversify to greater use of an all-of-the-above energy supply strategy. This helps to support a reliable energy system well into the future. Improving the efficiency of the nation's buildings also can play a major role in reducing pollution, as U.S. buildings account for a significant portion of man-made emissions of carbon dioxide, nitrogen oxides, and sulfur dioxide.

BTO leads a network of national laboratory, university, small business, and industry partners to develop innovative, cost-effective energy saving solutions—better products, better new homes, better ways to improve older homes, and better buildings in which we live and work. The United States has made significant progress in improving building energy efficiency over the last 30 to 40 years, due in part to the successful efforts of BTO and its partners. The Office's funded research has contributed to significant improvement in building energy efficiency including solid-state lighting, building energy-saving windows modeling, heat pump water heaters, and a number of consumer-facing tools.

While BTO works to improve the energy efficiency of homes and buildings, BTO and successful applicants must take steps in their research and development activities to ensure that energy-efficiency solutions do not sacrifice the comfort of building occupants or the performance of labor-saving household appliances, products, devices, and equipment. To do so, BTO focuses on accelerating the pace of innovation in technologies for both new and existing buildings. BTO invests in research and development (R&D) to deliver cost effective products and solutions that will improve energy productivity and enhance the services provided to building occupants. BTO's research also includes early-stage R&D on grid-interactive efficient building (GEB) technologies and approaches. Through GEB R&D, BTO enables industry and others to develop and deploy truly "smart" buildings capable of connecting with the power grid in new and increasingly adaptive manners.

This leads to overall energy system affordability, efficiency, reliability, resilience and environmental performance.

Lab Call Merit Review

The Department of Energy's Building Technologies Office (BTO) is seeking multi-year project proposals from national laboratories ("Labs") for activities to incorporate into the Annual Operating Plans (AOPs). Updates to the Lab Call will be announced on EERE Exchange at https://eere-exchange.energy.gov/.

For some topics, only specific DOE/NNSA Federally Funded Research and Development Centers (FFRDCs) and specific DOE Government-Operated Government-Owned laboratories (GOGOs) are eligible to apply for funding as a prime recipient. All DOE laboratories are listed on http://energy.gov/offices under the heading "Labs and Technology Centers." Only proposals for which the identified DOE national laboratory is the prime applicant will be considered for funding. Prime recipients are encouraged to form teams with other labs and to include other entities as sub-recipients.

Topics of Interest

Specific topics and subtopics of interest are described in Appendices A and B, which include identified lead project performers (where applicable), topic descriptions, anticipated deliverables, and budget guidance. A summary of topics of interest is included in Table 3.

For topics in Appendix A, the lead project's performers have already been identified and only one proposal will be accepted for each topic or subtopic. Appendix A project perfomers are permitted to negotiate a detailed work plan with BTO prior to submission and will follow a multi-step process:

1. Negotiate detailed work plan with BTO.
2. Submit draft work plan for external review.
3. Respond to reviewers' initial comments. Up to three pages of responses are allowed. Applicants have three business days to deliver this document after receiving the initial comments.
4. Submit a PowerPoint slide deck prior to the Merit Review (following reviewer's initial comments).
5. Present orally, using the submitted slide deck, at the BTO Merit Review or via webinar.
6. Finalize a detailed work plan with BTO to address feedback obtained from reviewers' comments.

For topics in Appendix B, the lead projects performers have not been identified and any DOE FFRDC or GOGO is eligible to apply. Applicants to Appendix B topics will follow a multi-step process:

1. Submit project proposal for external review.
2. Respond to reviewers' initial comments. Up to three pages of responses are allowed. Applicants will have three business days to deliver this document after receiving the initial comments.
3. Submit a PowerPoint slide deck prior to the Merit Review (following reviewer's initial comments).
4. The most promising applicants will present orally, using the submitted slide deck, at the Merit Review or via webinar.
5. Selected applicants develop a detailed work plan with BTO.

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Table 3. List of Topics of Interest

R&D Activity	Topics
Appendix A: Core R&D Topics	**A.1. Sensors & Controls:** A.1.1. Sensor and Meter Data Collection and Integration for Building Applications A.1.2. Automated Fault Detection and Diagnostics (AFDD) A.1.3. Predictive and Adaptive Controls Testing and Validation **A.2. Indoor Air Quality** A.2.1. Multi-Zone Building Ventilation A.2.2. Air Sealing and Ventilation Research for Residential Retrofits
Appendix B: Competed R&D Topics	**B.1. Building Energy Modeling:** B.1.1. Empirical Validation of Energy Simulation B.1.2. A Simplified Performance Rating Method for (Small) Commercial Buildings **B.2. Advanced Residential Ventilation Technologies** B.2.1. Advanced Residential Ventilation Technologies **B.3. Solid State Lighting** B.3.1. Open Lighting Topic

Written Proposals

Requirements for written proposals are described in Appendix C and D and are due by the "Full Proposals Due" date given in Table 1. The proposals will be reviewed by external reviewers, who will provide an initial evaluation of the proposals based on the review criteria defined in Appendix E. The evaluators' comments, in turn, will be made available to the applicants in EERE Exchange at https://eere-exchange.energy.gov/ so that applicants can take those comments into account as they prepare their PowerPoint slide deck for the oral presentations to reviewers.

Reports & Studies

If project work includes public-facing reports or studies, either initially or during the course of the project period of performance, the project Principal Investigator (PI) is required to communicate progress regularly with BTO staff, keeping them up to date on any changes in project direction, scope, or anticipated findings. Topics will be indicated in final decisions, and will remain subject to change over the life of projects.

Anticipated Resources, Funding Decisions, and Next Steps

BTO has provided guidance on the budget for project proposals. Proposals will be evaluated based on merit; the result of the external review following the criteria in Appendix E; and the likelihood of meeting the project targets, Program and overall BTO goals. BTO will make funding decisions, according to the schedule on the first page, that are informed by the written comments and scores provided by the external review committees, their scores in EERE Exchange, and other policy factors. BTO may choose to fund all, some, or none of the

applicants. BTO may also choose to fund only a portion of a proposed project. After funding decisions are announced, successful applicants will be asked to develop corresponding multi-year Statements of Work (SOWs) based on their proposals, feedback from the external reviewers, and feedback from BTO.

BTO expects to award up to $36 million over 3 years from this Lab Call, subject to Congressional direction and the availability of appropriated funds. The overall probability of selection will vary from topic to topic. Consistent with the EERE policy guidance, we encourage Labs to propose more high-quality ideas than BTO could necessarily fund for topics that do not feature restricted eligibility. EERE reserves the right to initiate projects not originally selected from the Lab Call at any time during the fiscal year due to any number of unforeseen changes (e.g. policy, mission priority, performance-related management decisions) that result in additional funding availability.

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APPENDIX A. Core R&D Topics

A.1. Sensors and Controls

Lab Consortium: Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory

Note that for some subtopics, a subset of the lab consortium has been identified. However, additional collaboration is encouraged if the team deems it useful to advancing the work objectives.

The HVAC control industry is undergoing a transition from reactive strategies designed to meet short-term thermal and ventilation loads to optimized strategies that can minimize energy use while meeting occupant comfort objectives. BTO seeks to accelerate this transition via sensors and controls (S&C) R&D. Achievement of BTO's S&C R&D could reduce primary energy use by 1.5 quads in 2030 and 3.8 quads in 2050,[1] equivalent to roughly 10% of total buildings sector energy consumption in 2017. These strategies are also available and necessary for implementing flexible electrical load shedding and shifting strategies that allow building technologies to provide grid services.

To meet these goals, BTO's S&C subprogram targets advances in both sensing and controls. In sensing, BTO focuses on reducing the cost, improving accuracy, and developing new sensing modalities (e.g., occupancy counting, and building equipment health monitoring). In controls, BTO focuses on developing algorithms that optimize building performance over time horizons of hours and days and at multiple spatial scales (e.g., occupant, zone, whole-building, campus). These algorithms incorporate predictions (e.g., occupancy, weather) and use sensing to continually update and refine their internal "model" of the building and its performance. The S&C sub-program also targets the data and workflow challenges that limit adoption and correct implementation at scale. These efforts include long-term software engine improvements that support controls development and evaluation and development of testing methods and frameworks, and that enable apples-to-apples algorithm comparisons and benchmarks, as well as performance validation in the field, to increase confidence in the technologies among building professionals and decision makers.

The S&C subprogram collaborates with the Building Energy Modeling (BEM) subprogram and the CBI and RBI programs through a national laboratory consortium. This call targets these national laboratory consortium-led activities, which began in FY17-19. The call consists of several topics, each with subtopics. A separate proposal or work plan should be submitted for each subtopic. Only one work plan will be accepted for each subtopic.

The proposed technical work plan for each topic/subtopic area must include a strategy for outreach to and feedback from appropriate stakeholders including researchers, vendors, engineers, and building owners and operators to ensure that the tools developed by the consortium will be utilized by the broader community and ultimately transition, where appropriate, to external, non-BTO partners. Projects involving the collection and curation of datasets for public use should ensure consistent and standardized naming conventions and schema are used and include a data repository and dissemination strategy.

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[1] Sofos, M., Langevin, J.T. (2018). "Laying Down the Foundation: An R&D Roadmap for Energy Savings through Advancements in Smart Building Technologies," 2018 ACEEE Summer Study on Energy Efficiency in Buildings.

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Topics:

A.1.1. Sensor and Meter Data Collection and Integration for Building Applications

A.1.1.1. Benchmark Dataset Collection and Curation.

The goal of this subtopic is to collect and curate high-resolution, well-calibrated time series of building operational and indoor/outdoor environmental data. These datasets will be used to identify the parameters and the temporal and spatial resolutions required to support a given use case or application (e.g., nonintrusive load monitoring, virtual sensing, building energy model calibration, load forecasting, performance benchmarking at the whole-building and sub-system levels, control optimization, fault detection). This subtopic builds on an initial FY19 scoping effort that has focused on characterizing potential use cases for buildings datasets, defining an appropriate data infrastructure, inventorying existing buildings datasets to identify resources that can be used/shared, and developing an experimental plan for the subsequent multiyear effort targeted through this sub-topic. The work plan submitted should include engagement with IEA Annex 70 that complements efforts already underway through the Annex, as well as a plan for collaboration across outputs from relevant and related BTO projects.

This project will be jointly managed by BTO's ET, CBI, and RBI programs.

Period of Performance: 3 years; Max. Budget: $1,250K/year
BTO Point of Contact: Amir.Roth@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.1.2. Sensor Impact Evaluation and Verification.

The objective of this subtopic is to evaluate and verify the impact of different sensor types on building systems (e.g., HVAC) and control co-design, as well as automated fault detection & diagnostics (AFDD) techniques. This includes identification of the sensor types and locations with the highest impacts; verification of reliability, accuracy, and long-term performance; and evaluation of different monitoring approaches (e.g., nonintrusive load monitoring, air-flow sensors) to improve understanding of the trade-offs necessary for optimization, based on the building type and configuration as well as the application of interest. The work plan submitted should include interrelated tasks with other topic proposals to leverage applicable outputs. Developments from this project will also integrate into the workplans for related projects.

This project will be jointly managed by BTO's ET and CBI programs.

Period of Performance: 3 years; Max. Budget: $750K/year
BTO Point of Contact: Erika.Gupta@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.1.3. Integrating Sensor Data with Physics-Based Models.

Lead Lab: Lawrence Berkeley National Laboratory

Physics-based energy simulation has many applications in building energy efficiency, including building design and operations, codes development and efficiency program administration. Building energy models can benefit from increasingly available sensor data to both enhance online applications and inform traditional offline applications. Previous work in this area has demonstrated that zone

temperature data streams available from connected thermostats can be used—in conjunction with modified simulation algorithms—to directly derive parameters that are otherwise difficult to obtain, such as zone infiltration rates and internal thermal mass. The objective of this subtopic is to develop sensor data and modeling fusion techniques for evaluating and quantifying energy flexibility and resilience at both the system and whole-building levels, as well as to continue to address challenges in traditional building energy modeling applications.

This project will be jointly managed by BTO's ET and CBI programs.

Period of Performance: 3 years; Max. Budget: $300K/year
BTO Point of Contact: Amir.Roth@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.2. Automated Fault Detection and Diagnostics (AFDD)

A.1.2.1. Evaluation of Fault Prevalence.

In aggregate, faults in U.S. commercial buildings alone have been estimated to waste 0.7 quads of energy annually (worth nearly $14 billion).[2] However, this fault impact estimate is based on uncertain estimates of fault prevalence and severity as found in the field. The lack of reliable fault prevalence data is a key barrier to developing both better AFDD algorithms and performance metrics. Lack of fault prevalence data also impairs the ability of researchers and developers to focus on modeling, detecting, and diagnosing the most important faults. The objective of this subtopic is to expand an initial FY19 analysis of the prevalence of the most common fault types in commercial buildings and to obtain reliable field estimates of fault prevalence, as well as to assess the impact of the most prevalent fault types. The work plan should include a strategy for coordination with recent RBI Building America awardees who are investigating fault prevalence in the residential sector.[3]

This project will be jointly managed by BTO's ET and RBI programs.

Period of Performance: 3 years; Max. Budget: $500K/year
BTO Points of Contact: Erika.Gupta@ee.doe.gov and Dale.Hoffmeyer@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.2.2. Fault Prioritization Methods and Curated Datasets.

The objective of this subtopic is to establish expected performance for emerging and commercialized AFDD solutions through curation of operational fault datasets that can be used for benchmarking along with a methodology for do-it-yourself testing. This project will extend the initially curated

[2] Roth, K., Westphalen, D., Feng, M., Llana, P., Quartararo, L. (2005). "Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential," TIAX LLC.

[3] https://www.energy.gov/eere/buildings/articles/department-energy-invests-115-million-building-america-industry-partnerships

datasets for faults in AHU-VAV systems and RTUs to other HVAC systems. The initial methodology developed to evaluate performance will also be expanded and applied to available AFDD solutions to generate additional case studies. Areas of additional interest for this subtopic include assessment of the impact of different procedural choices on evaluation outcomes, and development of prioritization metrics and methods to quantify and characterize faults by their impact.

Results from Topic A.1.1 should be leveraged where applicable to identify combinations of sensor and meter data with the highest impacts. The work plan should include coordination on the outcomes of relevant and related projects. An evaluation of the utilization of the BOPTEST framework should also be explored.

This project will be jointly managed by BTO's ET and CBI programs.

Period of Performance: 3 years; Max. Budget: $600K/year
BTO Point of Contact: Erika.Gupta@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.2.3. Technical Specification of Embedded AFDD Capabilities for Residential Buildings.
Performance, cost, and functionality specifications are needed for the purposes of supporting a challenge or bulk purchase. While AFDD capabilities are featured in a variety of products, higher-functioning sensors and notification systems are not found in most HVAC systems. Embedded AFDD in HVAC systems could be particularly useful for applications with limited operations and maintenance budgets (e.g., low-income housing). This project will focus on setting specifications for both detection and diagnostics in a variety of different residential HVAC – and potentially water heating – equipment, with the intent of achieving higher energy savings and improved performance at an affordable price point.

This project will be managed by BTO's RBI program.

Period of Performance: 1 year; Max. Budget: $300K/year
BTO Point of Contact: Dale.Hoffmeyer@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.3. Predictive and Adaptive Controls Testing and Validation
A.1.3.1 Building Optimization Testing (BOPTEST) Framework.
Lead Labs: Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory and Pacific Northwest National Laboratory

The Building Operation Testing (BOPTEST) framework, currently under development, consists of a series of test procedures, benchmark test cases, performance metrics, and a standard emulation environment that can be used to validate, compare, and debug advanced control strategies. The objective of BOPTEST is to benchmark the expected performance of novel advanced control strategies relative to a range of state-of-the-art solutions, to centralize information, and to motivate competition through a common testing framework. BOPTEST leverages recent innovations in building performance simulation, specifically the use of the Modelica and Functional Mockup Interface (FMI) standards to couple user-defined control strategies to HVAC systems via standards

APIs. Ultimately, BOPTEST will support the research community with a test case sandboxand industry with a performance verification framework. With the initial framework specification completed and first use case scenario that combines an emulator model and key performance indicator specification tested in FY19, the focus of FY20-22 will be on developing multiple representative test cases, using existing advanced control strategies to demonstrate the test methodology on the test cases in order to validate the performance characterization methodology and framework, and disseminating the completed methodology.

The project will continue to be conducted in collaboration with IBPSA Project 1 (https://ibpsa.github.io/project1), a five-year international project focused on next-generation computational tools for building and urban systems based on the open-source Modelica and FMI standards.

This project will be managed by BTO's ET program.

Period of Performance: 3 years; Max. Budget: $750K/year
BTO Point of Contact: Amir.Roth@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.3.2. OpenBuildingControl (OBC).
Lead Labs: Lawrence Berkeley National Laboratory and Pacific Northwest National Laboratory

OpenBuildingControl (OBC) is a platform for design and specification of HVAC control sequences that interoperates with both whole-building energy simulation and automated control implementation and testing workflows. The objective of OBC is to unify control design, evaluation, and optimization via whole-building energy simulation with control implementation, to eliminate the manual translation steps currently associated with HVAC control implementation and reduce errors, effort and costs. Control design, evaluation, implementation, and commissioning is digitized and automated by leveraging the Control Description Language (CDL), an open international standard specification language for control sequences. An initial case study implementing ASHRAE Guideline 36 "High Performance Sequences of Operation for HVAC Systems" using CDL demonstrated 30% energy savings. There is now a need for additional case studies that can verify the robustness of these savings. A prototype translator that would facilitate the integration of the CDL into control execution platforms is also currently under development. In addition to case studies of OBC, the focus in FY20-22 will be on supporting the unification of OBC with Spawn-of-EnergyPlus, as well as the use of CDL as a reference implementation and basis for a tool that could be used to select sequences for specification of control design.

This project will be jointly managed by BTO's ET and CBI programs.

Period of Performance: 3 years; Max. Budget: $750K/year
BTO Point of Contact: Amir.Roth@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.1.3.3. Co-Design of HVAC systems, controls, and sensing.

HVAC systems are currently designed to meet peak loads and avoid liability. Control strategies for energy efficiency are designed and added after the fact. Sensing to support system operation is also added after the fact and usually not "designed" in any real sense. This nonintegrated approach limits both performance and reliability. The objective of this sub-topic is to develop a methodology and framework for co-designing (i.e., simultaneously optimizing) HVAC system configuration (including equipment capacity and performance), control strategies, and sensor configuration including modality, spatial and temporal resolution, accuracy, placement, and redundancy for different HVAC system types and different control applications including high-performance control (using either rules or models), fault detection and diagnostics, and load shedding and shifting for grid response. The work plan should incorporate standardized (BEDES or Haystack-compliant) datasets from other relevant projects as applicable, develop simulation protocols and workflows using either traditional or next-generation tools as appropriate, and perform physical testing and demonstration as necessary.

This project will be jointly managed by BTO's ET and CBI programs.

Period of Performance: 3 years; Max. Budget: $750K/year
BTO Point of Contact: Erika.Gupta@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.2. Indoor Air Quality

Lead Lab: Lawrence Berkeley National Laboratory

Air tightness of a building envelope is an important factor affecting home energy use, because leaky homes require more energy for heating and cooling to maintain thermal comfort. Approximately one-third of the energy required for heating and cooling typical homes is due to uncontrolled infiltration of outdoor air into the home.[4] RBI estimates the technical potential of reducing air infiltration in all homes from current practice (~5 ACH50[5]) to BTO target level (1 ACH50) would be more than 3 quads per year in energy savings.[6] Although modern codes range from 3 to 7 ACH50, we know the 1 ACH50 target is feasible. An increasing number of new homes are being built to air-tightness levels at or below 1 ACH50, which suggests that air sealing at these advanced levels can be done cost effectively. Furthermore, some homes built today are significantly tighter. For example, the air-tightness limit for homes built to the voluntary Passive House standard is <0.6 ACH50.

[4] Several studies estimate from 30% to 50%, including Orme, M. 2001 "Estimates of the energy impact of ventilation and associated financial expenditures". Energy and Buildings 33, and Sherman, M.H. and Matson, N. 1993. "Ventilation-Energy Liabilities in US Dwellings". Proceedings of the 14th AIVC Conference. Air Infiltration and Ventilation Center.

[5] ACH50 is one of the standard measures of house air-tightness in the U.S. and refers to Air Changes per Hour at 50 Pascals of pressure difference between inside and outside conditions, as measured with a blower door.

[6] BTO internal analysis using BTO's Scout tool.

Although there is still a wide range of measured air-tightness in new homes built today,[7] they are on average about twice as tight as homes built before 1980.[8] In addition, cost-effective air sealing approaches continue to be adopted at increasing rates, due to competition over home performance and the availability of new materials and construction processes.

While BTO and others have investigated IAQ challenges in new single family home construction, and identified effective approaches to reducing such risks in this building sector, more research is needed to understand IAQ problems in multi-zone buildings, i.e., multifamily residential buildings and commercial buildings with residential spaces, as well as IAQ challenges that may occur in retrofitted buildings. This research is needed to inform R&D that in turn will lead to affordable, effective IAQ solutions in these building sectors.

Although multifamily dwellings have many of the same IAQ challenges as single family homes, multifamily buildings also present some unique issues, including pollutant transport between dwelling units and adjacent common areas, and the interactions between dwelling unit air-tightness ("compartmentalization") and multi-zone ventilation system configurations. In addition, higher occupant densities, significantly larger stack effects (for tall buildings), and mixed uses spaces (e.g., restaurants and laundromats) complicate multifamily buildings' IAQ conditions. Many commercial building space types, such as hospitality, dormitories, and mixed use buildings, face similar challenges,

Building envelope and HVAC system retrofits can create further unique IAQ challenges, including changes in heat, air, and moisture flows through building assemblies, which can substantially impact the ability of the assemblies to dry out after wetting. Such retrofits also present ventilation system design and installation challenges, particularly how to move fresh air to occupied spaces in existing buildings that have been air sealed to improve energy efficiency.

Remaining IAQ challenges include: 1) few to no affordable ventilation and IAQ solutions for multifamily dwellings; 2) few affordable ventilation and IAQ solutions for achieving acceptable IAQ when an existing building has been sealed for energy efficiency via a retrofit; and, 3) mechanical ventilation systems and equipment having very limited control capabilities (e.g., schedule-based controls only) and lacking fault detection capabilities.

For any of the following topics, applicants should address the building types described above, and focus on those research questions that are likely to have the greatest energy savings impact. Applicants should consider the likelihood that research will lead to solutions or technologies that will be broadly applied across different building types and locations, with no reduction in comfort, productivity or affordability.

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[7] DOE Building Energy Codes Program field studies include measured air-tightness data for homes built to recent codes: https://www.energycodes.gov/compliance/energy-code-field-studies

[8] Chan, W. R., Joh, J., & Sherman, M. (2012). Analysis of Air Leakage Measurements from Residential Diagnostics Database (No. LBNL-5967E). Berkeley, CA: Lawrence Berkeley National Laboratory: http://homes.lbl.gov/sites/all/files/lbnl-5967e.pdf

http://homes.lbl.gov/sites/all/files/lbnl-5967e.pdf

Topics:

A.2.1. Multi-Zone Building Ventilation

This topic seeks research that builds upon BTO's previous R&D on IAQ challenges and solutions for new single family homes, with a new focus on IAQ challenges unique to multi-zone buildings, specifically multifamily (and similar commercial) buildings. Successful applications will identify effective methods for addressing the complications that occur in multifamily resident buildings (as discussed earlier). Areas of interest include but are not limited to the following:

- Validation of energy and cost savings from improved ventilation strategies for multifamily dwellings.
- Optimal approaches for addressing both energy and IAQ goals in multifamily new and retrofitted buildings in varied climates.
- Improved methods and guidance for addressing IAQ needs of different usage areas (e.g., common spaces, corridors) and other challenges (e.g., local exhaust).
- Comparisons of exhaust, supply, and balanced approaches to ventilation.
- Field measurements of inside/outside airflows and simulation/analysis as appropriate.

Period of Performance: 3 years; Max. Budget: $500K/year
BTO Point of Contact: Eric.Werling@ee.doe.gov
Merit Review Presentation Time: 20 minutes

A.2.2. Air Sealing and Ventilation Research for Residential Retrofits.

Building on BTO's research on new homes, this topic calls for research and development on new, affordable, integrated retrofit approaches that save energy and reduce cost, while maintaining/improving IAQ and avoiding moisture problems.

Areas of interest include but are not limited to the following:

- Comparison of IAQ, energy use, peak demand, and installed cost of various IAQ approaches applicable to retrofitted buildings, such as air cleaning/filtration/humidity control, balanced vs. unbalanced mechanical ventilation, smart ventilation controls using occupancy or contaminant sensing, smart ventilation, and other IAQ-related technologies, e.g., automated range hoods. May require development of new methods for uniformly evaluating IAQ performance of various solutions.
- Simplified ventilation system installation & commissioning methods appropriate for the current workforce, e.g., one-shot simple installs. For example, effective solutions may include automatic/built-in commissioning and fault detection that make installed performance verification quick, easy, and cheap.
- Best practices for addressing burner and cooking pollutants when retrofitting existing homes that do not have ducting from kitchen to the outdoors.
- Valuation of health risk reduction benefits from retrofit measures, and/or comprehensive deep energy retrofits.

- Development and/or assessment of alternatives to mechanical ventilation to reduce cost, reduce energy use, and maintain good IAQ.

  Period of Performance: 3 years; Max. Budget: $500K/year
  BTO Point of Contact: Eric.Werling@ee.doe.gov
  Merit Review Presentation Time: 20 minutes

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APPENDIX B. Competed R&D Topics

B.1. Building Energy Modeling

Whole Building Energy Modeling (BEM) is a versatile, multipurpose tool that is used in new building and retrofit design, building-energy auditing, code compliance, building energy rating and certification, qualification for tax credits and utility incentives, and real-time building control. BEM is also used in large-scale analyses to inform energy efficiency policy, code development, and program design.

BTO has supported research, development, and deployment of BEM—and has itself been an active user of BEM—since the 1970s. BTO's program currently revolves around the development of two significant BEM software packages: the EnergyPlus engine and the OpenStudio software development kit (SDK) and application. BTO distributes EnergyPlus and OpenStudio under a commercial-friendly non-exclusive open-source license. BTO encourages companies to embed the software into applications and services, add features and content, provide commercial training and support, and generally focus on addressing the specific needs of a diverse set of BEM user communities. BTO is committed to supporting EnergyPlus and OpenStudio long-term to provide certainty to commercial vendors and their clients. The transparency and impartiality conferred by open-source and by EnergyPlus's comprehensive documentation is also important for some use cases, especially ones supporting codes and standards. BTO complements these flagship activities with core activities in testing and validation as well as research and development of next-generation simulation technologies and platforms. Information about BTO's BEM program and its project portfolio can be found at https://energy.gov/eere/buildings/building-energy-modeling.

Topics:

B. 1.1. Empirical Validation of Energy Simulation

One barrier to the adoption of EnergyPlus and BEM in general is the perception that BEM is not sufficiently "accurate" to be useful. Such a perception ignores that there is a difference between inaccuracy and input uncertainty; that many BEM applications are designed to cancel out input uncertainty; and that models can still be useful without being perfectly accurate. Nonetheless, the most direct way to rebut this perception is to demonstrate that BEM *is* accurate within acceptable tolerances. Such demonstrations have additional real benefits because they establish the boundaries of the effects of input uncertainty, as well as identify areas in which BEM is insufficiently accurate and in which additional research is needed.

In the period covering fiscal years 2016 to 2019, BTO funded a project that used well-characterized highly instrumented facilities at LBNL (FLEXLAB) and ORNL (FRP) to conduct several "validation grade" experiments, the descriptions and results of which could be published as tests in ASHRAE Standard 140. Although none of the tests has yet gone through the complete 140 process (which itself usually takes two to three years), several such tests covering seasonal heating and cooling loads are "in the pipeline."

BTO requests proposals for additional empirical tests focusing on different sets of building physics phenomena, different HVAC systems, and HVAC controls, which play an obvious and significant role

in energy performance and are interpreted and implemented by BEM engines in various ways. The work may use purpose-built test facilities at national labs like FLEXLAB and FRP, but is not limited to such facilities, as test facilities in other locations can be used. In some cases, e.g., for certain types of experiments, "real" buildings—including occupied buildings—may be used, provided characterization and instrumentation of sufficient quality is assured. The awardee is expected to work closely with ASHRAE Standing Special Projects Committee 140 to ensure suitability of the test apparatus and to facilitate incorporation of test results into the standard.

Period of Performance: 3 years; Max. Budget: $1,200K/year; number of awards: up to 2
BTO Point of Contact: Amir.Roth@ee.doe.gov
Merit Review Presentation Time: 50 minutes

B.1.2. A Simplified Performance Rating Method for (Small) Commercial Buildings

Performance Rating Methods (PRMs) use BEM to compare the energy performance of a building to that of a variant of the same building modified in controlled prescriptive ways; this variant is referred to as the "baseline" and typically represents minimum prescriptive code requirements. PRMs include ASHRAE Standard 90.1 Energy Cost Budget (ECB) and Performance Rating Method (PRM), and California Title 24's Alternative Calculation Method (ACM), while RESNET's Energy Rating Index (ERI) is a residential PRM. PRMs provide a flexible option for code compliance, allowing buildings to compensate for a failure to meet requirements in some areas (e.g., window-wall ratio) by exceeding requirements in others (e.g., lighting and HVAC). PRMs are also used as the basis of green certificate and energy efficiency incentive programs, with points and payments tied to calculated percentage improvements above code or program minimum levels. Historically, the creation of a building model and corresponding PRM baseline has consumed significant modeling—and model review—resources. As a result, PRM-based compliance paths and certificate and incentive programs have primarily been used in large commercial building projects with large budgets. Recently, several vendors have automated the creation of the baseline model from the model of the proposed building, reducing the time, effort and cost associated with PRM-based calculations and lowering the barriers to access PRM-based programs. However, the creation of the proposed building model is still a manual process and the level of detail and fidelity required of a proposed building model is still too onerous for many building projects.

BTO seeks proposals for pre-normative research and subsequent normative activities that would lead to the development and codification of a simplified PRM with reduced requirements for proposed building models that would be suitable and accessible to small commercial building projects with small budgets. The simplified PRM should target whole-building performance metrics (e.g., annual site or source energy use) and consider input simplifications in all aspects of BEM, including schedules, geometry and constructions, space planning and zoning, HVAC systems, lighting systems, hot water systems, plug and process loads, on-site renewables, and control systems. The simplified PRM should include parameters that specify the types of buildings and projects for which it may be used (e.g., buildings under 50,000 square feet, buildings without commercial kitchens, etc.). The awardee is expected to involve stakeholders in development, with energy efficiency program partners to plan and conduct pilot studies, and potentially to work with ASHRAE and other standards bodies to facilitate consideration of codification, and with energy efficiency program partners to plan and conduct pilot studies.

Period of Performance: 3 years; Max. Budget: $200K/year; number of awards: 1
BTO Point of Contact: Amir.Roth@ee.doe.gov
Merit Review Presentation Time: 25 minutes

B.2. Advanced Residential Ventilation Technologies

Mechanical ventilation systems and equipment available today for residential buildings have very limited control technologies (e.g., schedule-based controls only) and lack fault detection capabilities. Furthermore, ventilation equipment, other than standard exhaust fans, is perceived in the market as being too expensive. As BTO works toward reaching its air-tightness goal for residential buildings (1 ACH50), as described in Section A.2 above, cheaper, more effective and more flexible ventilation technologies are needed.

For this topic, applicants should focus on those advanced ventilation technologies that are likely to have the greatest building energy savings impact, including impact on space conditioning energy use. Therefore, applicants should consider the likelihood that research will lead to solutions or technologies that will be broadly applied across different residential building types and locations.

Topic:

B.2.1. Advanced Residential Ventilation Technologies.

These "seedling" projects will focus on development of new "smart" ventilation technologies that advance the state of the art in ventilation, along with IAQ sensors and controls applications. Research proposals aimed at advancing more affordable, high-performing, energy saving solutions with broad applicability to U.S. buildings are encouraged. Proposals must include applications for single family and/or multifamily buildings, but may also consider commercial building applications. Areas of interest include but are not limited to the following:

- Smart, adaptive technologies that deliver acceptable IAQ while saving energy and/or reducing peak energy use.
- Smart kitchen exhaust technologies; improved integration of makeup air and exhaust fan controls; contaminant sensing and cleaning technologies.
- Low-cost, high-performing, easy to use/automatic, and reliable sensors for residential applications.
- Efficient dehumidification alternatives to vapor compression-based refrigeration solutions for specific climates.
- Alternatives to spray foam insulation, e.g., low-cost attic construction and ventilation approaches (including integration with attic-based HVAC systems) for better moisture control in sealed attics.

Period of Performance: 3 years; Max. Budget: $300K/year per project
BTO Point of Contact: Eric.Werling@ee.doe.gov
Merit Review Presentation Time: 30 minutes

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B.3. Solid State Lighting

BTO has the programmatic goal to develop lighting technologies with a product system efficiency of 50% with the appropriate application spectrum. To achieve this goal, BTO supports foundational lighting R&D, aiming to deliver a range of benefits across topics and activities that are not expected from the lighting industry alone. This early-stage R&D advances the understanding of underlying physical phenomena, explores new technical and fabrication approaches, reduces the development risk with new technologies, and develops understanding of application requirements that improve lighting effectiveness. At the same time, these innovative approaches to lighting improve efficiency and maximize energy savings while maintaining or even improving people's health, comfort, and productivity. Despite rapid progress in solid state lighting (SSL) technologies, there is still potential for significant advancement in performance and fundamental understanding of core lighting materials and devices, the science of lighting as a system, and frontier applications with the promise of superior services and cost savings for Americans.

At the materials and device level, ongoing innovation and breakthroughs in materials, devices, advanced fabrication processes, and integration are needed to deliver light more reliably and efficiently. In lighting science there are new questions about how to control qualities of light, such as the spectrum, intensity, orientation and frequency, for known and emerging consumer needs. As SSL technologies find uses beyond general illumination, such as in health, agriculture and information technology, there are corresponding challenges to develop enabling technologies, integrative modeling, and processes associated with new and existing performance measures.

Topics:

B.3.1. Open Lighting Topic

This is an open topic for lighting research and development proposals. Proposals for R&D to improve lighting energy efficiency at a technology readiness level of 2-4 are requested.

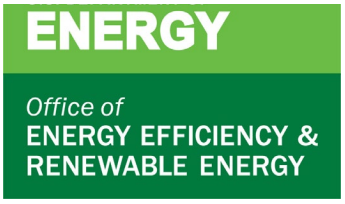
No more than three proposals should be submitted per lab. If more than three proposals are submitted only the first three received will be considered

Proposals should include and will be evaluated based on:

- The potential energy savings resulting from the work;
- The project's uniqueness to the existing DOE portfolio;
- The project's alignment to BTO and Secretarial priorities; and
- How the project aligns with, or is different from, the activities identified in the Solid State Lighting Research and Development Opportunities (RDO) document.

The top proposals will be invited to present their proposed projects and answer questions from the evaluators prior to final selection.

Period of Performance: 1-3 years; Max. Budget: $500K/year
BTO Point of Contact: Brian.Walker@ee.doe.gov
Merit Review Presentation Time: 40 minutes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APPENDIX C. Content and Form of Full Proposals for Core R&D Topics

BTO requests a 12-page (maximum) full technical proposal for Core R&D Topics as described in Table 4. Page limits are not provided for individual sections to allow applicants to determine the best way to organize the requested material within the total 12-page limit. The proposal should contain the following sections:

Table 4. Technical Proposal Sections for Core R&D Topics

SECTION	DESCRIPTION

Cover page (1 page, NOT included in page limit total)	• Project title
	• Topic Number and Sub topic Number X
	• Project focus area(s): i.e. HVAC, controls, etc.
	  ○ Note: This will help sort proposals and determine reviewer expertise areas needed for each proposal, so careful consideration here is helpful.
	• Project team and contact information, including:
	  ○ The Principal Investigator (Technical Point of Contact);
	  ○ Team Members (both internal and external);
	  ○ Key Participants (i.e., individuals who contribute in a substantive, measureable way to the execution of the proposed project).
	• Abstract: The abstract should be no more than 200 words in length, and should provide a truncated explanation of the proposed project. The abstract will be used to help with reviewer assignment.
	• Budget summary: Include a high-level overview of estimated project budget. List an estimated breakdown for each proposed year, separated by teaming partners and high level activities. Individual line item costs within high level activities (i.e. within staff time breaking out by employee 1, employee 2, etc.) not required. A detailed project budget will be completed during negotiations. The high level cost estimates should address the following categories:
	  ○ Labor
	  ○ Vendors/subcontracts
	  ○ Travel
	  ○ Equipment
	  ○ Supplies
	  ○ Other costs
	  ○ Totals

Full Technical Work Plan (TWP)	**Introduction:** The high-level overview of the final result of the project and the technical summary should guide reviewers who are not familiar with the project. Applicants should also provide a brief description of the rationale for organization of the project tasks. **Task 1:** Distinctive title, date range of the task in months (M1-M4), estimated task budget. **Task Description:** Task summaries shall explicitly identify: • A concise statement of the objectives of that task. • The work that is to be accomplished and how it will be accomplished (write: "we will" often to structure this in the right way). Tasks should be designed to mitigate/eliminate significant risks i.e. technology, and manufacturability risks for hardware proposals. Each task can address one or multiple risk categories. **(Optional) Subtask 1.1**: Distinctive title, date range (M1-M2) **(Optional)Subtask description:** Subtask descriptions shall: • Explicitly identify the task objectives/outcomes being addressed and a concise statement of the objectives of that subtask. • Describe the work and techniques that will be used and the expected result that will be generated from the effort. **(Optional) Subtask 1.2**: Distinctive title, Date range (M2-M7) (Continue until all Task 1 subtasks are listed) **Task 2:** (Continue in the format above until all tasks and subtasks are listed) **Subtask 2.1:** …
Team and Resources	Should contain the following information: • Describe the project team's unique qualifications and expertise, including those of key subcontractors and partners. • Describe the project team's existing equipment and facilities that will facilitate the successful completion of the proposed project. Include a justification of any new equipment or facilities requested as part of the project. • Describe relevant, previous work efforts, demonstrated innovations, and how these enable the submitter to achieve the project objectives. • Describe the time commitment of the key team members to support the project. • Further describe the budget from the cover page if needed. • For multi-organizational or multi-investigator projects, describe succinctly: ○ The roles and the work to be performed by each PI and key participant.

	○ Business agreements between the applicant and each PI and key participant. ○ How the various efforts will be integrated and managed. ○ Process for making decisions on scientific/technical direction. ○ Publication arrangements. ○ Intellectual Property issues. ○ Communication and engagement plans.
Technology Transition Plan	• The Technology Transition Plan section in the application should use plain language to describe the state of the technology and include a summary of the Value Proposition & Market Opportunity, Risk Mitigation Strategy, and Team. The significant impact sought by DOE depends upon successful projects finding a path to large-scale adoption. DOE projects are not required to achieve commercial deployment by the end of the project period, but the applicant should define a reasonable path for the proposed technology toward commercial success. • The Technology Transition Plan should contain the following information: ○ Value Proposition & Market Opportunity: Quantify the market opportunity and describe the value proposition and competitive differentiation. Include an explanation of why the proposed solution would be commercially relevant (e.g., what needs are you trying to address? How have previous solutions fallen short?) and how you plan to test and qualify your product concept in the market. Provide supporting information regarding the likelihood of market penetration at scale in new and/or existing buildings. ○ Risk Mitigation Strategy: Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant and discuss any scalability, regulatory, intellectual property (IP) or integration risks and considerations associated with the technology. Outline your mitigation strategies towards these challenges. Discuss any other factors key to successfully achieving the energy savings potential. Identify any known or perceived barriers to market adoption/dissemination and your plans for mitigating these. ○ Team: Identify the technology transition project team lead responsible for leading

	and coordinating all technology transition activities for the project.
Reports & Studies (not included in total page limit)	If project work includes, either initially or during the course of the project period of performance, publicly facing reports or studies, the project Principal Investigator (PI) is required to communicate progress regularly with BTO staff, keeping them up to date on any changes in direction, changes in scope, and anticipated findings. Topics will be indicated in final decisions, and will remain subject to change over the life of projects. For all proposals, respondents should be sure to highlight if any of their proposed work will result in publicly facing reports or studies.
Open Source Software Distribution Plan (only for applicable project, recommended length 1 page, not included in total page limit)	Applicants that are applying to topic areas for which open source software distribution is required must submit a plan describing how software produced will be distributed. The data rights clause, including rights and requirements pertaining to computer software, in its Management and Operating (M&O) Contract shall apply and shall take precedence over any requirement set forth in this Appendix. The plan must include the following elements: 1. A complete description of any existing software that will be modified or incorporated into software produced under this award, including a description of the license rights. The license rights must allow the modified or incorporated software to be distributed as open source. 2. A discussion of the open source license that the applicant plans to use for the software it plans to produce under this award, and how that choice furthers the goals of this project and BTO. The discussion must also address how the license conforms to the conditions listed below. 3. A method for depositing the software in a source code repository. 4. A method for sharing and disseminating the software and other information to team members or others when multiple parties will contribute to the development of the software or the project requires that the software or other information be shared or disseminated to others. See Appendix F for additional information.
Summary Slide (NOT included in page limit)	Applicants are required to provide a single PowerPoint slide summarizing the proposed project. The slide must be submitted in Microsoft PowerPoint format. This slide is used during the evaluation process and should be legible when viewed on a screen in a conference room.

	A template is provided on EERE exchange for this slide. The summary slide requires the following information: • The project's key idea/takeaway. • A description of the project's impact (reference Scout analysis). • Proposed project goals. • Any key graphics (illustrations, charts, and/or tables). • Project title, prime recipient, principal investigator, and subcontractors. • Requested BTO funds and proposed applicant cost share (if applicable).

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APPENDIX D. Content and Form of Full Proposals for Competed R&D Topics

BTO requests a 12-page (maximum) full technical proposal for Competed R&D Topics as described in Table 5. Page limits are not provided for individual sections to allow applicants to determine the best way to organize the requested material within the total 12 page limit. There should be just one proposal submission per project. Each topic may have multiple projects proposed. Do not place multiple projects into a single proposal. The proposal should contain the following sections:

Table 5. Technical Proposal Sections for Competed R&D Topics

SECTION	DESCRIPTION

Cover page
(1 page, NOT included in total page limit)
	• Project title
	• Project Topic Number and Sub topic Number X
	• Project focus area(s): i.e. HVAC, controls, etc.
	  ○ Note: This will help sort proposals and determine reviewer expertise areas needed for each proposal so careful consideration here is helpful.
	• Project team and contact information, including:
	  ○ The Principal Investigator (Technical Point of Contact);
	  ○ Team Members (both internal and external);
	  ○ Key Participants (i.e., individuals who contribute in a substantive, measureable way to the execution of the proposed project).
	• Abstract: The abstract provided should be approximately 200 words in length, and should provide a truncated explanation of the proposed project. The abstract will be used to help with reviewer assignment.
	• Budget summary: Include a high-level overview of the estimated project budget. List an estimated breakdown for each proposed year, separated by teaming partners and high level activities. Individual line item costs within high level activities (i.e. within staff time breaking out by employee 1, employee 2, etc.) are not required. A detailed project budget will be completed during negotiations. The high level cost estimates should address the following categories:
	  ○ Labor
	  ○ Vendors/subcontracts
	  ○ Travel
	  ○ Equipment
	  ○ Supplies
	  ○ Other costs
	  ○ Totals

Technical Narrative	The narrative should be organized in the following way and contain the following information:
	• *Project Overview:*
	  ○ Discuss the history, successes, current state of the art in the field of the proposed work, current applicant team capability, and a concise description of the concept or scope of work.
	  ○ Technical Details: If necessary, succinctly describe the relevant management, engineering, design, process, scientific or other principles and aspects of the project that warrant discussion here.
	• *Project Objectives:*
	  ○ Provide a clear and concise (high-level) statement of the goals and objectives of the project. Each objective should be numbered (Objective 1, Objective 2, etc.). A performance metric that is used throughout the project must improve with time/use and the improvement should be clearly documented. This improvement over time/use could be demonstrated through a tightening of the precision, and an improvement in the accuracy, of the metric. There should be objectives that mitigate/eliminate technological and market risks. To ensure that objectives are relevant, applicants should follow the SMART principle, which is that all objectives should be **S**pecific, **M**easurable, **A**ggressive (but achievable), **R**elevant, and **T**imely. At a minimum, annual objectives (milestones) should be provided.
	  ○ Note: This section (or any other section) should not include discussions of the merits of building energy efficiency or grid-integration research in general, or how the proposed technology may be related to or interact with other non-BTO relevant technologies.
	• *Impact if Successful:*
	  ○ Discuss the relevance the proposed work, if successful, will have to industry and to enhancing grid reliability and resilience and/or the cost and barrier reductions needed to reach the BTO MYPP targets. Applicants are strongly encouraged to use Scout's Baseline Energy Calculator (https://trynthink.github.io/scout/calculator.html) to determine national energy savings associated with their proposal, if applicable. Please also address:
	  ○ Expected project outputs.
	  ○ Audience/customers for the project end results.
	  ○ How the audience will utilize the results.
	• *Outreach plan to engage with target audience* (e.g. convenings, peer-reviewed publications, patent disclosures, licensed IP, and formation of related CRADAs with industry.)

	• *Risk identification and mitigation plans:* The applicant should discuss the items that are likely to put the proposed project goals at risk. Each risk should be described and one or more reasonable mitigation strategies should be provided for each risk. The risks and the associated mitigation strategies should be substantive and demonstrate specific technical knowledge of the proposed work (rather than general project management risks). ○ Any closing remarks the applicant feels should be discussed prior to the technical work plan.
Summary Technical Work Plan (TWP)	Full TWPs should not be developed at this stage; however, a summary of the general work involved is helpful for the review process. Provide a succinct description of the specific activities to be conducted over the proposed performance period. Descriptions should contain enough detail to convey and disclose the work occurring (i.e., vague statements such as "we will then complete a proprietary process" are unacceptable). It is the submitter's responsibility to prepare an adequately detailed task plan to convince reviewers that the proposed project and team can meet the goals of the funding program. The summary TWP should contain the following information: Tasks: • It is critical that the overall project objective is broken into separate Task sections that are clearly linked to, and combine to result in, the project milestone and final objective. A Task is an executable or an operation that is enabled by the collection of subtasks associated with it. As such, Tasks represent something more than just the collection of data. Each task description should include a budget amount for each year of proposed work. ○ (Optional) Subtasks may be included if further detail of the breakdown of the work is needed. • Each Task may be broken out into component Subtask sections to specify the activities that will be conducted to accomplish the task. A Subtask describes a specific activity that is designed to deliver a device, tool, or technique to collect data. The approach through which the activity is performed is designed to allow the associated task to have a determinant outcome. Note: Every proposal should include a task and deliverable focused on externally validating the core assumption that the research being pursued is on a path toward relevance to a marketplace problem. This task is expected to be approximately 5% of the total project budget. Work billed towards this task should include external validation and dissemination and will need to be discussed with and approved by the DOE project monitor. **Example Technical Work Plan Structure**

	Introduction (if necessary): The high-level overview of the final result of this project and the technical summary should already have been drafted in the Technical Narrative sections so they do not need to be repeated here. This space could be used to provide a brief description of the rationale for the organization of the project tasks. **Task 1:** Distinctive title, date range of the task in months (M1-M4), estimated task budget. **Task Description:** Task summaries shall explicitly identify: • A concise statement of the objectives of that task. • The work that is to be accomplished and how it will be accomplished (write: "we will" often to structure this in the right way). Tasks should be designed to retire significant risks i.e. technology, and manufacturability risks for hardware proposals. Each task can address one or multiple risk categories. **(Optional) Subtask 1.1**: Distinctive title, date range (M1-M2) **(Optional)Subtask description:** Subtask descriptions shall: • Explicitly identify the task objectives/outcomes being addressed and a concise statement of the objectives of that subtask. • Describe the work and techniques that will be used and the expected result that will be generated from the effort. ○ **(Optional) Subtask 1.2**: Distinctive title, Date range (M2-M7) • (Continue until all Task 1 subtasks are listed) **Task 2:** (Continue in the format above until all tasks and subtasks are listed) **Subtask 2.1:** …
Team and Resources	Should contain the following information: • Describe the project team's unique qualifications and expertise, including those of key subcontractors and partners; • Describe the project team's existing equipment and facilities that will facilitate the successful completion of the proposed project; include a justification of any new equipment or facilities requested as part of the project; • Describe relevant, previous work efforts, demonstrated innovations, and how these enable the submitter to achieve the project objectives; • Describe the time commitment of the key team members to support the project; • Further describe the budget from the cover page if needed; • For multi-organizational or multi-investigator projects, describe succinctly:

	○ The roles and the work to be performed by each PI and key participant. ○ Business agreements between the applicant and each PI and key participant. ○ How the various efforts will be integrated and managed. ○ Process for making decisions on scientific/technical direction. ○ Publication arrangements. ○ Intellectual Property issues. ○ Communication and engagement plans.
Technology Transition Plan	• The Technology Transition Plan section in the application should use plain language to describe the state of the technology and include a summary of the Value Proposition & Market Opportunity, Risk Mitigation Strategy, and Team. The significant impact sought by DOE depends upon successful projects finding a path to large-scale adoption. DOE projects are not required to achieve commercial deployment by the end of the project period, but the applicant should define a reasonable path for the proposed technology toward commercial success. • The Technology Transition Plan should contain the following information: ○ Value Proposition & Market Opportunity: Quantify the market opportunity and describe the value proposition and competitive differentiation. Include explanation of why the proposed solution would be commercially relevant (e.g., what needs are you trying to address? How have previous solutions fallen short?) and how you plan to test and qualify your product concept in the market. Provide supporting information regarding the likelihood of market penetration at scale in new and existing buildings. ○ Risk Mitigation Strategy: Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant and discuss any scalability, regulatory, intellectual property (IP) or integration risks and considerations associated with the technology. Outline your mitigation strategies towards these challenges. Discuss any other factors key to the achieving the energy savings potential. Also identify any known or perceived barriers to market adoption/dissemination and your plans for mitigating these. ○ Team: Identification of the technology transition project team lead responsible for leading and coordinating all technology transition activities for the project.
Reports & Studies	If project work includes, either initially or during the course of the project period of performance, publicly facing reports or studies,

(NOT included in total page limit)	the project Principal Investigator (PI) is required to communicate progress regularly with BTO staff, keeping them up to date on any changes in direction, changes in scope, and anticipated findings. Topics will be indicated in final decisions, and will remain subject to change over the life of projects. For all proposals, respondents should be sure to highlight if any of their proposed work will result in publicly facing reports or studies.
Open Source Software Distribution Plan (only for applicable project, recommended length 1 page, NOT included in total page limit)	Open Source Software Distribution Plan. See Appendix F for additional information. Applicants that are applying to one or more Topic Areas for which open source software distribution is required must submit a plan describing how software produced will be distributed. The data rights clause, including rights and requirements pertaining to computer software, in its Management and Operating (M&O) Contract shall apply and shall take precedence over any requirement set forth in this Appendix. The plan must include the following elements: 1. A complete description of any existing software that will be modified or incorporated into software produced under this award, including a description of the license rights. The license rights must allow the modified or incorporated software to be distributed as open source. 2. A discussion of the open source license that the applicant plans to use for the software it plans to produce under this award, and how that choice furthers the goals of this project and BTO. The discussion must also address how the license conforms to the conditions listed below. 3. A method for depositing the software in a source code repository. 4. A method for sharing and disseminating the software and other information to team members or others when multiple parties will contribute to the development of the software or the project requires that the software or other information be shared or disseminated to others.
Appendices (NOT included in total page limit)	• Applicants may attach ***one- or two-page*** resumes for key participating team members as an appendix. Resumes do not count towards the page limit. Resumes over two pages are not allowed and will not be reviewed. • Applicants may attach ***one-page*** letters of support or commitment from partners/end users as an appendix. Letters of support do not count towards the page limit. Multi-page letters of support are not allowed and will not be reviewed. • Applicants may include references as a footnote on each page or as an appendix that will not count towards the page limit. References and outside links to additional content may be

	considered by reviewers. However, proposals should not require references or outside content to be understood and reviewed. • Applicants should list any current or prior related funding support, including project title, beginning and ending dates, total funding amount, PI(s), and funding source. If any current or prior funding seems very closely related to the proposed work, the Applicants should discuss in the Technical Volume how the proposed work is distinct from the other project(s). There are no page limits for this section. Descriptions of current or prior related funding will not count towards the page limit.
Summary Slide (NOT included in total page limit)	Applicants are required to provide a single PowerPoint slide summarizing the proposed project. The slide must be submitted in Microsoft PowerPoint format. This slide is used during the evaluation process and should be legible when viewed on a screen in a conference room. A template is provided on EERE Exchange that matches the format of the initially submitted ITS Slide. The single-page ITS Slide originally submitted can be updated prior to submitting as a summary slide with the full proposal. The summary slide requires the following information: • The project's key idea/takeaway. • A description of the project's impact. • Proposed project goals. • Any key graphics (illustrations, charts, and/or tables). • Project title, prime recipient, principal investigator, and subcontractors. • Requested BTO funds and proposed applicant cost share (if applicable).

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APPENDIX E. Merit Review Criteria

Criterion 1: Technical Merit, Innovation, and Impact (Weight: 50%)

- Degree to which the project addresses program barriers, contributes to achieving national goals (e.g., climate, oil dependency, and economic competitiveness) and BTO targets/goals, and has potential to contribute to state-of-the-art advancements.
- Extent to which the proposed project addresses EERE core questions: addresses a high-impact problem, complements industry investments, has the potential for enduring economic impact/provides high value to the government, presents an innovative approach and/or involves new performers, and is appropriate for federal funding.
- Sufficient technical detail to assess whether the proposed work is scientifically meritorious.
- Degree to which the proposed project goal and go/no-go decision points are informed by significant prior industry engagements or market analyses.

Criterion 2: Project Approach (Weight: 30%)

- Relevance and appropriateness of the approach and critical path; description of key tasks, metrics (including baseline), and SMART milestones leading to a major outcome.
- Degree of likelihood the work plan will successfully meet project goals.
- Identification of key technical risks and the quality of management and mitigation strategies that will be used to address them.
- The level of suitability of the Data Management Plan for the proposed research and the extent to which it supports the validation of research results.
- Degree to which the approach incorporates industry engagement and technology-to-market activities.
- If a project is focused on R&D, does the project approach identify and address the current and/or potential opportunities to transition technology to the private sector? If a project is not focused on R&D, how does it contribute to or further enable the technology transfer of one or more EERE technologies?

Criterion 3: Team, Resources, and Inter-Lab Collaboration (Weight: 20%)

- Degree to which the project leverages a core or enabling capability.
- Capability of the PI(s) and team members to address all aspects of the work, including the qualifications, expertise, and time commitment of the team.
- Sufficiency of the facilities to support the work, if applicable.
- Degree to which the team demonstrates the ability to facilitate and expedite further development and commercial deployment of the proposed technologies (or wider implementation of the proposed deployment activity), as appropriate.
- Degree to which inter-lab collaboration is occurring, as appropriate.
- Level and appropriateness of partnerships, and clarity in the description of roles and responsibilities.
- Reasonableness of budget and spend plan for proposed project and objectives.
- Sufficiency of the budget for the innovation proposed.

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APPENDIX F. Open Source Software Guidance

BTO develops and distributes several software packages including EnergyPlus, OpenStudio, and VOLTTRON under Open Source licenses. Open Source licensing is critical in situations where transparency is important. Open Source licensing also helps collaboration and follow-on research. In certain cases, Open Source licensing may help commercialization and greater market adoption. Open Source licensing is 99.99% about use of a centralized resource and 0.01% about contributions to that resource. Open Source software does not imply crowd-sourced development and crowd-sourced development does not imply good software.

The Open Source Initiative (OSI) defines Open Source licensing here (https://opensource.org/docs/osd) and provides a listing of licenses that meet these definitions here (https://opensource.org/licenses/category). Of these, BTO strongly prefers the subset of licenses that maximize freedom of use for any purpose, commercial or otherwise, of the software in whole or in part. This eliminates the GNU licenses, but leaves such licenses as BSD, MIT, Mozilla, Apache, and Eclipse available. For example, EnergyPlus and OpenStudio are distributed under the BSD license, while VOLTTRON is distributed under the Eclipse license.