FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

ADVANCED RESEARCH PROJECTS AGENCY – ENERGY (ARPA-E)
U.S. DEPARTMENT OF ENERGY

SAVING ENERGY NATIONWIDE IN STRUCTURES WITH OCCUPANCY RECOGNITION (SENSOR)

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Funding Opportunity Announcement (FOA) Issue Date:	January 18, 2017
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, Tuesday, March 7, 2017
Submission Deadline for Concept Papers:	5 PM ET, Friday, March 17, 2017
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	5 PM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	TBD
Total Amount to Be Awarded	Approximately $20 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.H.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.
- For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 through III.C.3 of the FOA.

Questions about this FOA? Check the Frequently Asked Questions available at http://arpa-e.energy.gov/faq. For questions that have not already been answered, email ARPA-E-CO@hq.doe.gov (with FOA name and number in subject line); see FOA Sec. VII.A. Problems with ARPA-E eXCHANGE? Email ExchangeHelp@hq.doe.gov (with FOA name and number in subject line).

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REQUIRED DOCUMENTS CHECKLIST

For an overview of the application process, see Section IV.A of the FOA.

For guidance regarding requisite application forms, see Section IV.B of the FOA.

For guidance regarding the content and form of Concept Papers, Full Applications, and Replies to Reviewer Comments, see Sections IV.C, IV.D, and IV.E of the FOA.

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: o Concept Summary o Innovation and Impact o Proposed Work o Team Organization and Capabilities • Applicants may submit Concept Papers addressing Category A, B, C or any combination thereof. Applicants may also submit Concept Papers solely to Category D. Concept Papers submitted to Category D must be devoted solely for Category D. ARPA-E is not limiting the number of Applications that may be submitted by Applicants, provided that each Application is scientifically distinct. Thus, Applicants may submit a Concept Paper for Category A and/or B and/or C, plus a separate Concept Paper for Category D. However, a Concept Paper submitted to Category D may not identify any other technical Category, or else it will be found to be noncompliant.	Mandatory	IV.C	5 PM ET, Friday, March 17, 2017
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]	Mandatory	IV.D	5 PM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]	Optional	IV.E	5 PM ET, TBD

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy (DOE), is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358) to:

"(A) to enhance the economic and energy security of the United States through the development of energy technologies that result in—
(i) reductions of imports of energy from foreign sources;
(ii) reductions of energy-related emissions, including greenhouse gases; and
(iii) improvement in the energy efficiency of all economic sectors; and
(B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies."

ARPA-E issues this Funding Opportunity Announcement (FOA) under the programmatic authorizing statute codified at 42 U.S.C. § 16538. The FOA and any awards made under this FOA are subject to 2 C.F.R. Part 200 as amended by 2 C.F.R. Part 910.

ARPA-E funds research on and the development of high-potential, high-impact energy technologies that are too early for private-sector investment. The agency focuses on technologies that can be meaningfully advanced with a modest investment over a defined period of time in order to catalyze the translation from scientific discovery to early-stage technology. For the latest news and information about ARPA-E, its programs and the research projects currently supported, see: http://arpa-e.energy.gov/.

ARPA-E funds transformational research. Existing energy technologies generally progress on established "learning curves" where refinements to a technology and the economies of scale that accrue as manufacturing and distribution to develop drive down the cost/performance metric in a gradual fashion. This continual improvement of a technology is important to its increased commercial deployment and is appropriately the focus of the private sector or the applied technology offices within DOE. By contrast, ARPA-E supports transformative research that has the potential to create fundamentally new learning curves. ARPA-E technology projects typically start with cost/performance estimates well above the level of an incumbent technology. Given the high risk inherent in these projects, many will fail to progress, but some may succeed in generating a new learning curve with a projected cost/performance metric that is significantly lower than that of the incumbent technology.

ARPA-E funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately

become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have the clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

ARPA-E funds applied research and development. The Office of Management and Budget defines "applied research" as "systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met" and defines "development" as the "systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements."[1] Applicants interested in receiving financial assistance for basic research should contact the DOE's Office of Science (http://science.energy.gov/). Office of Science national scientific user facilities (http://science.energy.gov/user-facilities/) are open to all researchers, including ARPA-E applicants and awardees. These facilities provide advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. Projects focused on the improvement of existing technology platforms along defined roadmaps may be appropriate for support through the DOE offices such as: the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy (http://fossil.energy.gov/), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

B. PROGRAM OVERVIEW

1. SUMMARY

This program aims to dramatically reduce the amount of energy used for heating and cooling residential buildings (by 30%) via user-transparent sensor systems that accurately sense human presence (not merely motion). This program also aims to reduce energy usage in commercial buildings (also by 30%) by enabling ventilation control based on sensor systems that can accurately count the number of humans in a pre-determined zone. If these sensing technologies can be widely deployed with disruptively low price targets and failure rates, a significantly lower usage of energy will result without impact to comfort of the occupants of the space. Heating, cooling, and ventilation (HVAC) reduction is only one way energy can be saved; such human presence sensing and people counting will enable drastic improvements in the way buildings communicate with and respond to their occupants.

[1] OMB Circular A-11 (http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/a11_2014.pdf), Section 84, p. 8.

The accuracy, reliability, and cost requirements to deliver such substantial energy savings are far beyond the limits of sensor systems available today. However, ARPA-E believes that by building on recent trends in improved performance and reduced cost in low-power consumer electronics and wireless communication technologies, it is possible to achieve the required performance levels through a focused push in the SENSOR program. Supporting systems currently exist (i.e., thermostats/controls, variable air volume systems, etc.) that could utilize data from such sensor systems to achieve the program's energy reduction targets today, with only slight modifications. In order to ensure impact for the new sensor systems, significant adoption barriers must be identified and clearly understood, technical paths to overcome these barriers must be defined, and real-world performance of these technical solutions validated.

There are four areas of focus for this program, as described further in this FOA:

A. Human presence sensors for residential use (these deliver a binary "occupied or not occupied" signal to enable temperature adjustment (setbacks) between setpoints used for the normal comfort range vs those for an unoccupied residence;
B. People counting sensors for commercial use (these deliver the number of occupants in a specific defined HVAC zone to enable both temperature and ventilation setbacks);
C. Low-cost, stable, and easily deployable CO_2 sensors to enable adoption of ventilation setbacks;
D. Real-World testing and validation of A, B, and C in both laboratory controlled quasi-real world environments and actual field deployment tests throughout the program timeframe.

2. BACKGROUND

The amount of energy currently used to heat, cool, and ventilate buildings is enormous – equivalent to 13 quad BTUs (Quadrillion British Thermal Units) of energy; the *entire* United States energy consumption was 97.5 quad BTUs in 2015. 37% of all energy used in commercial buildings is used for heating, cooling, and ventilation (HVAC)[2]. Much of this is wasted, and is being used when buildings are either not occupied at all, or occupied well under the maximum levels they are designed for.

Human presence sensing and people counting have significant potential to generate energy savings in a number of ways. Currently, simple motion sensing is used to control lighting to save energy (albeit with high failure rates when occupants are not in motion.) These failures have minimal drawbacks (aside from transient user annoyance): lights can easily be set to the proper state immediately by the occupant, with relatively little impact to comfort, productivity, and

[2] Data adapted from EIA's Commercial Building Energy Consumption Survey (CBECS 2012) data and EIA's Residential Energy Consumption Survey (RECS 2008) data

safety. This would not be true for an HVAC scenario, where a thermostat would have to be manually reset and a potential for thermal inertia would result in extended discomfort. More seriously, such failures could set ventilation to an inappropriately low setting and result in CO_2 or other volatile organic compound (VOC) increases that could impact productivity, comfort, and potentially health – all *invisibly* without notice to the occupant. Thus, sensor systems used for HVAC control require significantly better accuracy than what movement sensors can provide, and must address the user adoption issue of "invisible failure".

Individual sensor system applications and requirements will vary based on the building type and use case. For the purposes of this Funding Opportunity, the market has been divided into two high-level categories, Residential and Commercial. The technical distinction between these two high-level categories is one where only temperature setbacks are used (Residential – Category A), requiring only binary occupancy information, and one where ventilation control can be added (Commercial – Category B), where the number of people within each HVAC zone is needed to properly tailor the ventilation settings. ARPA-E does not want to limit technology applications to any specific niche of the market, and strongly encourage submissions with technologies that have the flexibility to provide excellent savings across a range of building types in order to maximize impact, thus Categories A and B are technology agnostic.

Here, a "Sensor system" is defined as the sensor(s) needed to determine the desired output data as well as the hardware to transmit these data to an existing type of control system. The sensors themselves include the actual sensing modality hardware, a power source, a communication source, any onboard computation hardware that is needed such that the sensor is self-contained, and packaging. An example for the residential use case could be a small number of sensors that all communicate directly to the control system (i.e. thermostat); an example for the commercial use case could be a distributed network of several very low power, distributed wireless sensing points that all communicate back to a hub, which transmits the people count data to a control system. There are many more configurations that could be possible depending on the specific sensor modality chosen. This FOA, defines a set of requirements for a system to be successful in delivering energy savings, regardless of the specific sensing modality or sensor network configuration. ARPA-E encourages an emphasis on retrofit installations, technologies capable of multiple deployment scenarios, and testing and validation.

Category A: Residential (Human Presence Sensors)

The ability to control heating and cooling set-points directly has been available for over a hundred years, and well predates electronics, even for programmable versions[3]. It is perhaps shocking that the potential energy usage benefits of this technology have yet to be fully realized in residential or commercial buildings, despite the semiconductor revolution and significant advances in HVAC control strategies.

[3]Bernan, Walter. On the History and Art of Warming and Ventilating Rooms and Buildings, London, 1845

When programmable thermostats using solid-state controls became available, they were heralded as true differentiators in terms of HVAC energy savings, *potentially* enabling HVAC energy usage reductions of 20-30% (see references in Table 1, See Section I.E of the FOA). However, after several years of wide commercial availability and usage, multiple studies in different geographic areas conducted at different times found that they were conclusively not saving energy; in fact, in some cases users even *increased* their energy usage[4,5]. As a result of the lack of energy reduction by programmable thermostats, the Environmental Protection Agency announced a decision to sunset the Energy Star program for this technology in 2009. This impacted both the Energy Start Homes Program and LEED for Homes; both programs discontinued award points for this product. [6]

Since that time, research has shown that the deleterious impact of user interfaces is much more important than originally appreciated.[7] This issue does not seem to be improving as newer, "smarter" thermostats grow increasingly more complicated. A disruptive change in this area is needed, and it must *fundamentally* solve this issue, not merely provide an iteration with regard to existing thermostat user interface design. The need for human input and continuing attention clearly must be *removed* in a way that is user-acceptable, and this challenge could be solved and validated with the technology envisioned within this FOA.

Categories B and C: Commercial (People Counting Sensors and CO_2 Sensors)

For the case of commercial buildings, there is an additional energy savings opportunity over that of temperature setbacks: ventilation. Most large buildings are outfitted with variable speed fans for controlling the amount of ventilation delivery ("VAV" or variable air volume systems, often found in HVAC systems with economizers), and these fan speeds can be adjusted to use more or less energy, depending on the ventilation needs[8]. It is difficult for these systems to be utilized largely because this would require the certain knowledge of the number of people occupying the space at any time, which is not available. Therefore, many buildings are strikingly over-ventilated. Recent concerns about indoor air quality ("IAQ") have driven up ventilation rates even more despite the increased energy usage and cost associated with this strategy. The limiting case of a highly occupied building defines the settings, as described by ASHRAE standards driven by IAQ[9]. However, if the number of people in the space could be determined, IAQ could be ensured even at reduced fan speed set points, and the building confirmed to be in continuous accordance with ASHRAE ventilation standards. Ventilation is an exciting energy

[4] Peffer,T., et al., Building and Environment **46** (12) 2011
[5] Malinick, T., et al., ACEEE Summer Study on Energy Efficiency, **7** 2012 (pp 162-173 and references therein)
[6] U.S. Environmental Protection Agency. Summary of Research Findings from the Programmable Thermostat Market. Memo to Manufacturers on Programmable Thermostat Specification Review. 2003, Washington, D.C.: U.S. Environmental Protection Agency.
[7] Meier, A., et al., Building and Environment **46** (12) 2011
[8] J. Zhang, G Liu, MR Brambley, RG Lutes, PNNL # 22072, 2013
[9] Standards 62.1 & 62.2 – The Standards For Ventilation And Indoor Air Quality – ANSI/ASHRAE Standards 62.1 and 62.2 are the recognized standards for ventilation system design and acceptable IAQ

savings opportunity, as it can be changed quickly and doesn't suffer from the thermal lag of extended temperature set-points.

IAQ concerns are identified as a potentially critical user adoption barrier for ventilation control, because ventilation is "invisible". Building managers and end users have no timely, affordable, and easy to deploy method to detect that the system is performing as it should to meet standards, and thus deliver an environment that promotes comfort, productivity, and even health. IAQ markers such as CO_2 can be measured, but current technology is expensive, requires wired installation, and is plagued with calibration issues such that costly manual calibration needs to be performed every year. The drive toward more ventilation and not less is likely to continue as the understanding of IAQ impacts grows[10]. On the other hand, advanced building standards such as LEED platinum are challenging to meet without adequate ventilation control. If CO_2 could be measured reliably and cheaply on demand wherever an end user desired, it could be used as an *indicator* that ventilation rates are set to appropriate levels, and thus enable existing VAV systems to be used in conjunction with the people counting sensor technology described in this FOA. To this end, CO_2 sensor development is included in Category C as a partial solution and adoption enabler, even if this sensing modality cannot be used alone to deliver an occupancy count. If a submission intends to use CO_2 sensing as an actual *occupancy count* modality, this would follow the requirements of Category B. If a submission intends to deliver CO_2 sensors as an adoption enabler as discussed above, this would follow the requirements of Category C.

Category D: Testing and Validation (both Residential and Commercial)

Finally, there is a key need in this application space for testing and validation research. Because building spaces, usage patterns, and HVAC systems vary widely, as do climates, validating the energy savings from a particular technology in the building space can be challenging. ARPA-E knows of no existing tools that can fully assess and validate presence sensor and people counting technologies as described in this FOA. In order to enable widespread adoption of such technologies for both retrofit and new building scenarios, a way to validate energy saving claims must be developed and implemented.

Testing and validation research must deliver a clear means for assessing the energy saving impact of both the residential and commercial (Categories A and B) technologies in a wide variety of floorplans. To this end, both a simulation tool and real-world field trials must be completed for multiple building types. A method for determining ground truth must be established and used to compare against novel sensor systems in both the residential and commercial spaces.

[10] Recent studies have indicated that productivity suffers at CO_2 levels currently considered benign (~ 650 to <1000 ppm) MacNaughton, Et al., Int. J. Environ. Res. Public Health **12** 2015, 14709-14722

C. PROGRAM OBJECTIVES

The principal objective of the SENSOR program is to reduce energy used by HVAC systems in buildings by 30% for both residential and commercial buildings, which could total 2-4 Quads of energy consumption in the U.S. (Section I.F of the FOA provides a detailed accounting of the available savings, including breakdown across different sectors and types of buildings.)

In pursuit of this objective, the SENSOR program will develop new classes of sensor systems: human presence sensors (for residential use), people counting sensors (for commercial use), and low-cost CO_2 sensors (as a critical enabling technology for VAV actuation in commercial buildings). These sensor technologies seek to minimize or eliminate the need for human intervention, and thus the SENSOR program represents a fundamentally new approach to energy savings in HVAC, which has been pursued for decades but has thus far proven elusive.

All newly developed sensor systems under the program must meet aggressive cost, performance, and usability requirements in order to gain the acceptance and penetration levels necessary for a 30% reduction in HVAC energy consumption. The SENSOR program will subject all technologies to rigorous testing to demonstrate performance in relevant deployment scenarios. In addition, testing and validation research will deliver tools for accurately assessing the real-world impact of these new sensing technologies.

Section I.F of the FOA shows how deployment in even just a few key market areas is adequate to reach the energy and cost savings goals of this program. These areas, chosen as they have lower barriers to adoption than the others, must drive the program's technical and testing/validation pathways. For residential buildings, these market areas are detached and attached single family housing, and for commercial buildings, these market areas are office buildings, lodging, education, and public assembly. Finally, Section I.F details the method used to derive the price metrics presented in Section I.E of the FOA.

D. TECHNICAL CATEGORIES OF INTEREST

The SENSOR program will fund transformational R&D on building sensor systems in four categories:

A. Human presence sensors for residential use
B. People counting sensors for commercial use
C. Low-cost, stable, and easily deployable CO_2 sensors to enable commercial adoption
D. Real-world testing and validation for both residential and commercial validation

Submissions addressing Categories A, B, and/or C must be included in one Concept Paper, and Submissions addressing Category D must be included in a separate Concept Paper. For example, this could include a residential solution that includes full, real-world field testing and validation development (Categories A and D – two distinct Concept Papers); a complete

commercial solution with both people counting and CO_2 sensors and development of a real-world field testing and validation protocol (Categories B, C, and D – two Concept Papers); a sensor system for people counting and CO_2 detection (Categories B and C – one Concept Paper), or other combinations. Applicants submitting to Categories A, B, and C but not submitting to Category D must still perform controlled laboratory-based hardware testing (see Section I.E of the FOA), but they will not be required to submit their technologies for testing and validation by Category D teams. Teams submitting in Category D only will develop simulation tools and real-world field testing protocols for human presence or people counting technologies in general. Collaboration between Categories A, B, C and Category D teams are strongly encouraged but not required.

Category A: Human presence sensors for residential use

Must deliver a binary "occupied or not occupied" signal to enable temperature setbacks in residential buildings.

SENSOR seeks technical solutions that can detect the presence of a human body in a residence of a wide variety of types, structures, or geometries, and discriminate between that of a human or pet (cat or dog). A number of existing sensor solutions available on the market (for example, passive infrared "PIR" and/or ultrasonic modalities) attempt to provide rough presence detection of a moving, warmer-than-background item through use of motion detectors integrated with a timing delay circuit. Such movement-based sensor systems typically detect the passing of people through a threshold (door or window) or across a certain field of view, and thus infer indirectly whether a space is occupied or not[11,12]. Such modalities will not be acceptable for the sensors described in this FOA. Here, true presence sensing is required – that of a moving *or* non-moving body – in order to reduce the false-negative rate to acceptable levels, as described in Section I.E of the FOA.

"Geofencing" (GPS accessing) or Bluetooth tracking technologies that track the presence of a device such as smartphone have been seen in this application area. This has limited functionality, as it requires the occupant to carry an item and ensure that it is powered up with the proper communication protocol enabled. This may act as a partial solution for a small controlled subset of users with non-critical systems, but would miss the detection of people not having the device on their person, powered up, in the right communication configuration. Here the interest is in technologies that detect the actual human body, with no "beacon" requirements, in order to reach the widest adoption at lowest cost. To this end all proposed solutions must not require any "beacons" – this includes the presence of a particular item by the person (say, a smartphone), a wearable item, or the like.

Some other sensor configurations have potential for presence counting.[13] Beyond those mentioned above, pressure sensitive rug tiles, image capture technologies, RF and radar systems, and audio systems have been investigated for other uses, such as security or retail

[11] Lu J., *et al.*, Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems, Zurich, Switzerland Nov. 03-05, 2009 (pp 211-224)
[12] Duarte, et al., Energy and buildings **67** (2013) 587-595.
[13] Labeodan et al., Energy and Building **93** (2015) 303-314.

tracking. In general, there are significant drawbacks with respect to price, commissioning concerns, and/or challenges with accuracy. For example, many visible camera-based technologies work by comparing captured frames against a background frame, and thus effectively work as movement sensors, resulting in high false-negative rates when a body is not in motion.

Due to the market desire for a solution and the difficulty of obtaining this solution, some researchers have implemented a "data fusion" scheme, and combining information from multiple types of sensors is a growing effort.[14,15] The greater availably of very low cost and low power distributed sensing networks, based on hardware incorporating communication and significant computation abilities, coupled with novel work in the algorithm space, could have great promise for this sensor fusion area. ARPA-E encourages work in this field and believes there is promise in the data fusion space, as long as any proposed work meets the metrics in this FOA.

It is noted that data from *all* of these sensor systems must be readily available to multiple types and styles of thermostats – thus, an existing open source (encryptable) communication scheme for the sensor output (noting that any *internal* algorithms limited to the sensor system do not need to be open source). In addition, Applicants must submit a plan showing that the proposed technologies will address end-user privacy concerns. Finally, hardware that would not require a residence to have an existing WiFi system is encouraged; the percentage of American homeowners with broadband access (not all with WiFi connectivity) in 2015 was 67%, and is actually decreasing slightly with time, due mostly to price and the growing use of "smartphone-only" connectivity[16].

In order to address issues of security and privacy, as well as ensure the lowest barriers to adoption, sensors in Categories A, B, and C must be "self-contained" regarding computation. No "cloud" computation or communication will be acceptable, and the only communication/data link "external" to the sensor system will be between the sensors and/or sensor hub to the control system. *The only communication required must be between sensor nodes, hubs (if used), and control system*. There are multiple types of communication schemes that could be used, and flexibility in this space is acceptable for this program as long as the scheme is open-source, encryption enabled, and well defined, such that a building automation system could easily incorporate it (or already has it).

Category B: People counting sensors for commercial use.

Must deliver the number of occupants in a specific defined HVAC zone to enable both temperature and ventilation setbacks

[14] Zhou, et al., CISBAT 2013 - September 4-6, 2013 - Lausanne, Switzerland
[15] Zhang, et al. Build Simul (2012) 5: 179-188.
[16] Horrigan, J B and Duggan, M., Pew Research Center, "Home Broadband 2015", 2015

Some sensor configurations have been investigated for presence and people counting.[17] Beyond those mentioned above, and as discussed for Category A, there are systems that show promise for people counting, for example pressure sensitive rug tiles, image capture technologies, RF and radar systems, and audio systems. Each has individual challenges for a cost-effective people counting technology, most notably price, commissioning concerns, and/or challenges with accuracy.

Also as described for Category A, "geofencing" GPS and Bluetooth detection of smartphones has been proposed as a solution in this area, but again, requiring a beacon is out of scope for this proposal. Failures could easily occur when a device is left in a different area, out of power, or without communication enabled. User adoption needs require no additional badges or items to be worn or carried. ARPA-E encourages the field of data fusion for people counting.

A significant amount of research has been performed to identify whether CO_2 sensors can be used to count the number of occupants and preemptively increase the amount of ventilation to a highly occupied zone. The findings conclude that due to the diffusion time and the transient airflow patterns within a building, even state-of-the-art CO_2 sensors, regardless of cost, cannot alone be used to accurately assess the level of occupancy or used to predict the level of occupancy in a building.[18] ASHRAE specifically recommends against placing CO_2 sensors in air returns for this purpose.[19] Regardless, as Category B is technology agnostic, submissions will be considered using CO_2 as the counting modality for this section, but these challenges would have to be addressed.

As noted above, sensors must be "self-contained" regarding computation, and the only communication/data link "external" to the sensor system will be between the sensors and/or sensor hub to the control system.

Category C: Low-cost, stable, and easily deployable CO_2 sensors to enable commercial adoption

Must provide accurate, easily accessible CO_2 data to enable adoption of ventilation setbacks in commercial buildings

As previously discussed, CO_2 sensing where an end-user desires is critically important for the deployment and acceptance of any ventilation control technology in a commercial environment. ASHRAE has guidelines stating that for especially densely populated rooms, the CO_2 must be monitored and the ventilation system must react to increased levels of CO_2 within any given room.[20] Currently, systems respond by either always running at high ventilation levels, or HVAC systems can be equipped with expensive CO_2 detection and integration for those particular rooms that are expected to have large density of occupants for extended

[17] Labeodan et al., Energy and Building **93** (2015) 303-314.
[18] Cali, et al., Building and Environment **86** (2015) 39-49.
[19] Schell, et al., Demand Control Ventilation Using CO_2, ASHRAE Journal February 2001, pg 1.
[20] ASHRAE 60.1

amount of time, although current sensing modalities suffer from baseline drift and need frequent manual (and thus expensive) recalibration.

Here, ARPA-E seeks the development of CO_2 sensors that solve the problems with baseline drift as well as can be deployed easily and affordably where an end user requires. As described in the metrics section below, this will require a truly disruptive change regarding sensing modality. The cost metrics alone are challenging to meet with any technology that would require wired installation, and a low-power, wireless, easy-to-deploy sensor is not an incremental change in this area.

As noted above, sensors must be "self-contained" regarding computation, and the only communication/data link "external" to the sensor system will be between the sensors and/or sensor hub to the control system.

Category D: Testing and Validation for Both Residential and Commercial Validation
Laboratory controlled, quasi-real world environments, and actual field deployment tests for technologies from Categories A, B, C, and others in the market throughout the program timeframe.

Finally, this FOA includes provision for developing and implementing the testing and validation of potential occupancy sensor and people counting technologies. There is no accepted global method for testing and validating such sensors, and this has been a key barrier for adoption in these fields, especially as some unrelated technologies in the energy efficiency market have had difficulty validating claimed energy savings, increasing the perceived risk of adoption of such technologies. ARPA-E sees the development of greatly improved testing and validation methodologies as a key need for this program.

Emphasis will be placed on demonstrating that sensors can meet the acceptable failure rates as defined in the metrics below (see Section I.E of the FOA), as well as validate the energy saved in real-world retrofit scenarios. This must be done while demonstrating the flexibility of occupancy sensors and people counting technologies in three clearly distinct types of building geometries. For residential spaces, this could mean older homes built in the ~1940s, housing stock from the 1970-80s with distinctly different floor plans, a modern very open-plan home, and the like; for commercial spaces, this could be satisfied by demonstrating the technology in an open office scenario with conference rooms, a closed individual office scenario with conference rooms, or an academic building with classrooms and an auditorium mixed with offices. The commercial space must use building examples from at least two distinct sub-markets (for example, office and lodging, office and academic, etc.) ARPA-E intends that this part of the program will develop tools and field testing protocol that can be utilized by this sensor-driven HVAC energy reduction field in general. ARPA-E strongly encourages but does not require teams in this area to collaborate in various ways with any stand-alone sensor hardware teams.

Applicants are encouraged to review the "priority market segments" detailed in Section I.F of the FOA for guidance on preferred relevant building environments and use cases for testing.

E. TECHNICAL PERFORMANCE TARGETS

This FOA defines separate high-level technical metrics for residential and commercial building sensor systems as described below. Successful submissions will provide preliminary analyses of their sensing modalities that provide a path and detailed explanation toward achieving these metrics.

Program structure and schedule

Table 1 below gives a rough guide for the timeline for each section of this FOA; this is followed by a discussion of program performance targets.

Table 1. SENSOR Program Structure and Schedule

	Year 1				Year 2				Year 3			
A: Residential -- presence sensing												
Simulation and savings baseline												
Hardware development												
Lab-based hardware testing												
B: Commercial -- people counting												
Simulation and savings baseline												
Hardware development												
Lab-based hardware testing												
C: Commercial -- CO_2 sensing												
Hardware development												
Lab-based hardware testing												
D: Testing and Validation												
System-level testing protocol and simulation development												
System-level controlled lab testing												
System-level Field Trial Testing and Simulation Validation												

Metrics

The particular needs and requirements for these sensor technologies to be successful and make an impact in these markets are addressed in the following sections. As sensors differ in deployment requirements, fields of view, communications/hour, etc., we have written these metrics to be technology agnostic. This means that the sensors, at early stages, will have to be simulated using tools that include control schemes and building simulations. There are no specific requirements as to the method and tools used for doing this, as long as they are well described and documented.

For illustration regarding these failure metrics we provide an example of simple analyses with simplifying assumptions to establish a baseline for the level of detail required to be included in submissions in Section I.G of the FOA. We emphasize that more complex and accurate simulations with more "real-life" data using multiple deployment scenarios will be required as the program progresses. In general, submissions should incorporate milestones at the 6 month mark providing extensive baseline simulations of required performance and at the 2 year mark provide simulations that incorporate actual detector system measurements showing clear progress towards the final metrics of the program.

Category A: Residential occupancy

For the residential market, there is a particular sensitivity to perceivable "false negatives" – when a sensor does not detect that the space is inhabited such that the temperature setbacks are triggered, which risks making the occupant becoming uncomfortable, and thus harming the user adoption of the technology. The Program requirement is 2 or fewer of these "failure events" a year, and a more detailed explanation of this requirement can be found in Section I.G of the FOA. "False positives", on the other hand, reduce the energy saved by having the temperature setbacks reversed when the domicile is unoccupied, and are less detrimental to user adoption. As long as the energy saved can be shown to be at least 30%, there is more flexibility for error for this case. This "Energy Savings" metric indicates energy savings directly resulting from deployment of the human presence sensors or people counters in a real-world scenario, using existing control systems. These metrics must be met including households occupied by both humans and pets.[21]

The price metric calculation can be found in Section I.F of the FOA. Other requirements relate to the specific needs to ensure large-scale adoption.

Table 2. Metrics and Requirements: Category A

Category A Performance Metrics:	
Demonstrated Energy Savings	$\geq$ 30%
Number of Failures (false negatives)/year, 95% confidence	$\leq$ 2

[21] In 2012, 36% of households had a dog, and 30% of households had a cat : 2012 US Pet Ownership and Demographics Sourcebook, via the AVMA

Minimum Maintained & Recalibration Requirement		≥ 3 years
Price Metrics:		
Residential Price:	≤ 0.06 $/sqft	Total sensor system price including installation/commissioning
General Requirements for all Hardware:		
No Beacons Required	For example, smartphones or any other wearable tech	
Communication Protocol for output to Control System	Open-source and secure	
Privacy concerns addressed	Deliver plan for addressing privacy (or perceived privacy) barriers to deployment and use (For example, demonstrating adherence to wiretapping laws in all states)	
Security and Flexibility	No cloud computation – all computation to occur locally at sensors or within local sensor system	
Ease of self-commissioning	A plan must be presented. Example: inclusion of simple screen, app, LED indicators, or the like available to a user such that the system can be easily self-tested upon startup, and the number of occupants validated; "peel, stick, and button press" technology that does not require skilled labor for placement or installation	
Testing and Validation		
Ensuring adoption diversity	Ensure a varied number of skin colors, body types, and physical ability levels (i.e. use of wheelchairs and the like) are adequately represented in both simulation and laboratory-scale testing scenarios	
Ensure adoption flexibility	Validation protocols must be developed for at least three distinct scenarios in the residential sector, including household pets, for both the simulation and laboratory-scale testing scenarios.	

Category B: Commercial people counting

For the commercial market, accuracy of people counting is described using a different method. Here, "failures" for the commercial scenario are miscounts *10% lower* than the true count, with a 95% probability of no more than 4 failures per year. This strict requirement is crucial for ensuring that ventilation meets ASHRAE standards[22], which state that a +/- 10% error is in line with the balancing tolerance included with the standard for ventilation requirements.

[22] Standard 62.1-2016, Table 8.2

Miscounts higher will reduce the amount of energy saved via over-ventilation, but do otherwise not pose any risk, and are captured in the "Energy Savings" metric (similar to false-positives in Category A).

In order to satisfy these requirements, similar procedures are used as for the residential case. It is encouraged, but not required that Concept Papers provide initial preliminary simulations that justify the feasibility of the proposed technical approach to achieve the energy savings and failure rate metrics. This will be required with Full Application submissions, please see Section IV of the FOA. A very simple methodology is also shown in Section I.G of the FOA.

Table 3. Metrics and Requirement: Category B

Category B Performance Metrics:		
Demonstrated Energy Savings		≥ 30%
Commercial: Number of Failures (10% lower than true count)/year, 95% confidence		≤ 4
Minimum Maintained & Recalibration Requirement		≥ 3 years
Price Metrics:		
Commercial Price:	≤ 0.08 $/sqft	Total sensor system price including installation/commissioning
General Requirements for all Hardware:		
No Beacons Required	For example, smartphones or any other wearable tech	
Communication Protocol for output to Control System	Open-source and secure	
Privacy concerns addressed	Deliver plan for addressing privacy (or perceived privacy) barriers to deployment and use (For example, demonstrating adherence to wiretapping laws in all states)	
Security and Flexibility	No cloud computation – all computation to occur locally at sensors or within local sensor system	
Ease of self-commissioning	A plan must be presented. Example: inclusion of simple screen, app, led indicators, or the like available to a user such that the system can be easily self-tested upon startup, and the number of occupants validated; "peel, stick, and button press" technology that does not require skilled labor for placement or installation	
Testing and Validation		
Ensuring adoption diversity	Ensure a varied number of skin colors, body types, and physical ability levels (i.e. use of wheelchairs and the like) are adequately represented in both simulation and laboratory-scale testing scenarios	

Ensure adoption flexibility	Validation protocols must be developed for at least three distinct scenarios in the commercial sector for both the simulation and laboratory-scale testing scenarios

Category C: Commercial CO_2 sensing

As described in previous sections, CO_2 sensors can be used in conjunction with commercial sensor systems as needed in order to achieve end user adoption. These sensors must meet the price requirements of the commercial sensor systems, with the following technical requirements, which resolve issues with calibration and drift over time:

Table 4. Metrics: Category C

Price Metrics:		
Commercial Price:	≤ 0.08 $/sqft	Total sensor system price including installation/commissioning
CO2 Sensor Metrics:		
Sensor Range and Precision	Dynamic range 400-2000 ppm, 30 ppm precision	
Drift	< 10 ppm / year	
Lifetime	≥ 3 years	
Selectivity	< 5 ppm change for common gasses such as N_2, H_2O, and VOCs commonly found inside buildings	
Time response	< 1 minute	

Category D: Testing and Validation

Testing and validation protocols, simulation tools, and real-world field testing are needed to enable adoption of the sensing technologies in this FOA. Here, these must be developed and deployed for both residential and commercial cases, with three distinct use cases in each. For residential spaces, this could mean older homes built in the ~1940s, housing stock from the 1970-80s with very different floor plans, a modern very open-plan home, and the like; for commercial spaces, this could be satisfied by demonstrating the technology in an open office scenario with conference rooms, a closed individual office scenario with conference rooms, or an academic building with classrooms and an auditorium mixed with offices. The commercial space must use building examples from at least two distinct sub-markets (for example, office and lodging, office and academic, etc.) ARPA-E intends that this part of the program will develop tools and field testing protocol that can be utilized by this sensor-driven HVAC energy reduction field in general.

As described in Table 1 above, there are three components to this Category. A simulation tool including three distinct use cases for both residential and commercial scenarios will be developed; this simulation tool will be tested in controlled laboratory environments where ground truth is independently measured (A significant overlap with the laboratory-scale testing for Categories A and B, which would be convenient for collaboration, is noted); and finally, the last five quarters consist of testing human presence and people counting sensor systems in the field, using the testing protocols developed (field testing arrangements would be developed in earlier quarters prior to deployment).

Table 5. Testing and Validation: Category D

Testing and Validation	
Testing Accuracy	Sufficient to clearly validate the performance metrics for Categories A and B, including both energy savings and failure rates. A method for establishing initial ground truth must be fully described.
Ensuring adoption diversity	Ensure a varied number of skin colors, body types, and physical ability levels (i.e. use of wheelchairs and the like) are adequately represented in both simulation and real world testing scenarios.
Ensure adoption flexibility	Validation protocols must be developed for at least three distinct scenarios in the residential sector, including household pets, for both the simulation and real world testing scenarios. For the commercial sector, simulations and real world testing for two distinct sub-markets must be developed and performed, with at least 3 distinct floor plans included in total. (For example, a large open office layout including conference rooms; a closed door office layout including conference rooms; a medium-range lodging hotel-type layout.) A set of occupancy data must also be developed that tests these different scenarios such that they represent real-world use.

F. TECHNICAL SUPPLEMENT: CALCULATIONS OF ENERGY SAVINGS, IMPACT AND PRICE METRIC DEVELOPMENT

Based on ARPA-E evaluation of existing studies using simulations or experimental systems with testing, ARPA-E has determined that a potential savings of 30% of baseline HVAC usage is a viable target for both the Commercial and Residential sectors. There are many factors that must be considered in the determination of the exact level of energy savings. A sample of published work addressing many of these (including both theoretical and experimental scenarios) is provided in Table 6 below. Provided high accuracy human sensing and people

counting data as envisioned by this FOA, HVAC control systems will potentially respond with even better precision and time granularity than even the best case scenarios in Table 6, and thus a 30% energy savings goal appears to be reasonable and achievable.

Table 6. Select publications demonstrating theoretical and limited deployment of occupancy sensors

Target Sector	Savings Estimate	Technical Study Details	Source
Residential	27.92% of HVAC load	Simulation: Theoretical Rule-based control strategies for Temperature and PMV	Homod, RZ, Sahari KSM. EnergyBuild 60 (2013).
Residential	28% of HVAC load	One wired movement sensor in every room + a wired door switch on each exterior doorway to the home.	Lu, J, et al., "The Smart Thermostat: Using Occupancy Sensors to save energy in homes", SenSys '10 Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems, Zurich, Switzerland Nov. 03-05, 2009, Pages 211-224
Residential	10-30% of HVAC load	Programmable Thermostat – theoretical performance	U.S. Environmental Protection Agency. Summary of Research Findings from the Programmable Thermostat Market. Memo to Manufacturers on Programmable Thermostat Specification Review. 2003, Washington, D.C.: U.S. Environmental Protection
Commercial	37% of HVAC load	Energy Plus Simulations – Including various climate breakouts	J. Zhang, G Liu, MR Brambley, RG Lutes, PNNL- 22072, 2013
Commercial	10-15% of HVAC load	Wired entryway and motion sensors, 10 commercial Offices over a 10 week period	Agarwal, et al, "Occupancy-driven energy management for Smart Building Automation", BuildSys 2010 November 2, 2010, Zurich, Switzerland. Copyright c 2010 ACM 978-1-4503-0458-0/10/11/02
Commercial	14% of HVAC load	Wired Cameras, Large multi-function building	Erickson, et al., Proceedings of the 1st ACM Workshop On Embedded Sensing Systems For Energy-Efficiency In Buildings (BuildSys) 2009

Commercial	Overall > 20% Aggressive cases 35-75% of HVAC load	Modelling of large Office Building in multiple climate scenarios using accurate scheduling	Fernandez, et al., PNNL-21569, 2012

Magnitude of Impact by Sector and Type of Building

Here, the potential energy savings possible via the full adoption of the proposed technology is demonstrated, and further break down the HVAC market to demonstrate how adoption will be driven. While HVAC usage represents the largest opportunity for energy savings at the present time, appealing secondary markets for occupancy sensing and people counting technologies would be for plug-loads[23], enhancing building security and higher productivity, and enabling building space optimization – a rapidly growing and very high value field. Finally, enabling demand response to be adopted in the residential sector could be a very significant additional benefit, where various demand response schemes could be adjusted to only occur when a home had no occupants. This is an example of how true occupancy sensing and people counting will potentially revolutionize the way buildings communicate with and respond to their occupants.

Using a 30% reduction in HVAC energy usage in buildings as described above, the potential energy savings impacts are significant. Tables 7 and 8 below show total energy usage and potential savings for both the residential and commercial sectors, divided into several sub-sectors. All calculations are performed at an adoption rate of 100%. Certain sectors are highlighted in green that appear to present the lowest barriers to adoption, and these sectors to drive the testing and validation plans for this FOA are encouraged.

Table 7. Residential Energy Usage and Potential Savings, in quad BTUs [From CBECS, 2012]

Housing Unit Type	ALL U.S. RESIDENTIAL BUILDING STOCK	
	Total Energy Usage	30% ENERGY SAVINGS
Single-Family: Detached	5.163	1.549
Single-Family: Attached	0.372	0.112

[23] In commercial spaces, the Dept. of Energy CBECS database showed an overall growth of 115% per year over the 2003-2012 time period (CBECS 2003, CBECS 2012), with much higher growth in specific sectors

Multi-Family: 2-4 Unit Buildings	0.473	0.142
Multi-Family: 5 or More Unit Buildings	0.682	0.205
Mobile Homes	0.363	0.109
Total All Building Usage	**7.053**	**2.116**
Total Priority Segments only	**5.535**	**1.660**

For the residential case, the energy savings are straightforward and result from the usage of moderate temperature setbacks (for example, 62/78 F). This would equal over a quad and a half of savings for the single family housing sector, a key target for this FOA.

For the commercial case, an additional breakdown ("weighted for VAV") in which this technology is only applied to buildings that are estimated to have VAV systems (based on 2012 CBECS estimates) is added. This is a conservative estimate; as building stock is replaced, the percentage of buildings with VAV systems will stand to increase with time, however, this gives us a "lower bound" target for commercial savings estimates that ARPA-E believes is reasonable to estimate a potential impact range.

The impact range forecasted for this program is based upon the targeting of specific key sectors in which occupancy sensing represents a realistic option (based on both potential savings and prospective ease of implementation). The rows highlighted in green in Tables 7 and 8 identify key sectors in which ARPA-E foresees early or especially impactful adoption of advanced sensor technology, with lower barriers to entry. Cumulatively they represent approximately 2.6 quadrillion BTUs ("quads") of energy savings in a 100% adoption scenario, or ~ 2.1 quads of savings if only those commercial buildings with current VAV systems installed adopt advanced sensors (based on a 30% savings target per building).

Table 8. Commercial Energy Usage and Potential Savings, in Quad BTUs [From CBECS, 2012].

		Current VAV Buildings Only			Current VAV Buildings Only
Principal Building Activity	ALL U.S. COMMERCIAL BUILDING STOCK				
	Total HVAC Energy Usage			**30% HVAC Energy Savings**	
Education	0.81	0.38		0.24	0.11

Food sales	0.09	0.01		0.03	0.00
Food service	0.25	0.07		0.07	0.02
Health care-inpatient	0.50	0.40		0.15	0.12
Health care-outpatient	0.20	0.16		0.06	0.05
Lodging	0.36	0.12		0.11	0.03
Mercantile/ Retail	0.87	0.10		0.3	0.03
Office	1.37	0.67		0.41	0.20
Public assembly	0.54	0.25		0.16	0.08
Public order and safety	0.10	0.05		0.03	0.01
Religious worship	0.17	0.08		0.05	0.02
Service	0.22	0.04		0.07	0.01
Warehouse and storage	0.27	0.05		0.08	0.01
Other/ Vacant	0.24	-		0.07	-
Total All Building Usage	**5.98**	**2.38**		**1.80**	**0.71**
Total Priority Segments only	**3.08**	**1.42**		**0.92**	**0.43**

Single-family home and large/medium office sector segments are identified as the greatest drivers of savings, as they have the largest potential impact footprint and the best existing infrastructure to support the implementation of these human presence and counting sensors (programmable thermostats, high penetration of VAV systems in a cyclically occupied building). Outside of this, other high value early market adopters include the education and public assembly sectors, which also have large energy footprints and wide variations in occupancy throughout an average day, lending themselves to high savings potential if people sensing is correctly implemented. Finally, the lodging sector has already begun experimenting with human presence in hotel room spaces, and could benefit greatly from having improved (and lower cost) capabilities on this front. It is crucial that proposed technologies demonstrate impact in multiple types of floorplans for the residential sector, and multiple types of segments for the commercial sector.

Price Metric Development

Identifying the key barriers to the adoption of occupancy-sensing and people counting technologies is crucial. One of the most important barriers to user adoption is price – inclusive of hardware, installation, and commissioning. Other barriers are the accurate validation of energy savings, concerns about privacy (true or perceived), legal restrictions (such as wiretapping or other public privacy laws), and security. These others barriers are addressed Sections I.D and I.E of the FOA, and a set of guidelines included to ensure the technologies proposed to this FOA will address these issues. A thorough description of the desired price metrics are described here.

Price considerations must include not just the price of the hardware, but installation, commissioning, and upkeep. Here, price targets are defined simply by a one year return on investment (ROI) considering an average energy cost, delivering a 30% reduction in HVAC energy usage. A path toward meeting these targets must be shown at scale (scale = 1 million units or more). The cost of the control "system" (a thermostat), or the ability to interface to an existing control system (programming a VAV system) has also been subtracted out. These numbers are general guidelines, but given the aggressive one-year ROI, there is still quite a bit of room for customer acceptability.

After taking these criteria into account the price targets that will be utilized for the purposes of this FOA are $0.08/sqft for commercial applications, and $0.06/sqft for residential applications. An overview of how these numbers were calculated is provided below in Table 9 for reference.

These price targets are technology limiting. Any wired installations require semi-specialized labor that drives up cost significantly. Technical platforms that do not require wired installation (say, a long-life battery powered distributed sensor network), that could be self-installed and need little to no commissioning, with little to no maintenance; such a system could have the potential of reaching the price metrics in this FOA are encouraged. Even if a wall-powered hub was required, or fewer distributed, non-line of sight sensors were required, as long as the power budget was so low as to still enable a 30% energy savings, such a system could be transformative and not require high installation costs.

Table 9. Calculation of Price Metrics for Residential and Commercial Sensor Systems

Commercial Price Build			Residential Price Build		
Input Variable	Estimate	Reference Info	Input Variable	Estimate	Reference Info

Building Size (sqft)	15,552	Average commercial building size, based on CBECS 2012 data	House Size (sqft)	2000	Average residential single family home size based on RECS data
Total Value to Customer	$ 2,700	Based on 30% savings, $0.10/kwh, $0.03/therm, 1 Year Payback requirements	Total Value to Customer	$ 260	Based on 30% savings, $0.10/kwh, $0.03/therm, 1 Year Payback requirements
Cost to integrate Sensors into existing infrastructure	$ 1,500	Generalized number for software adjustment to existing VAV system control box to enable sensor based control	Wifi Programmable Thermostat Cost	$ 140	Median of commercially available models on Amazon.com
Allowable Sensor Price	$ 1,200	Amount of total value remaining to customer after integration	Allowable Sensor Price	$ 120	Amount of total value remaining to customer after cost of Thermostat is removed
Sensor Target per square ft (excludes labor)	**$ 0.08**	$/SF required to yield a 1 year payback after non-sensor costs are accounted for	Sensor Target Per SF	**$ 0.06**	$/SF required to yield a 1 year payback after non-sensor costs are accounted for

G. TECHNICAL SUPPLEMENT: EXAMPLE CALCULATIONS OF PERFORMANCE

Residential failures per year metric

The residential failures per year metric is driven by the need to assure high adoption rates, with the perception of discomfort to be clearly avoided. The metric as stated in Table 2 is quite stringent: 2 failures per year at the end of the program. Failure in the context of residential dwellings is defined as the possibility occupants finding themselves in an uncomfortable environment due to the detector system misreporting the presence of occupants. This is a system-level goal, driven by the occupancy sensors giving the correct output. There may be systems using multiple redundant networked sensors, or systems using very few to one – these would all result in very different individual sensor metrics. Regardless of what is used, the sensor system itself must send information to the control system that is in accordance with the metrics in Table 2.

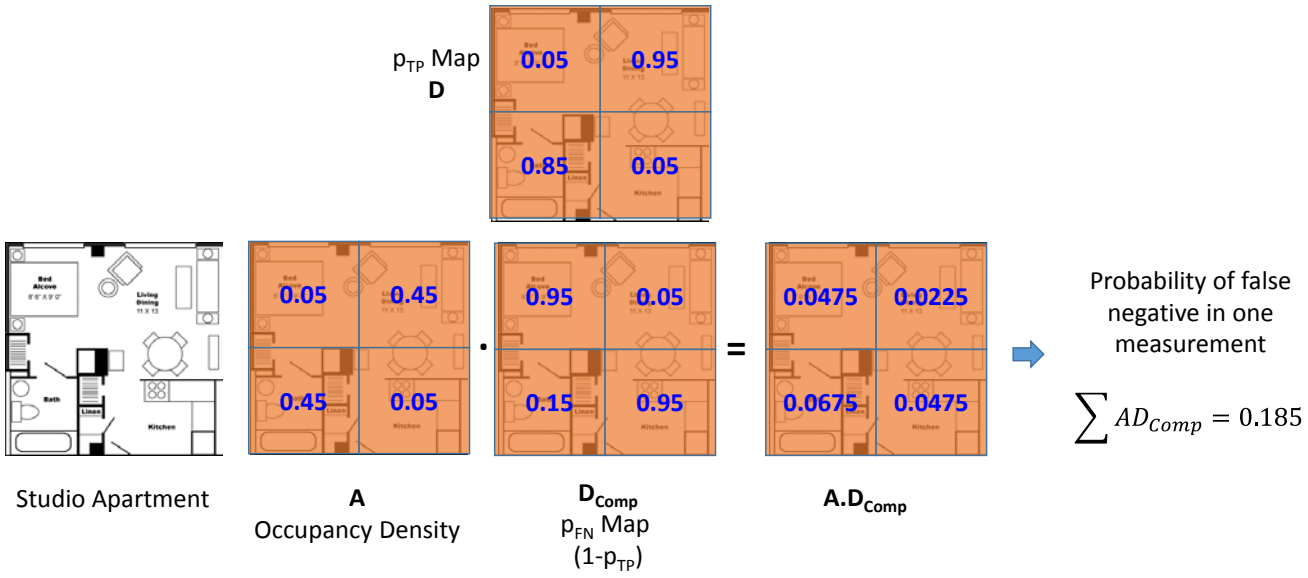

Figure 1. Schematic illustrating the estimation of the probability for false negatives for a single measurement.

As illustration the following analysis is provided. Given a floor plan of a representative extremely simple residential dwelling, knowledge of the spatial occupancy density ($A(x,y)$) at some point in time and the spatial detectivity of the detector system ($D(x,y)$) the probability of false negative p_{FN} could be calculated at this time as (see also Figure 1):

$$p_{FN}(t) = \sum_{x,y} A(x,y) \cdot (1 - D(x,y))$$

Schematic illustrating the estimation of the probability for false negatives for a single measurement.

A more detailed calculation would calculate these probabilities for each time t (appropriately weighed by the probability of occupants being present at that time) and calculate the probability for different number of failures in a year. In what follows, to simplify the model, assume that this probability is constant in time, that the proper time interval to consider is half an hour and that the dwelling is occupied half of the time. Under these assumptions the number of measurements n is 365 x 24 x 0.5 x 2 = 8760, so that the probability of having no more than K failures can be calculated as:

$$P(k \leq K) = \sum_{k=0}^{K} \binom{n}{k} p^{n-k}(1-p)^k$$

Now the probability can be estimated of having no more than K failures per year as a function of the detector system probability of true positives p_{TP}. Figure 1 shows such a calculation

where the probability of a current detector with an average of 1 failure per week is shown for reference. This calculation shows that the requirement for the probability of detection (p_{TP}) for a system to have 95% probability of having no more than 2 failures per year would be in the order of 0.9995.

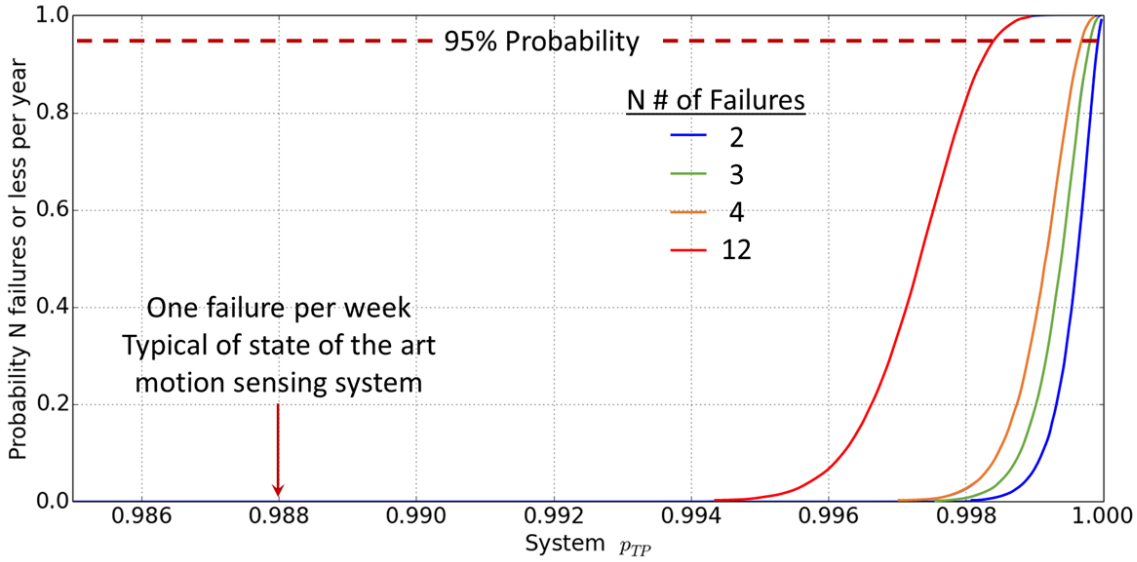

Figure 2. Plot of the probability of N failures or less per year as a function of system probability of true positives (under assumptions given in the text)

These calculations are offered as an illustration of the stringent requirements imposed by the metrics in this FOA. The ultimate test for satisfying the requirement is achieving the 2 failures per year rate. The testing and validation part of this FOA includes simulation work demonstrating a path toward achieving the metric. This will require an initial 6 month simulation with reasonable estimates and more thorough baseline data than that demonstrated here in this simple example, and a 2nd year simulation informed by experimental measurements in suitable conditions (representative dwelling, verified occupancy model, sensor measurements, etc.). Models used by the Applicants may have significantly different assumptions than the ones presented here, in which case a detailed explanation is expected, but the end prediction of the models must justify the final metric of 95% probability of no more than 2 failures per year.

Commercial failures per year metric

For the commercial use case, the number of occupants will be used to identify the optimal ventilation rate for an HVAC zone. As an example of a simple preliminary analysis, similar to the above residential case, consider a detector system with a Gaussian distribution response for a room occupied by *m* individuals. This can be represented as a normal distribution with mean μ

equal to m and standard deviation σ proportional to m,:

$$N(\mu, \sigma), \qquad \mu = m, \qquad \sigma = am$$

Under this assumption, the probability that the detector system will report a number of occupants fewer than 10% of the true value can be computed as a function of a which is detector system dependent. Note also that under these assumptions this probability is independent of m and the spatial configuration of the HVAC zone, which may not be the case in general. Similar to the residential case, assuming the detector system reports every half an hour, the 95% probability of the detector system achieving the goal of no more than 4 failures per year could be calculated: this would require a probability of detection of 0.998. Models used by the Applicants may have significantly different assumptions and dependencies than the simple ones presented here, in which case a detailed explanation is expected, but the end prediction of the models must justify the final metric of 95% probability of achieving no more than 4 failures per year. Applicants are encouraged to reference the above parameters and the effects changes in number of occupants in the zone, spatial configuration of occupants within the zone, occupant trajectories, structural variations within a zone, and other transients within the environment have on the proposed system's ability to achieve the 95% confidence interval.

The above analyses of the presence and occupant counting offered here are illustrations only, and Applicants are free to present other analyses with different assumptions as long as a detailed justification for their methodology is included in the submission.

H. SUPPLEMENT: RESEARCH INVOLVING THE USE OF HUMAN OR ANIMAL SUBJECTS

Any research funded under this FOA that involves the use of human or animal subjects will be subject to all applicable requirements with respect to those activities, and it will be the responsibility of each award recipient to ensure compliance with those requirements.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $20 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 5-15 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

Individual awards may vary between $250,000 and $10 million.

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be December 2017, or as negotiated.

ARPA-E encourages submissions stemming from ideas that still require proof-of-concept R&D efforts as well as those for which some proof-of-concept demonstration already exists.

Submissions requiring proof-of-concept R&D can propose a project with the goal of delivering on the program metric at the conclusion of the period of performance. These submissions must contain an appropriate cost and project duration plan that is described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. If awarded, such projects should expect a rigorous go/no-go milestone early in the project associated with the proof-of-concept demonstration. Alternatively, submissions requiring proof-of-concept R&D can propose a project with the project end deliverable being an extremely creative, but partial solution. However, the Applicants are required to provide a convincing vision how these partial solutions can enable the realization of the program metrics with further development.

Applicants proposing projects for which some initial proof-of-concept demonstration already exists must submit concrete data that supports the probability of success of the proposed project.

ARPA-E will provide support at the highest funding level only for submissions with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

ARPA-E will accept only new submissions under this FOA. Applicants may not seek renewal or supplementation of their existing awards through this FOA.

ARPA-E plans to fully fund your negotiated budget at the time of award.

B. ARPA-E FUNDING AGREEMENTS

Through Cooperative Agreements, Technology Investment Agreements, and similar agreements, ARPA-E provides financial and other support to projects that have the potential to realize ARPA-E's statutory mission. ARPA-E does not use such agreements to acquire property or services for the direct benefit or use of the U.S. Government.

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[24] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.C below.

[24] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[25]

Cooperative Agreements involve the provision of financial or other support to accomplish a public purpose of support or stimulation authorized by Federal statute. Under Cooperative Agreements, the Government and Prime Recipients share responsibility for the direction of projects.

ARPA-E encourages Prime Recipients to review the Model Cooperative Agreement, which is available at http://arpa-e.energy.gov/arpa-e-site-page/award-guidance.

2. FUNDING AGREEMENTS WITH FFRDCS/DOE LABS, GOGOS, AND FEDERAL INSTRUMENTALITIES

Any Federally Funded Research and Development Centers (FFRDC) involved as a member of a Project Team must provide the information requested in the "FFRDC Lab Authorization" and "Field Work Proposal" section of the Business Assurances & Disclosures Form, which is submitted with the Applicant's Full Application.

When a FFRDC/DOE Lab (including the National Energy Technology Laboratory or NETL) is the *lead organization* for a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple agreements, the FFRDC/DOE Lab is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

When a FFRDC/DOE Lab is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple agreements, the Prime Recipient under the Cooperative Agreement is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

Funding agreements with DOE/NNSA FFRDCs take the form of Work Authorizations issued to DOE/NNSA FFRDCs through the DOE/NNSA Field Work Proposal system for work performed under Department of Energy Management & Operation Contracts. Funding agreements with non-DOE/NNSA FFRDCs, GOGOs (including NETL), and Federal instrumentalities (e.g., Tennessee Valley Authority) will be consistent with the sponsoring agreement between the U.S. Government and the Laboratory. Any funding agreement with a FFRDC or GOGO will have

[25] The Prime Recipient is the signatory to the funding agreement with ARPA-E.

similar terms and conditions as ARPA-E's Model Cooperative Agreement (http://arpa-e.energy.gov/arpa-e-site-page/award-guidance).

Non-DOE GOGOs and Federal agencies may be proposed to provide support to the project team members on an applicant's project, through a Cooperative Research and Development Agreement (CRADA) or similar agreement.

3. TECHNOLOGY INVESTMENT AGREEMENTS

ARPA-E may use its "other transactions" authority under the America COMPETES Reauthorization Act of 2010 or DOE's "other transactions" authority under the Energy Policy Act of 2005 to enter into Technology Investment Agreements (TIAs) with Prime Recipients. ARPA-E may negotiate a TIA when it determines that the use of a standard cooperative agreement, grant, or contract is not feasible or appropriate for a project.

A TIA is more flexible than a traditional financial assistance agreement. In using a TIA, ARPA-E may modify standard Government terms and conditions. See 10 C.F.R. § 603.105 for a description of a TIA.

In general, TIAs require a cost share of 50%. See Section III.B.2 of the FOA.

C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

ARPA-E is substantially involved in the direction of projects from inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- Project Teams must adhere to ARPA-E's agency-specific and programmatic requirements.
- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- During award negotiations, ARPA-E Program Directors and Prime Recipients mutually establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. In addition, ARPA-E will negotiate and establish "Go/No-Go" milestones for each project. If the Prime Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Contracting Officer, ARPA-E may – at its discretion - renegotiate the statement of

project objectives or schedule of technical milestones and deliverables for the project. In the alternative, ARPA-E may suspend or terminate the award in accordance with 2 C.F.R. §§ 200.338 and 200.339.

- ARPA-E may provide guidance and/or assistance to the Prime Recipient to accelerate the commercial deployment of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits to provide mentoring and networking opportunities for Prime Recipients. ARPA-E may also organize and sponsor events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E may establish collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[26] as the lead for a Project Team,[27] or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[28] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

FFRDCs/DOE Labs are eligible to apply for funding as the lead organization for a Project Team or as a member of a Project Team that includes institutions of higher education, companies, research foundations, or trade and industry research collaborations, but not as a Standalone Applicant.

[26] A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.
[27] The term "Project Team" is used to mean any entity with multiple players working collaboratively and could encompass anything from an existing organization to an ad hoc teaming arrangement. A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.
[28] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

State, local, and tribal government entities are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

Federal agencies and instrumentalities (other than DOE) are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

3. FOREIGN ENTITIES

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. Foreign entities must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed or to be formed) under the laws of a State or territory of the United States to receive funding. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate. The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

Consortia, which may include domestic and foreign entities, must designate one member of the consortium as the consortium representative to the Project Team. The consortium representative must be incorporated in the United States. The eligibility of the consortium will be determined by reference to the eligibility of the consortium representative under Section III.A of the FOA. Each consortium must have an internal governance structure and a written set of internal rules. Upon request, the consortium entity must provide a written description of its internal governance structure and its internal rules to the Contracting Officer (ARPA-E-CO@hq.doe.gov).

Unincorporated consortia must provide the Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This collaboration agreement binds the individual consortium members together and shall include the consortium's:

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;
- Provisions for members' cost sharing contributions; and

- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

B. COST SHARING[29]

Applicants are bound by the cost share proposed in their Full Applications.

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime Recipient must provide at least 20% of the Total Project Cost[30] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[31]

2. INCREASED COST SHARE REQUIREMENT

Large businesses are strongly encouraged to provide more than 20% of the Total Project Cost as cost share. ARPA-E may consider the amount of cost share proposed when selecting applications for award negotiations (see Section V.B.1 of the FOA).

Under a Technology Investment Agreement, the Prime Recipient must provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this minimum cost share requirement, as appropriate.

3. REDUCED COST SHARE REQUIREMENT

ARPA-E has reduced the minimum cost share requirement for the following types of projects:

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is required to provide at least 5% of the Total Project Cost as cost share.

- Small businesses – or consortia of small businesses - will provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the "Cost Share Grace Period").[32] If the project is continued beyond the Cost Share

[29] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[30] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.
[31] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.
[32] Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards).

Grace Period, then at least 10% of the Total Project Cost (including the costs incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80%, but less than 100%, of the total work under the funding agreement (as measured by the Total Project Cost) the Project Team are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.[33]

- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs are required to provide at least 5% of the Total Project Cost as cost share.

- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80%, of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.

- Projects that do not meet any of the above criteria are subject to the minimum cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

4. LEGAL RESPONSIBILITY

Although the cost share requirement applies to the Project Team as a whole, the funding agreement makes the Prime Recipient legally responsible for paying the entire cost share. The Prime Recipient's cost share obligation is expressed in the funding agreement as a static amount in U.S. dollars (cost share amount) and as a percentage of the Total Project Cost (cost share percentage). If the funding agreement is terminated prior to the end of the period of performance, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

The Prime Recipient is solely responsible for managing cost share contributions by the Project Team and enforcing cost share obligations assumed by Project Team members in subawards or related agreements.

Applicants that are small businesses will be required to certify in the Business Assurances & Disclosures Form that their organization meets the SBA's definition of a small business under at least one NAICS code.

[33] See the information provided in previous footnote.

5. COST SHARE ALLOCATION

Each Project Team is free to determine how much each Project Team member will contribute towards the cost share requirement. The amount contributed by individual Project Team members may vary, as long as the cost share requirement for the project as a whole is met.

6. COST SHARE TYPES AND ALLOWABILITY

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G.1 of the FOA.

Project Teams may provide cost share in the form of cash or in-kind contributions. Cash contributions may be provided by the Prime Recipient or Subrecipients. Allowable in-kind contributions include but are not limited to personnel costs, indirect costs, facilities and administrative costs, rental value of buildings or equipment, and the value of a service, other resource, or third party in-kind contribution. Project Teams may use funding or property received from state or local governments to meet the cost share requirement, so long as the funding or property was not provided to the state or local government by the Federal Government.

The Prime Recipient may not use the following sources to meet its cost share obligations:

- Revenues or royalties from the prospective operation of an activity beyond the period of performance;
- Proceeds from the prospective sale of an asset of an activity;
- Federal funding or property (e.g., Federal grants, equipment owned by the Federal Government); or
- Expenditures that were reimbursed under a separate Federal program.

In addition, Project Teams may not use independent research and development (IR&D) funds[34] to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment Agreements.

Project Teams may not use the same cash or in-kind contributions to meet cost share requirements for more than one project or program.

[34] As defined in Federal Acquisition Regulation Subsection 31.205-18.

Cost share contributions must be specified in the project budget, verifiable from the Prime Recipient's records, and necessary and reasonable for proper and efficient accomplishment of the project. Every cost share contribution must be reviewed and approved in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

Applicants may wish to refer to 2 C.F.R. Parts 200 and 910, and 10 C.F.R Part 603 for additional guidance on cost sharing, specifically 2 C.F.R. §§ 200.306 and 910.130, and 10 C.F.R. §§ 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

Because FFRDCs are funded by the Federal Government, costs incurred by FFRDCs generally may not be used to meet the cost share requirement. FFRDCs may contribute cost share only if the contributions are paid directly from the contractor's Management Fee or a non-Federal source.

Because GOGOs/Federal Agencies are funded by the Federal Government, GOGOs/Federal Agencies may not provide cost share for the proposed project. However, the GOGO/Agency costs would be included in Total Project Costs for purposes of calculating the cost-sharing requirements of the applicant.

8. COST SHARE VERIFICATION

Upon selection for award negotiations, Applicants are required to provide information and documentation regarding their cost share contributions. Please refer to Section VI.B.3 of the FOA for guidance on the requisite cost share information and documentation.

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

- The Applicant meets the eligibility requirements in Section III.A of the FOA;
- The Concept Paper complies with the content and form requirements in Section IV.C of the FOA; and

- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Concept Papers found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Concept Papers, including Concept Papers submitted through other means, Concept Papers submitted after the applicable deadline, and incomplete Concept Papers. A Concept Paper is incomplete if it does not include required information. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Full Applications are deemed compliant if:

- The Applicant submitted a compliant and responsive Concept Paper;
- The Applicant meets the eligibility requirements in Section III.A of the FOA;
- The Full Application complies with the content and form requirements in Section IV.D of the FOA; and
- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Full Applications found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Full Applications, including Full Applications submitted through other means, Full Applications submitted after the applicable deadline, and incomplete Full Applications. A Full Application is incomplete if it does not include required information and documents, such as Forms SF-424 and SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploads its response to ARPA-E eXCHANGE by the deadline stated in the FOA; and
- The Replies to Reviewer Comments comply with the content and form requirements of Section IV.E of the FOA.

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments, including Replies submitted through other means and Replies submitted after the applicable deadline. ARPA-E will not extend the submission deadline for Applicants that fail to submit required

information due to server/connection congestion. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

2. RESPONSIVENESS CRITERIA

ARPA-E performs a preliminary technical review of Concept Papers and Full Applications. The following types of submissions may be deemed nonresponsive and may not be reviewed or considered:

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Submissions for proposed technologies that are not transformational, as described in Section I.A of the FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress.
- Submissions that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.
- Submissions that describe a technology but do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

Submissions that propose the following will be deemed nonresponsive and will not be merit reviewed or considered:

- New HVAC system controls, pure control algorithms development, and/or improvements to HVAC equipment.
- Sensor systems that use a beacons and/or electronic asset tags – this includes such technologies that detect the presence of a particular identifiable item (say, a

smartphone, or a Radio Frequency IDentification RFID tags), a wearable item, or the like rather than the human body.

- Sensor systems that require direct human intervention (i.e. an "app" running on a computation device that requires user input in any way).
- "Geofencing" (GPS accessing) or Bluetooth tracking technologies that track the presence of a device such as smartphone rather than detecting building occupants.
- Sensor systems that use only motion as the sensing modality and cannot detect the presence of occupancy when motion ceases.
- Energy harvesting concepts as a power source when existing solutions can be used.

4. LIMITATION ON NUMBER OF SUBMISSIONS

ARPA-E is not limiting the number of submissions from Applicants. Applicants may submit more than one application to this FOA, provided that each application is scientifically distinct.

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

The first step in applying to this FOA is registration in ARPA-E eXCHANGE, ARPA-E's online application portal. For detailed guidance on using ARPA-E eXCHANGE, please refer to Section IV.H.1 of the FOA and the "ARPA-E eXCHANGE User Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

2. CONCEPT PAPERS

Applicants must submit a Concept Paper by the deadline stated in the FOA. Section IV.C of the FOA provides instructions on submitting a Concept Paper.

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria and program policy factors in Sections V.A.1 and V.B.1of the FOA.

ARPA-E will encourage a subset of Applicants to submit Full Applications. Other Applicants will be discouraged from submitting a Full Application in order to save them the time and expense of preparing an application submission that is unlikely to be selected for award negotiations. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. Unsuccessful Applicants should continue to submit innovative ideas and concepts to future FOAs.

3. FULL APPLICATIONS

Applicants must submit a Full Application by the deadline stated in the FOA. Applicants will have approximately 45 days from receipt of the Encourage/Discourage notification to prepare and submit a Full Application. Section IV.D of the FOA provides instructions on submitting a Full Application.

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Full Applications found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA.

4. REPLY TO REVIEWER COMMENTS

Once ARPA-E has completed its review of Full Applications, reviewer comments on compliant and responsive Full Applications are made available to Applicants via ARPA-E eXCHANGE. Applicants may submit an optional Reply to Reviewer Comments, which must be submitted by the deadline stated in the FOA. Section IV.E of the FOA provides instructions on submitting a Reply to Reviewer Comments.

ARPA-E performs a preliminary review of Replies to determine whether they are compliant, as described in Section III.C.1 of the FOA. ARPA-E will review and consider compliant Replies only. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be non-compliant.

5. PRE-SELECTION CLARIFICATIONS AND "DOWN-SELECT" PROCESS

Once ARPA-E completes its review of Full Applications and Replies to Reviewer Comments, it may, at the Contracting Officer's discretion, conduct a pre-selection clarification process and/or perform a "down-select" of Full Applications. Through the pre-selection clarification process or down-select process, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, written correspondence, or site visits that can be used to make a final selection determination. ARPA-E will not reimburse Applicants for travel and other expenses relating to pre-selection meetings or site visits, nor will these costs be eligible for reimbursement as pre-award costs.

ARPA-E may select applications for award negotiations and make awards without pre-selection meetings and site visits. Participation in a pre-selection meeting or site visit with ARPA-E does not signify that Applicants have been selected for award negotiations.

6. SELECTION FOR AWARD NEGOTIATIONS

ARPA-E carefully considers all of the information obtained through the application process and makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA. The Selection Official may select all or part of a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

Applicants are promptly notified of ARPA-E's selection determination. ARPA-E may stagger its selection determinations. As a result, some Applicants may receive their notification letter in advance of other Applicants. Please refer to Section VI.A of the FOA for guidance on award notifications.

7. MANDATORY WEBINAR

All selected Applicants, including the Principal Investigator and the financial manager for the project, are required to participate in a webinar that is held within approximately one week of the selection notification. During the webinar, ARPA-E officials present important information on the award negotiation process, including deadlines for the completion of certain actions.

B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424 and Budget Justification Workbook/SF-424A. A sample Summary Slide is available on ARPA-E eXCHANGE. Applicants may use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the template for the Summary Slide, the template for the Summary for Public Release, the template for the Reply to Reviewer Comments, and the template for the Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures Form is available on ARPA-E eXCHANGE.

C. CONTENT AND FORM OF CONCEPT PAPERS

The Concept Paper is mandatory (i.e. in order to submit a Full Application, a compliant and responsive Concept Paper must have been submitted) and must conform to the following formatting requirements:

- The Concept Paper must not exceed 4 pages in length including graphics, figures, and/or tables.
- The Concept Paper must be submitted in Adobe PDF format.
- The Concept Paper must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11 inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator's Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.

- The first paragraph must include the Lead Organization's Name and Location, Principal Investigator's Name, Technical Category, and Project Duration. Proposed Funding (Federal and Cost Share) is optional.

- Applicants may submit Concept Papers addressing Category A, B, C or any combination thereof. Applicants may also submit Concept Papers solely to Category D. Concept Papers submitted to Category D must be devoted solely for Category D. ARPA-E is not limiting the number of Applications that may be submitted by Applicants, provided that each Application is scientifically distinct. Thus, Applicants may submit a Concept Paper for Category A and/or B and/or C, plus a separate Concept Paper for Category D. However, a Concept Paper submitted to Category D may not identify any other technical Category, or else it will be found to be noncompliant.

Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section III.C of the FOA).

Each Concept Paper must be limited to a single concept or technology. Unrelated concepts and technologies must not be consolidated into a single Concept Paper.

A fillable Concept Paper template is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Concept Papers must conform to the content requirements described below. If Applicants exceed the maximum page length indicated above, ARPA-E will review only the authorized number of pages and disregard any additional pages.

1. CONCEPT PAPER

a. CONCEPT SUMMARY

- Describe the proposed concept with minimal jargon, and explain how it addresses the Program Objectives of the FOA.

b. INNOVATION AND IMPACT

- Clearly identify the problem to be solved with the proposed technology concept.

- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.

- Explain the concept's potential to be disruptive compared to existing or emerging technologies.

- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the Technical Performance Targets in Section I.E of the FOA.

c. PROPOSED WORK

- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives.

- Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.

- Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach. Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.

- Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?

- Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant.

- Estimated federal funds requested; total project cost including cost sharing.

d. TEAM ORGANIZATION AND CAPABILITIES

- Indicate the roles and responsibilities of the organizations and key personnel that comprise the Project Team.

- Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.

- Identify key capabilities provided by the organizations comprising the Project Team and how those key capabilities will be used in the proposed effort.

- Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

F. INTERGOVERNMENTAL REVIEW

This program is not subject to Executive Order 12372 (Intergovernmental Review of Federal Programs).

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

H. OTHER SUBMISSION REQUIREMENTS

1. USE OF ARPA-E eXCHANGE

To apply to this FOA, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx). ARPA-E will not review or consider applications submitted through other means (e.g., fax, hand delivery, email, postal mail). For detailed guidance on using ARPA-E eXCHANGE, please refer to the "ARPA-E eXCHANGE User Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

Upon creating an application submission in ARPA-E eXCHANGE, Applicants will be assigned a Control Number. If the Applicant creates more than one application submission, a different Control Number will be assigned for each application.

Once logged in to ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx), Applicants may access their submissions by clicking the "My Submissions" link in the navigation on the left side of the page. Every application that the Applicant has submitted to ARPA-E and the corresponding Control Number is displayed on that page. If the Applicant submits more than one application to a particular FOA, a different Control Number is shown for each application.

Applicants are responsible for meeting each submission deadline in ARPA-E eXCHANGE. **Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.** Under normal conditions (i.e., at least 48 hours in advance of the submission deadline), Applicants should allow at least 1 hour to submit a Concept Paper, or Full Application. In addition, Applicants should allow at least 15 minutes to submit a Reply to

Reviewer Comments. Once the application is submitted in ARPA-E eXCHANGE, Applicants may revise or update their application until the expiration of the applicable deadline.

Applicants should not wait until the last minute to begin the submission process. During the final hours before the submission deadline, Applicants may experience server/connection congestion that prevents them from completing the necessary steps in ARPA-E eXCHANGE to submit their applications. **ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.**

ARPA-E will not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications will be deemed noncompliant (see Section III.C.1 of the FOA). The following errors could cause an application to be deemed "incomplete" and thus noncompliant:

- Failing to comply with the form and content requirements in Section IV of the FOA;
- Failing to enter required information in ARPA-E eXCHANGE;
- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA;
- Uploading the wrong document(s) or application(s) to ARPA-E eXCHANGE; and
- Uploading the same document twice, but labeling it as different documents. (In the latter scenario, the Applicant failed to submit a required document.)

ARPA-E urges Applicants to carefully review their applications and to allow sufficient time for the submission of required information and documents.

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

ARPA-E performs a preliminary review of Concept Papers and Full Applications to determine whether they are compliant and responsive (see Section III.C of the FOA). ARPA-E also performs a preliminary review of Replies to Reviewer Comments to determine whether they are compliant.

ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to encourage the submission of a Full Application and whether to select a Full Application for award negotiations.

1. CRITERIA FOR CONCEPT PAPERS

(1) *Impact of the Proposed Technology Relative to FOA Targets* (50%) - This criterion involves consideration of the following:

- The potential for a transformational and disruptive (not incremental) advancement compared to existing or emerging technologies;
- Achievement of the Technical Performance Targets defined in Section I.E of the FOA;
- Identification of techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; and
- Demonstration of awareness of competing commercial and emerging technologies and identifies how the proposed concept/technology provides significant improvement over existing solutions.

(2) *Overall Scientific and Technical Merit* (50%) - This criterion involves consideration of the following:

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- Sufficiency of technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches and how technical risk will be mitigated;
- Clearly defined project outcomes and final deliverables; and
- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among team members supporting the proposed project.

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement. The above criteria will be weighted as follows:

Impact of the Proposed Technology Relative to FOA Targets	50%
Overall Scientific and Technical Merit	50%

2. CRITERIA FOR FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

In addition to the above criteria, ARPA-E may consider the following program policy factors in determining which Concept Papers to encourage to submit a Full Application and which Full Applications to select for award negotiations:

I. **ARPA-E Portfolio Balance**. Project balances ARPA-E portfolio in one or more of the following areas:
   a. Diversity (including gender) of technical personnel in the proposed Project Team;
   b. Technological diversity;
   c. Organizational diversity;
   d. Geographic diversity;
   e. Technical or commercialization risk; or
   f. Stage of technology development.

II. **Relevance to ARPA-E Mission Advancement.** Project contributes to one or more of ARPA-E's key statutory goals:
   a. Reduction of US dependence on foreign energy sources;
   b. Stimulation of domestic manufacturing/U.S. Manufacturing Plan;
   c. Reduction of energy-related emissions;
   d. Increase in U.S. energy efficiency;
   e. Enhancement of U.S. economic and energy security; or
   f. Promotion of U.S. advanced energy technologies competitiveness.

III. **Synergy of Public and Private Efforts**.
   a. Avoids duplication and overlap with other publicly or privately funded projects;
   b. Promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer; or
   c. Increases unique research collaborations.

IV. **Low likelihood of other sources of funding.** High technical and/or financial uncertainty that results in the non-availability of other public, private or internal funding or resources to support the project.

V. **High-Leveraging of Federal Funds**. Project leverages Federal funds to optimize advancement of programmatic goals by proposing cost share above the required minimum or otherwise accessing scarce or unique resources.

VI. **High Project Impact Relative to Project Cost.**

2. ARPA-E REVIEWERS

By submitting an application to ARPA-E, Applicants consent to ARPA-E's use of Federal employees, contractors, and experts from educational institutions, nonprofits, industry, and governmental and intergovernmental entities as reviewers. ARPA-E selects reviewers based on their knowledge and understanding of the relevant field and application, their experience and skills, and their ability to provide constructive feedback on applications.

ARPA-E requires all reviewers to complete a Conflict-of-Interest Certification and Nondisclosure Agreement through which they disclose their knowledge of any actual or apparent conflicts and agree to safeguard confidential information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments. In addition, ARPA-E trains its reviewers in proper evaluation techniques and procedures.

Applicants are not permitted to nominate reviewers for their applications. Applicants may contact the Contracting Officer by email (ARPA-E-CO@hq.doe.gov) if they have knowledge of a potential conflict of interest or a reasonable belief that a potential conflict exists.

3. ARPA-E SUPPORT CONTRACTOR

ARPA-E utilizes contractors to assist with the evaluation of applications and project management. To avoid actual and apparent conflicts of interest, ARPA-E prohibits its support contractors from submitting or participating in the preparation of applications to ARPA-E.

By submitting an application to ARPA-E, Applicants represent that they are not performing support contractor services for ARPA-E in any capacity and did not obtain the assistance of ARPA-E's support contractor to prepare the application. ARPA-E will not consider any applications that are submitted by or prepared with the assistance of its support contractors.

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

Noncompliant and nonresponsive Concept Papers and Full Applications are rejected by the Contracting Officer and are not merit reviewed or considered for award. The Contracting Officer sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. The notification letter states the basis upon which the Concept Paper or Full Application was rejected.

2. CONCEPT PAPER NOTIFICATIONS

ARPA-E promptly notifies Applicants of its determination to encourage or discourage the submission of a Full Application. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. ARPA-E provides feedback in the notification letter in order to guide further development of the proposed technology.

Applicants may submit a Full Application even if they receive a notification discouraging them from doing so. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. The purpose of the Concept Paper phase is to save Applicants the considerable time and expense of preparing a Full Application that is unlikely to be selected for award negotiations.

A notification letter encouraging the submission of a Full Application does not authorize the Applicant to commence performance of the project. Please refer to Section IV.G.2 of the FOA for guidance on pre-award costs.

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2017]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

Upon the issuance of a FOA, only the Contracting Officer may communicate with Applicants. ARPA-E personnel and our support contractors are prohibited from communicating (in writing or otherwise) with Applicants regarding the FOA. This "quiet period" remains in effect until ARPA-E's public announcement of its project selections.

During the "quiet period," Applicants are required to submit all questions regarding this FOA to ARPA-E-CO@hq.doe.gov. Questions and Answers (Q&As) about ARPA-E and the FOA are available at http://arpa-e.energy.gov/faq. For questions that have not already been answered, please send an email with the FOA name and number in the subject line to ARPA-E-CO@hq.doe.gov. Due to the volume of questions received, ARPA-E will only answer pertinent questions that have not yet been answered and posted at the above link.

- ARPA-E will post responses on a weekly basis to any questions that are received that have not already been addressed at the link above. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- ARPA-E will cease to accept questions approximately 10 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted approximately one business day in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- Responses are published in a document specific to this FOA under "CURRENT FUNDING OPPORTUNITIES – FAQS"" on ARPA-E's website (http://arpa-e.energy.gov/faq).

Applicants may submit questions regarding ARPA-E eXCHANGE, ARPA-E's online application portal, to ExchangeHelp@hq.doe.gov. ARPA-E will promptly respond to emails that raise legitimate, technical issues with ARPA-E eXCHANGE. ARPA-E will refer any questions regarding the FOA to ARPA-E-CO@hq.doe.gov.

ARPA-E will not accept or respond to communications received by other means (e.g., fax, telephone, mail, hand delivery). Emails sent to other email addresses will be disregarded.

During the "quiet period," only the Contracting Officer may authorize communications between ARPA-E personnel and Applicants. The Contracting Officer may communicate with Applicants as necessary and appropriate. As described in Section IV.A of the FOA, the Contracting Officer may arrange pre-selection meetings and/or site visits during the "quiet period."

B. DEBRIEFINGS

ARPA-E does not offer or provide debriefings. ARPA-E provides Applicants with a notification encouraging or discouraging the submission of a Full Application based on ARPA-E's assessment of the Concept Paper. In addition, ARPA-E provides Applicants with reviewer comments on Full Applications before the submission deadline for Replies to Reviewer Comments.

VIII. OTHER INFORMATION

A. FOAS AND FOA MODIFICATIONS

FOAs are posted on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/), Grants.gov (http://www.grants.gov/), and FedConnect (https://www.fedconnect.net/FedConnect/). Any modifications to the FOA are also posted to these websites. You can receive an e-mail when a modification is posted by registering with FedConnect as an interested party for this FOA. It is recommended that you register as soon as possible after release of the FOA to ensure that you receive timely notice of any modifications or other announcements. More information is available at https://www.fedconnect.net.

B. OBLIGATION OF PUBLIC FUNDS

The Contracting Officer is the only individual who can make awards on behalf of ARPA-E or obligate ARPA-E to the expenditure of public funds. A commitment or obligation by any individual other than the Contracting Officer, either explicit or implied, is invalid.

ARPA-E awards may not be transferred, assigned, or assumed without the prior written consent of a Contracting Officer.

C. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

Applicants are required to make a full and complete disclosure of the information requested in the Business Assurances & Disclosures Form. Disclosure of the requested information is mandatory. Any failure to make a full and complete disclosure of the requested information may result in:

- The rejection of a Concept Paper, Full Application, and/or Reply to Reviewer Comments;
- The termination of award negotiations;
- The modification, suspension, and/or termination of a funding agreement;
- The initiation of debarment proceedings, debarment, and/or a declaration of ineligibility for receipt of Federal contracts, subcontracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

D. RETENTION OF SUBMISSIONS

ARPA-E expects to retain copies of all Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions. No submissions will be returned. By applying to ARPA-E for funding, Applicants consent to ARPA-E's retention of their submissions.

E. MARKING OF CONFIDENTIAL INFORMATION

ARPA-E will use data and other information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments strictly for evaluation purposes.

Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

The cover sheet of the Concept Paper, Full Application, Reply to Reviewer Comments, or other submission must be marked as follows and identify the specific pages containing confidential, proprietary, or privileged information:

> Notice of Restriction on Disclosure and Use of Data:
>
> Pages [___] of this document may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes or in accordance with a financial assistance or loan agreement between the submitter and the Government. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure." In addition, every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

F. TITLE TO SUBJECT INVENTIONS

Ownership of subject inventions is governed pursuant to the authorities listed below. Typically, either by operation of law or under the authority of a patent waiver, Prime Recipients and Subrecipients may elect to retain title to their subject inventions under ARPA-E funding agreements.

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions. If they elect to retain title, they must file a patent application in a timely fashion.

- All other parties: The Federal Non-Nuclear Energy Research and Development Act of 1974, 42. U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below)*.

- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues "class patent waivers" under which large businesses and foreign entities that meet certain stated requirements, such as cost sharing of at least 20%, may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.

- GOGOs are subject to the requirements of 37 C.F.R. Part 501.

- Determination of Exceptional Circumstances (DEC): Each Applicant is required to submit a U.S. Manufacturing Plan as part of its Full Application. The U.S. manufacture provision included in Attachment 2 of an award is included as part of the U.S. Manufacturing Plan. If selected, the U.S. Manufacturing Plan may be incorporated into the award terms and conditions for domestic small businesses and nonprofit organizations. DOE has determined that exceptional circumstances exist that warrants the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to the extent necessary to implement and enforce the U.S. Manufacturing Plan. For example, the commitments and enforcement of a U.S. Manufacturing Plan may be tied to subject inventions. Any Bayh-Dole entity (domestic small business or nonprofit organization) affected by this DEC has the right to appeal it. The DEC is dated September 9, 2013 and is available at the following link: http://energy.gov/gc/downloads/determination-exceptional-circumstances-under-bayh-dole-act-energy-efficiency-renewable.

G. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

Where Prime Recipients and Subrecipients retain title to subject inventions, the U.S. Government retains certain rights.

1. GOVERNMENT USE LICENSE

The U.S. Government retains a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the world. This license extends to contractors doing work on behalf of the Government.

2. MARCH-IN RIGHTS

The U.S. Government retains march-in rights with respect to all subject inventions. Through "march-in rights," the Government may require a Prime Recipient or Subrecipient who has elected to retain title to a subject invention (or their assignees or exclusive licensees), to grant a license for use of the invention. In addition, the Government may grant licenses for use of the subject invention when Prime Recipients, Subrecipients, or their assignees and exclusive licensees refuse to do so.

The U.S. Government may exercise its march-in rights if it determines that such action is necessary under any of the four following conditions:

- The owner or licensee has not taken or is not expected to take effective steps to achieve practical application of the invention within a reasonable time;
- The owner or licensee has not taken action to alleviate health or safety needs in a reasonably satisfactory manner;
- The owner has not met public use requirements specified by Federal statutes in a reasonably satisfactory manner; or
- The U.S. Manufacturing requirement has not been met.

3. U.S. MANUFACTURING REQUIREMENT

ARPA-E requires that awards address whether products embodying or produced through the use of subject inventions (i.e., inventions conceived or first actually reduced to practice under ARPA-E funding agreements) are to be substantially manufactured in the United States by Project Teams and their licensees. The requirement varies depending upon whether an awardee is a small business, University or other type of awardee. The Applicant may request a modification or waiver of the U.S. Manufacturing Requirement.

H. RIGHTS IN TECHNICAL DATA

Data rights differ based on whether data is first produced under an award or instead was developed at private expense outside the award.

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.

- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

I. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

Applicants may not include any Protected Personally Identifiable Information (Protected PII) in their submissions to ARPA-E. Protected PII is defined as data that, if compromised, could cause harm to an individual such as identity theft. Listed below are examples of Protected PII that Applicants must not include in their submissions.

- Social Security Numbers in any form;
- Place of Birth associated with an individual;
- Date of Birth associated with an individual;
- Mother's maiden name associated with an individual;
- Biometric record associated with an individual;
- Fingerprint;
- Iris scan;
- DNA;
- Medical history information associated with an individual;
- Medical conditions, including history of disease;
- Metric information, e.g. weight, height, blood pressure;
- Criminal history associated with an individual;
- Ratings;
- Disciplinary actions;

- Performance elements and standards (or work expectations) are PII when they are so intertwined with performance appraisals that their disclosure would reveal an individual's performance appraisal;
- Financial information associated with an individual;
- Credit card numbers;
- Bank account numbers; and
- Security clearance history or related information (not including actual clearances held).

J. COMPLIANCE AUDIT REQUIREMENT

A prime recipient organized as a for-profit entity expending $750,000 or more of DOE funds in the entity's fiscal year (including funds expended as a Subrecipient) must have an annual compliance audit performed at the completion of its fiscal year. For additional information, refer to Subpart F of: (i) 2 C.F.R. Part 200, and (ii) 2 C.F.R. Part 910.

If an educational institution, non-profit organization, or state/local government is either a Prime Recipient or a Subrecipient, and has expended $750,000 or more of Federal funds in the entity's fiscal year, the entity must have an annual compliance audit performed at the completion of its fiscal year. For additional information refer to Subpart F of 2 C.F.R. Part 200.

IX. GLOSSARY

Applicant: The entity that submits the application to ARPA-E. In the case of a Project Team, the Applicant is the lead organization listed on the application.

Application: The entire submission received by ARPA-E, including the Concept Paper, Full Application, and Reply to Reviewer Comments.

ARPA-E: is the Advanced Research Projects Agency – Energy, an agency within the U.S. Department of Energy.

Cost Sharing: is the portion of project costs from non-Federal sources that are borne by the Prime Recipient (or non-Federal third parties on behalf of the Prime Recipient), rather than by the Federal Government.

Deliverable: A deliverable is the quantifiable goods or services that will be provided upon the successful completion of a project task or sub-task.

DOE: U.S. Department of Energy.

DOE/NNSA: U.S. Department of Energy/National Nuclear Security Administration

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

GOCOs: U.S. Government Owned, Contractor Operated laboratories.

GOGOs: U.S. Government Owned, Government Operated laboratories.

Milestone: A milestone is the tangible, observable measurement that will be provided upon the successful completion of a project task or sub-task.

Prime Recipient: The signatory to the funding agreement with ARPA-E.

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing inventive supportive work that is part of an ARPA-E project.

Standalone Applicant: An Applicant that applies for funding on its own, not as part of a Project Team.

Subject Invention: Any invention conceived or first actually reduced to practice under an ARPA-E funding agreement.

Task: A task is an operation or segment of the work plan that requires both effort and resources. Each task (or sub-task) is connected to the overall objective of the project, via the achievement of a milestone or a deliverable.

Total Project Cost: The sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.

TT&O: Technology Transfer and Outreach. (See Section IV.G.8 of the FOA for more information).