FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

DELIVERING EFFICIENT LOCAL THERMAL AMENITIES (DELTA)

Announcement Type: ~~Initial Announcement~~ Modification 01
Funding Opportunity No. DE-FOA-0001127
CFDA Number 81.135

FOA Issue Date:	April 29, 2014
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, June 6, 2014
Submission Deadline for Concept Papers:	5 PM ET, June 13, 2014
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 $30 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.
- ARPA-E will not review or consider noncompliant or nonresponsive applications. For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 and III.C.2 of the FOA.

Questions about this FOA? 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).

MODIFICATIONS

All modifications to the Funding Opportunity Announcement (FOA) are highlighted in yellow in the body of the FOA.

Mod. No.	Date	Description of Modifications
01	05/30/2014	• Clarified that Category 2 includes both home and office items. See Section I.D of the FOA. • Clarified that Category 3 includes small portable electronics devices such as mobile phones. See Section I.D of the FOA • Inserted a footnote to the Category 2 Primary Metrics Table, Metric No.: 2.3 Range of Motion, to clarify that this requirement is waived for concepts where motion is not expected. See Section I.E of the FOA.

TABLE OF CONTENTS

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 include the following: ○ Technology Description (2 pages max.) ○ Addendum (2 pages max.)	Mandatory	IV.C	5 PM ET, June 13, 2014
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]	Mandatory	IV.D	5 PM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]	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, 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 support the creation of transformational energy technologies and systems through funding and managing Research and Development (R&D) efforts. Originally chartered in 2007, the Agency was first funded through the American Recovery and Reinvestment Act of 2009. Since that time, the Agency has invested over $900 million across 362 projects through 18 focused programs and two open funding solicitations across the entire technology landscape.[1]

The mission of ARPA-E is to identify and fund research to translate science into breakthrough energy technologies that are too risky for the private sector and that, if successfully developed, will create the foundation for entirely new industries. To date, 22 ARPA-E projects have attracted more than $625 million in private-sector follow-on funding after ARPA-E's investment of approximately $95 million. In addition, at least 24 ARPA-E project teams have formed new companies to advance their technologies, and more than 16 ARPA-E projects have partnered with other government agencies for further development.

Successful projects will address at least one of ARPA-E's two Mission Areas:

1. Enhance the economic and energy security of the United States through the development of energy technologies that result in:
   a. reductions of imports of energy from foreign sources;
   b. reductions of energy-related emissions, including greenhouse gases; and
   c. improvement in the energy efficiency of all economic sectors.
2. Ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

ARPA-E funds applied research and development. ARPA-E exists to fund applied research and development, defined by the Office of Management and Budget as a "study (designed) to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met" and 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." ARPA-E funds technology-focused applied research to create real-world solutions to important problems in energy creation, distribution and use and, as such, will not support basic research, defined as a "systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without

[1] Information on ARPA-E's projects is available at http://arpa-e.energy.gov/?q=projects.

specific applications towards processes or products in mind." While it is anticipated that in some instances some minor aspects of fundamental science will be clarified or uncovered during the conduct of the supported applied research, the major portion of activities supported by ARPA-E are directed towards applied research and development of new technologies.

While all technology-focused applied research will be considered, two instances are especially fruitful for the creation of transformational technologies:

- the first establishment of a technology based upon recently elucidated scientific principles; and
- the synthesis of scientific principles drawn from disparate fields that do not typically intersect.

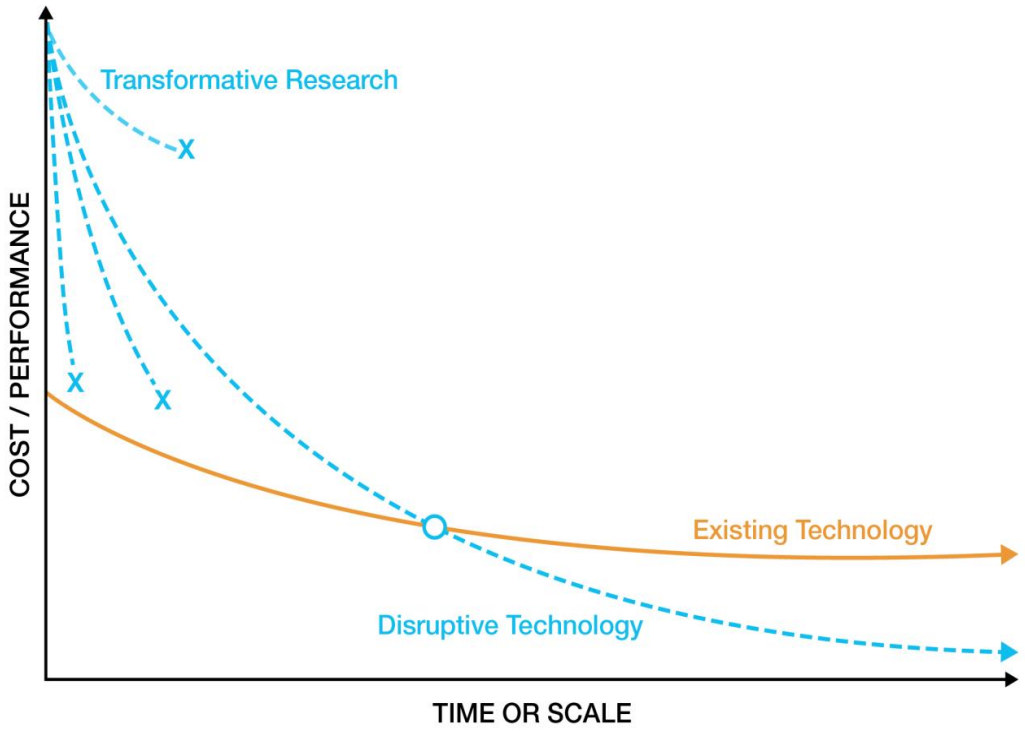

Figure 1: Description of transformational and disruptive technologies in terms of cost per unit performance versus time or scale. ARPA-E seeks to support research that establishes new learning curves that lead to disruptive technologies.

ARPA-E exists to support transformational, rather than incremental research. Technologies exist on learning curves (Figure 1). Following the creation of a technology, refinements to that technology and the economies of scale that accrue as manufacturing and widespread distribution develop drive technology down that learning curve until an equilibrium cost/performance is reached. While this incremental improvement of technology is important to the ultimate success of a technology in the marketplace, ARPA-E exists to fund transformational research – i.e., research that creates fundamentally new learning curves rather than moving existing technologies down their learning curves.

ARPA-E funded technology has 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. Energy technologies typically become disruptive at maturity rather than close to inception and the maturation of nascent technologies often require significant incremental development to drives the technology down its natural learning curve to its ultimate equilibrium (see Figure 1 above). Such development might include modification of the technology itself, the means to produce and distribute that technology, or both. Thus, while early incarnations of the automobile were transformational in the sense that they created a fundamentally new learning curve for transportation, they were not disruptive, because of the unreliability and high cost of early automobiles. Continuous, incremental refinement of the technology ultimately led to the Ford Model T: as the first affordable, reliable, mass-produced vehicle, the Model T had a disruptive effect on the transportation market.

ARPA-E will not support technology development for extended periods of time; rather, ARPA-E supports the initial creation of technology. Following initial testing of the first prototype of a device, a system, or a process, other Federal agencies and the private sector will support the incremental development necessary to bring the technology to market.

While ARPA-E does not require technologies to be disruptive at the conclusion of ARPA-E funding, ARPA-E will not support technologies that cannot be disruptive even if successful. Examples of such technologies are approaches that require elements with insufficient abundances of materials to be deployed at scale, or technologies that could not scale to levels required to be impactful because of, for example, physical limits to productivity.

ARPA-E will not support basic research aimed at discovery and fundamental knowledge generation, nor will it undertake large-scale demonstration projects of existing technologies. ARPA-E is not a substitute for existing R&D organizations within the Department of Energy, but rather complements existing organizations by supporting R&D objectives that are transformational and translational. Applicants interested in receiving basic research financial assistance should work with the Department of Energy's Office of Science (http://science.energy.gov/). Similarly, projects focused on the improvement of existing technology platforms may be appropriate for support by the applied programs – for example, 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://nuclear.energy.gov/), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

B. PROGRAM OVERVIEW

1. SUMMARY

Building heating, ventilation, and air conditioning (HVAC) account for 13% of energy consumption in the United States.[2] The DELTA program seeks to enable saving 2% of domestic energy use by funding the development of Localized Thermal Management Systems (LTMS). LTMS modify the local thermal envelope around the human body rather than the building. When implemented in a built environment, LTMS are expected to enable an expansion of the temperature setpoints in buildings. ARPA-E analyses demonstrate that a potential energy savings for building heating and cooling >15% is available when compared to traditional HVAC setpoints.

ARPA-E envisions DELTA supporting a broad range of LTMS that would enable the energy savings and emissions reduction objectives described in this FOA. Such technologies may range from on-body wearable devices to off-body installed systems. Installed systems could provide near range (< 1 m) and long range (>1 m) energy transfer to the human body without substantially heating or cooling the surrounding air. ARPA-E expects adoption of LTMS for both the commercial and residential sectors. Due to the lower cost and ease of implementation, it is expected that wearable technologies are more likely to make early penetration into the residential sector. ARPA-E recognizes the tremendous opportunities for energy savings offered by LTMS due to their inherent high energy efficiency, low capital installation cost, ease of upgrading and ability to offer personalized thermal environmental control. This FOA presents a radical shift of thermal comfort management away from centralized building systems to distributed, local solutions. This approach will leverage recent and future advancements in distributed sensing, communications, control, innovative materials and wearable technologies for the development of quickly deployable devices to significantly improve building HVAC efficiencies. While the scope of this program focuses on LTMS for quick adoption in existing buildings, our long term vision is that LTMS solutions may eventually reduce our reliance on tightly controlled building environments, thus enabling radical new sustainable architecture in next generation energy-efficient building designs.

[2] Estimation base on Energy Information Administration's (EIA) Annual Energy Overview 2014 Early Release Overview, http://www.eia.gov/forecasts/aeo/er/tables_ref.cfm, retrieved March 2014.

2. MOTIVATION

The Need to Reduce Building HVAC Energy Consumption

Heating and cooling of buildings represents more than 13% of all energy used domestically[3], about 12 Qbtu of energy annually (primary) and accounts about 13% of the domestic greenhouse gas emissions. Approximately 4 Qbtu of electricity is used for cooling. The US consumes about 8 Qbtu per year on space heating, with ~2 Qbtu from electricity, and the rest is mostly from fossil fuels (natural gas and heating oil). Consequently, reducing the energy consumption for heating and cooling by 15% can have a transformative impact on the nation's electricity usage, consumption of fuels, and greenhouse gas emissions.

3. CURRENT APPROACHES

Building HVAC Improvements and the Retrofit Challenge

Due to the potential for significant energy savings, there are many ongoing efforts to achieve improved building heating and cooling efficiency. Current approaches can generally be categorized as either improved efficiency of HVAC components and systems or improved control of HVAC systems. Energy efficient technologies under current development include, but are not limited to, geothermal heat pumps, heat exchangers, new working fluids, more efficient fans and compressors, magnetic cooling, and absorption cooling. Advanced solutions, such as walls with variable insulation that modulate the thermal flow in and out of building structures are also being pursued.[4] Improved temporal control is provided by digital thermostats. However, improved spatial control requires a reconfiguration of the building interior or complete replacement of the building HVAC units. It is highly unlikely that spatial control with current building HVAC technologies will reach the resolution of the individual occupant.

Furthermore, a fundamental disadvantage preventing adoption of HVAC improvements are high costs. Retrofitting existing buildings with new technologies is not cost effective because of the extremely long service life of many building components (e.g, residential HVAC systems are designed for 10 to 25 years). Moreover, the building envelope is designed to last between 20 to 50 years, with the whole building lasting from 40 to 120 years. Building retrofit often has a payback period of longer than 5 years, which is too long to be of interest to the building owners as opposed to maintaining the status quo with inefficiently operating systems. It is thus

[3] Buildings Technologies Program, Energy Efficiency and Renewable Energy, U.S. Department of Energy: 2011 Buildings Energy Data Book, March 2012.

[4] F. Kuznik et al., Renewable and Sustainable Energy Reviews, 15(1) (2011) 379-391; *See also* Department of Energy, Energy Efficiency Renewable Energy, Building Technology Office, https://www1.eere.energy.gov/buildings/technologies/building_envelope_research.html, accessed 5/30/2013..

essential to develop technologies that can be cost effectively implemented into existing buildings.

4. CHALLENGE AND OPPORTUNITY

Human Comfort Perception and Challenges with Setpoint Efficiency

The primary function of building heating and cooling is to maintain occupant comfort. Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55).[5] P.O. Fanger's work [6] represents the foundation for the standards used both by the International Organization for Standardization (ISO 7730 2005) and the American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE 55 2010). Fanger's climate chamber experiments yielded the Predicted Mean Vote (PMV) formulation that has been widely adopted as the standard for thermal comfort for conditioned environments.

Based on the PMV model, the ANSI/ASHRAE Standard 55 provides recommendations for operational parameters for buildings, which includes a goal of ensuring at least 80% satisfaction rate among building occupants. As expected, human thermal comfort is strongly influenced by personal physiology. Consequently, it is not possible to achieve a 100% satisfaction rate for a given set of environmental conditions. The PPD (Predicted Percentage Dissatisfied)-PMV correlation (Figure 2) illustrates this distribution as recommended by the ISO 7730 standard.

[5] ANSI/ASHRAE Standard 55-2010: Thermal Environmental Conditions for Human Occupancy.
[6] Fanger, P. O. 1972. Thermal Comfort. New York:McGraw-Hill.

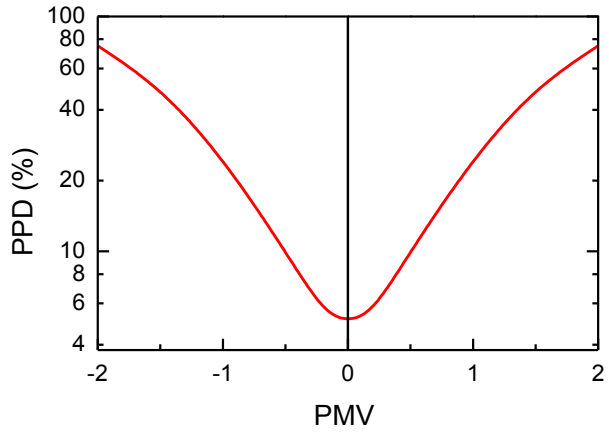

Figure 2. The PPD-PMV relationship based on Fanger's model.[7] Note: even at PMV of 0 which defines thermal neutral, the PPD value does not go to 0, reflecting the complexities of thermal comfort.

The operating temperature range or the neutral-band, the temperature range between setpoints where no action is taken by a building HVAC system, is usually between 70 and 75°F. This practice is tighter than the ANSI/ASHRAE standards with acceptable target temperatures of 68°F during the heating season and 76°F during the cooling season, with appropriate humidity levels. The reasons for the narrowing of neutral bands are many and complex. One of the primary reasons is poor building control and lack of zone resolution. The PMV model assumes a uniform building thermal environment, while in reality wide temperature gradients exist within the building. In addition, complaints by building occupants tend to drive the building managers to tighten the neutral band further, resulting in even higher energy consumptions and inefficiencies.[8]

Setpoint Expansion as an Energy Saving Mechanism

Since the goal of an HVAC system is to maintain the building interior at temperatures that are different from the outside, the actual setpoint has a large influence on the energy required to operate the system. According to Fourier's law, heat flow through the building envelope is proportional to the temperature gradient across it. Thus, the thermal exchange rate across the building envelope is driven by the temperature difference between inner and outer surface temperatures of the building. When the interior temperature is closer to the exterior temperature, thermal exchange will be smaller, which in turn, reduces the energy consumption of the HVAC to maintain a steady interior temperature.

[7] ANSI/ASHRAE Standard 55-2010: Thermal Environmental Conditions for Human Occupancy.
[8] Federspiel, C. C., 2000, "Predicting the Cost and Frequency of Hot and Cold Complaints in Buildings," International Journal of HVAC&R Research, 6(4), 217-234.

A number of published findings have quantified the effect of the setpoint on HVAC energy consumption and the potential for LTMS to enable energy savings via a setpoint change. For example, Hoyt et al. calculated the percent annual energy savings for four different cities when the setpoint is expanded from a baseline of 70.5-75°F (Figure 3).[9] For the city of Phoenix, lowering the setpoint in the winter months to 66°F results in an annual savings of ~14% while raising the setpoint in summer months to 79°F results in an annual savings of ~20%. Consequently, a setpoint of 66-79°F would save a total of ~34% annually versus the comparative baseline building. The potential savings may vary based on location and climate, but is estimated at over 20%. Note that the estimation did not consider downsizing the HVAC unit, only changing the cycling time of an existing unit. Additional energy savings could be realized through reduction of the HVAC unit size enabled by a wider setpoint range. Based on this study, ARPA-E has determined a very conservative estimate of 15% savings for an expansion of setpoints by 4°F in each direction.

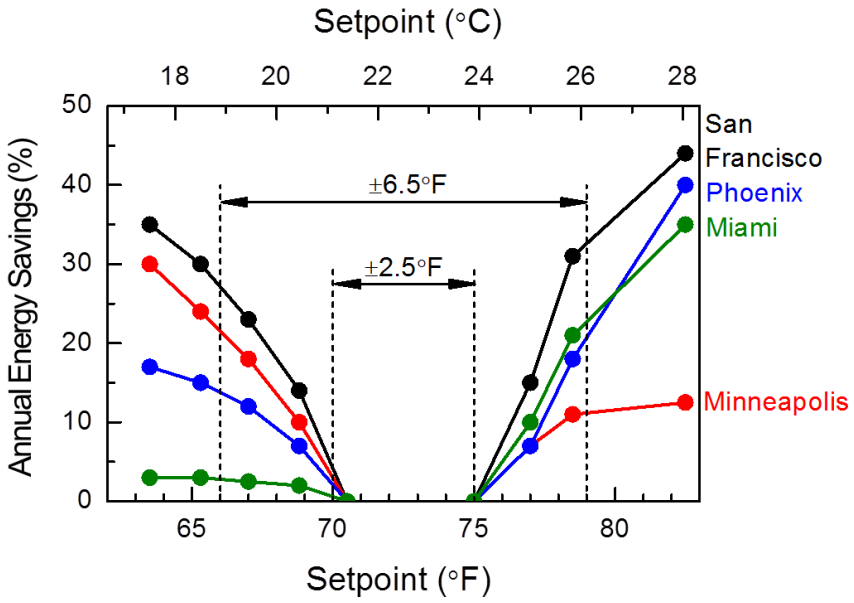

Figure 3. Percent energy savings for widened air temperature setpoints relative to conventional setpoint range in San Francisco, Miami, Phoenix, and Minneapolis. The percentage savings for lowering the setpoints in the winter are calculated by assuming no change in the summer setpoints (75°F). Similar calculations are performed for increasing the setpoints in the summer. Consequently, the percentage savings from the summer and the winter are approximately (and conservatively) the summation of the percent savings.

[9] Hoyt, T., H.L. Kwang, H. Zhang, E. Arens, T. "Energy savings from extended air temperature setpoints and reductions in room air mixing." International Conference on Environmental Ergonomics August 2-7, 2009.

5. PROGRAM APPROACH

The Inherent Energy Efficiency Advantages of LTMS

To enable expansion of the building setpoints, it is necessary to provide supplemental thermal management to the building occupants to maintain thermal comfort. LTMS can fulfill this role and lead to significant overall energy savings because LTMS are inherently more localized in their delivery of thermal energy than building HVAC systems.

The thermal exchange rate for a thermal envelope is proportional to the surface area and inversely proportional to the thermal resistance. For a temperature gradient driven heat flux, the large difference in surface area between a building and a person is the factor that drives the potentially large energy savings with LTMS. The average adult has a surface area of 1.8 m^2.[10] The building surface area per person is dependent on the building type. As an illustrative example, consider a residential home with a floor area of 185.8 m^2 based on a rectangle 15.24 m long by 6.1 m wide. With an envelope height of 6.1 m, this home's thermal envelope surface area is 334.45 m^2. Assuming the house has four residents, the surface area per resident will be 83.6 m^2, which is over 46 times the surface area of a person.

The effect of the large difference in the surface area can be partially offset by the larger thermal resistance associated with building insulation compared with that for clothing worn by building occupants. For example, building walls can have a thermal resistance 10 times that of full business attire clothing. Unfortunately, window glass is a poor insulator, with a thermal resistance on par with clothing.[11] By including windows, which often occupy more than 30% of building exterior, the overall effective thermal resistance, for the home in this example, decreases to 5 times that of a full business suit. Consequently, the thermal resistance is an order of magnitude lower than what is necessary to compensate for the large surface area. In addition, the thermal resistance of a piece of clothing is easily adjustable, while changing the thermal resistance for an existing structure is extremely difficult and expensive.

Other Advantages of LTMS

In addition to tremendous potential for energy savings, LTMS offers other advantages over current building HVAC systems.

Improvement in thermal comfort for building occupants. As has been shown in Fanger's model, it is not possible to achieve 100% thermal comfort for all building occupants using a single setpoint, no matter the setpoint. In addition, the ASHRAE standards mandate achieving thermal comfort for 80% of the occupants. Field data show that the 80% value is rarely achieved,

[10] ANSI/ASHRAE Standard 55-2010: Thermal Environmental Conditions for Human Occupancy.
[11] Cengel, Y. & Ghajar, A. Heat and Mass Transfer: Fundamentals and Applications. McGraw-Hill Higher Education, 2011.

reflecting the fundamental limitations of today's HVAC systems.[12] These lack the high resolution zone control necessary to cater to individual thermal management needs. In contrast, LTMS can be viewed as the quintessential individualized zone control. In principle, 100% thermal comfort is achievable when personal zone control is implemented. This has been demonstrated in previous field studies.[13]

Energy efficiency improvement beyond buildings. In the case of wearable technologies, the building occupant will continue to have access to the technology after exiting the building. Outside environments can be far more extreme than the indoor environment controlled by an HVAC system within a specified temperature band. However, the basic functionality of wearables with advanced thermal management properties will continue to assist in maintaining personal thermal comfort outside the building. For example, these technologies could buffer the impact of abrupt temperature changes at the exit of the building. In fact, such a benefit can serve as a powerful incentive for early adoption.[14] Moreover, these technologies could reduce the power load needed for air conditioning in automobiles; this could be especially impactful on the driving range of electric vehicles.[15]

Low capital investment with overnight installation in existing buildings. ARPA-E envisions LTMS retrofit solutions as small and easily installed without the need to significantly reconfigure the building interior or alter the building structure itself. In addition, wearable technologies could be rapidly adopted based on the short lifecycle of common apparel.

Challenges Facing Current LTMS Approaches

The potential of LTMS to provide high quality, individualized thermal comfort is well recognized. As a result, numerous commercial products exist.[16] However, cooling is by far more challenging than heating, primarily due to the problem of dealing with rejected heat. For personalized cooling, a desktop cooling unit can blow chilled air towards the occupant. One such device[16] uses a thermoelectric module to deliver cold air; however, with any heat pump device, heat must be rejected from the device and is typically done so at the rear of the unit, which is also very close to the occupant and has a net effect of raising average room temperature. This desktop cooling unit only consumes 60 W but performs poorly (not effective beyond 0.3 m) and is too costly ($140) for widespread adoption. Various evaporative coolers have been developed,

[12] Goins, J. Moezzi, M. Linking occupant complaints to building performance. Indoor Environmental Quality (IEQ), Center for the Built Environment, Center for Environmental Design Research, UC Berkeley. http://www.tandfonline.com/doi/abs/10.1080/09613218.2013.763714.
[13] T. Law, The future of thermal comfort in an energy-constrained world, Springer, 2013, p. 186
[14] Martin, Claire. *Rolling Up Their Sleeves, as a Team.* The New York Time: New York ed. p. BU5, May 19, 2013.
[15] Rugh, J.P. "Electric Drive Vehicle Climate Control Load Reduction." (2012, May 14). Retrieved from: http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2012/veh_sys_sim/vss090_rugh_2012_p.pdf.
[16] T. Law, The future of thermal comfort in an energy-constrained world, Springer, 2013, p. 204.

but they invariably increase the indoor humidity, and the building HVAC will incur a heavy load to bring down the humidity. For wearable technologies, an air-conditioned jacket was marketed in Japan[16]. It uses a fan that puffs up the jacket to create airflow within, which is then exhausted at the cuffs and collar. It is unsuitable for indoor use in an office environment due to very poor aesthetics that limit adoption. Various cooling vests were also developed that use evaporation of water to remove heat from the wearer. However, they are usually bulky, heavy, and only suitable for occupational uses such as firefighting and factory workers.

For stationary office use, personal environment modules have been developed which primarily consist of air nozzles targeting the upper body and a radiant panel heating the legs.[17] While effective, they require either a pressurized floor plenum or individual ducting to every workstation, both of which are costly to retrofit into existing office settings. In addition, the occupant is required to place feet very close to the heating panel, greatly restricting any movement. More recently, a ductless task air conditioning (DTAC) unit was developed.[16] This unit can provide refrigerated air while storing the exhausted heat in a phase change material, to be discharged when the space is not occupied. Each unit is projected to consume 200 W and costs approximately $300. The potential of the laboratory prototype of reaching market adoption is too early to tell.[18]

Localized heating is much easier to implement and heaters are usually low cost and can be flexible. However, most of the portable heaters on the market consume very large amounts of power (~ 1500 W typical).[19] Radiative heaters, such as infrared heaters, can in principle be of very high efficiency due to lack of transmission loss in air. However, efficiency drops significantly when the heating targets move slightly off the transmission path. In this case, most of the radiation is absorbed by the first object in its path, such as the floor or wall, where it is converted to heat that is subsequently transmitted to the occupants by convection, thus negating the inherent advantage of radiative heating. Furthermore, infrared heaters also have emission spectra that tend to heat exposed skin much more efficiently than clothing. This is due to the strong absorption by water at approximately 3 μm and coincides with the emission peak of many infrared sources. As a result, overhead infrared heaters tend to overheat the exposed areas of the human body (face and head) and under-heat the clothed areas (feet and legs), creating discomfort due to the thermal asymmetry. A final challenge with using a high power infrared heater as part of a building infrastructure is its strong visible emission. The visible appearance of the heaters greatly impacts the aesthetics of building interior. As a result, these

[17] E. Aren, Defining and Improving Personal Comfort: in the News and in the Lab. Centerline, winter 2013.
[18] T. Law, The future of thermal comfort in an energy-constrained world, Springer, 2013, p. 206
[19] "Portable Heaters," Retrieved from http://energy.gov/energysaver/articles/portable-heaters, in March 2014.

heaters have only been popular with outdoor or large warehouses where convective heating is impractical.

In summary, despite the potential of great energy savings, existing LTMS have not enjoyed adoption in today's building environment due to one or more of the following reasons: poor thermal performance, low energy efficiency, high cost, poor aesthetics, and location specific sensitivities (e.g., noise, immobility, thermal asymmetry). It is the primary goal of DELTA to support the development of transformational next generation LTMS that can overcome these challenges.

C. PROGRAM OBJECTIVES

1. ACHIEVE THERMAL COMFORT IN AN EXPANDED AMBIENT TEMPERATURE RANGE OF 66 TO 79°F

To expand the neutral band for buildings from 70-75°F to at least 66-79°F, or an expansion of 4°F in each direction, a local thermal envelope around individuals is needed to manage the thermal balance so as not to sacrifice thermal comfort. One could employ the PMV model to estimate the thermal compensation required to enable the new setpoints. Analysis shows that a change in thermal exchange rate of 15 W/m^2 is required for a change of 3.6°F.[20] Similarly, if one only tries to change clothing insulation, a change of 20% in thermal resistance is required from a baseline value of 0.279 m^{2}F/W, or 0.056 m^{2}F/W. In order to enable some simple scaling, we consider that the steady state heat flux through a planar wall can be expressed as:

$$q''=(1/R)*(T_o-T_1)$$

where T_1 is the ambient temperature, T_o is the skin temperature, and R is the overall thermal resistance. Assuming that the thermal resistance does not change and T_1 changes to a new temperature, T_2, the change in heat flux is:

$$\Delta q''=(1/R)*(T_2-T_1)$$

and the percentage change in heat flux is:

$$\Delta q''/q''=(T_2-T_1)/(T_o-T_1)$$

[20] Fan, J. "Human Physiology & Clothing, Personal Thermal Management Systems to Reduce Building Energy Consumption," November 12 & 13, 2013. Retrieved from: http://www.arpa-e.energy.gov/sites/default/files/documents/files/Personal_Thermal_Workshop_Fan_Presentation.pdf.

Since ambient skin temperature is at a comfortable state around 93°F, when T_1 = 75°F and T_2 = 79°F, $\Delta q''/q''$ is 22.2%. Similarly, when T_1=70°F and T_2 = 66°F, $\Delta q''/q''$ is -17.3%. For an adult human in a sedentary state, the base metabolism 58.2 W/m^2 and an average adult has a surface area of 1.8 m^2, resulting in a total metabolism of 105 W[21]. In other words:

- If the ambient temperature is raised from 75 to 79°F, a removal of 23 W, or 22% is needed to maintain the same skin temperature;
- If the ambient temperature is lowered from 70 to 66°F, a supply of 18 W, or 17% is needed to maintain the same skin temperature.

Alternatively, the thermal balance can be achieved by changing the thermal resistance. For a change in ambient temperature from T_1 to T_2, the same heat flux can be maintained by changing the respective thermal resistance from R_1 to R_2, such that:

$$R_2/R_1=(T_o-T_2)/(T_o-T_1)$$

- The percentage change needed in the thermal resistance to maintain the same heat flux is the percentage change in heat removal or supply with same thermal resistance.

2. OTHER CONSIDERATIONS TO ENSURE THERMAL COMFORT

In the ANSI/ASHRAE 55 standard, building HVAC design parameters are chosen to result in a PPD value of < 10%. Further, an additional 10% of occupants are assumed to be dissatisfied due to reasons not accounted for by the PMV model. This allowance reflects the complex nature of thermal comfort. Many factors contribute to a deviation of the PMV model, among which thermal asymmetry is an important consideration.

[21] Bradshaw, V. The Building Environment: Active and Passive Control Systems, 3rd Edition, Wiley Publishing, May 2006.

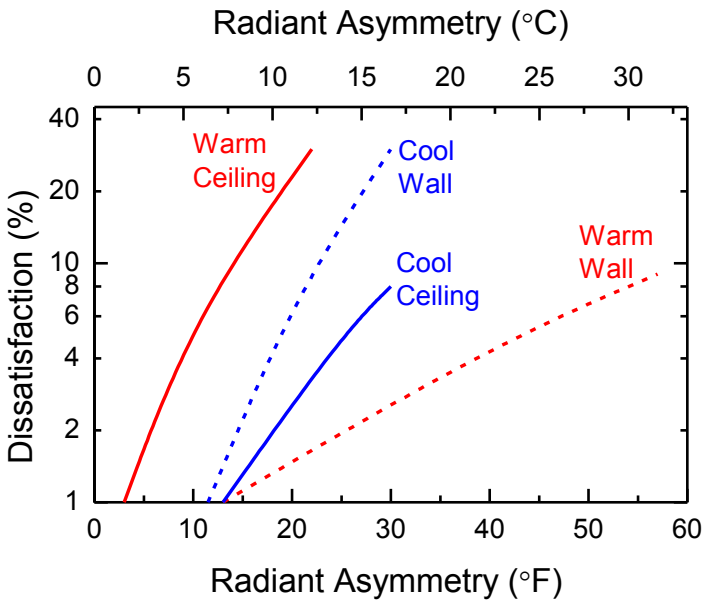

Figure 4. The percentage of occupants dissatisfied as a function of radiant temperature asymmetry. Note that the warm ceiling effect is the most undesirable, reflecting the disadvantage of overheating one's head.

Figure 4 shows the percentage dissatisfied occupants as a function of radiant temperature asymmetry. In particular, a ceiling with a temperature higher than other faces of a room has the most significant impact. A difference of 12°F will result in 10% dissatisfaction. This is due to the fact that humans generally prefer cooler heads and warm feet rather than the other way around. It is thus important that:

- Any local thermal envelope solution shall not aggravate undesirable thermal asymmetry, most commonly overheating the head.

3. ENERGY EFFICIENCY OF BUILDING LOCAL THERMAL ENVELOPE

Since the goal of the program is to use a local thermal envelope to reduce the reliance on a tightly controlled building envelope, the energy required to run the LTMS has to be substantially smaller than the energy saved by the building HVAC when the setpoint is widened. The average HVAC energy use per person in commercial buildings in the United States is approximately 2.4 MWh/year.[22] Assuming HVAC is operational on 261 days and for 10 hours

[22] Estimation based on Energy Information Administration's (EIA) 2003 Commercial Buildings Energy Consumption Survey (CBECS) Database located at http://buildingsdatabook.eren.doe.gov/CBECS.aspx. Selected commercial office building sampling approximately consumed 12.2 kWh/sqft for heating and cooling the sampled offices. The expected average occupancy for this building sampling was ~200 sqft per occupant as indicated in NREL/TP-5500-

per day, the power consumption would be 937 W on average with symmetrical heating and cooling seasons. By selecting a 4°F setpoint offset the expected savings will total about 22% or ~206 W at the system level. With a target savings of 15%, 65 W of power can be allocated to operate the LTMS. This value is much higher than the 23 W required to compensate for the temperature difference, allowing the use of technologies operating with a Coefficient of Performance (COP) of 0.35 or higher.[23] However, it is worth noting that many of the technologies, such as those modulating thermal loss rates from the human body, can have a COP much greater than 1. Such technologies will be preferred since they offer much greater energy savings and expect shorter payback periods. Therefore, DELTA will support:

- Technology concepts that can be developed into a LTMS with a minimum sustained COP of 0.35.

4. ECONOMICS

As far as cost targets for the LTMS, DELTA has a goal of a 3-year payback period, including both capital and operational costs. The 141 W/person saving equals to ~20$/year assuming an energy price of 5.4 cents/kWh.[24] Therefore,

- Technologies should cost less than 60 $/person for a 4°F change in setpoints in each direction

For certain wearable technologies, such as apparel and shoes, ARPA-E estimates the cost requirements as the following based on residential applications. In 2011, the per capita HVAC energy expense at home was ~$352 while the per capita clothing and shoe expense was $682.[25] For a 15% savings in energy expenses, the allowable increase in clothing and shoe expenses is ~ 8%. Therefore,

- Wearable technologies, such as apparel and shoes, should not have an increase in cost of >10% for a 15% energy savings.

46861, February 2011, "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock".

[23] COP is energy delivered to the occupant divided by the wall plug energy consumption by the LTMS.

[24] Estimation based on EIA's Annual Energy Overview 2014 Early Release Overview. Price average considers the relative contribution from electricity, natural gas, and heating oil and their respective prices.

[25] Estimation based on EIA's Annual Energy Overview 2014 Early Release Overview. Apparel purchase estimations are based on U.S. Bureau of Labor Statistics March 2014 Report 1046. Consumer apparel expenditures in 2011 were $1740 per household with a household occupancy factor of ~2.55 individuals per home resulting in a per capita annual expenditure of $680.

5. OTHER ATTRIBUTES OF LTMS THAT IMPACT TECHNOLOGY ADOPTION

In order for any LTMS solutions to make an impact in building energy savings, they not only need to provide the thermal performance and cost but also need to meet or exceed the quality of experience offered by current HVAC systems. Such quality, due to the close proximity and direct interaction with the human body, can be quite subjective. However, in order to facilitate wide spread adoption by the consumer, it is important for any LTMS technology to pay close attention to the issue of quality of experience. In this section, we briefly discuss the various aspects of experience quality that can be important to consider.

Automated control. Current HVAC systems usually do not require frequent user intervention to achieve comfort for the majority of the occupants. Despite the potential benefits of providing individual users with personalized control as discussed above, LTMS solutions should not require user intervention to achieve comfort, although providing the option of user intervention is considered highly beneficial.

Range of motion. One basic feature of the current HVAC system is that it covers the entire building space regardless of location. Consequently, any LTMS solution needs to offer a similar range of motion. An exception is made for technologies targeted at sedentary office workers. In that case, however, a limited range to enable freedom of motion is desirable (see next section).

Aesthetics of non-wearable systems. Current HVAC systems are only visible to the occupants as vents on ceilings, walls, and edge of flooring. Any installed systems as a retrofit to the existing building should aspire to match the architectural designs of the building so that the added LTMS does not present a major disruption in both space utilization and aesthetics. For office furniture-related solutions, they should not occupy significant space, so as to avoid interference with other office functions.

Discrete wearable systems. The aesthetics of wearable items is the most subjective among all the potential LTMS solutions, although they potentially offer the greatest benefit in energy savings and the largest market. However, fashion is a highly personal choice that makes it difficult to define. Nevertheless, wearable LTMS, such as clothing and devices, should aspire to enhance rather than limit fashion choices. Some general guidelines are possible:

- LTMS should not add significant weight;
- LTMS should not impose strict restrictions in type of fabric, color, texture;
- LTMS may be separable from garments so that consumers have the choice of freely using clothing without advanced thermal management properties.

D. TECHNICAL CATEGORIES OF INTEREST

DELTA aims to support the development of transformational technologies that establish a local thermal envelope around the human body. These technologies are expected to enable a widening of the temperature setpoints in buildings to lower than 66°F in winter months and higher than 79°F in summer months, while maintaining the thermal comfort of building occupants above ANSI/ASHRAE standards. ARPA-E envisions supporting a broad range of technologies that can achieve these objectives.

Such technologies can range from on-body wearable technologies, to near range (<1 m) energy transfer, to direct energy transfer to the human body from a distance (>1 m) without substantially heating or cooling the surrounding air. Figure 5 illustrates the three approaches as well as a system level approach that employs any combinations of the three primary approaches.

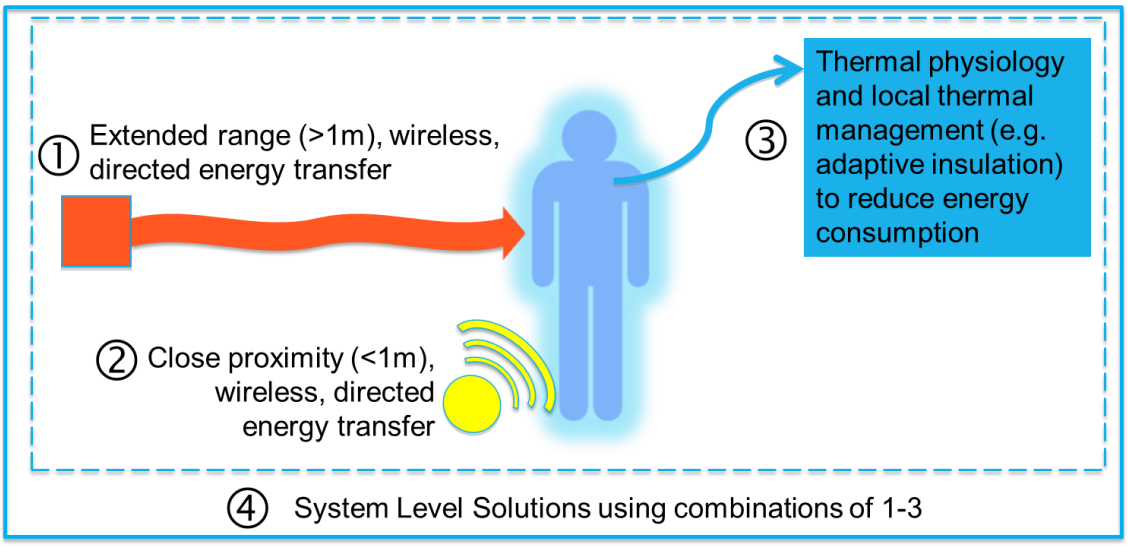

Figure 5. Energy transfer approaches to build a thermal envelope around the human body.

ARPA-E emphasizes that while the three approaches are categorized based on their proximity to the human body, proposed concepts need not be confined by a separated approach. In fact, these approaches can be utilized synergistically to achieve the programmatic goals.

ARPA-E strongly encourages submissions that address both localized heating and cooling. However, submissions that address only heating or cooling are permissible, but must meet the

program metrics. Given the historical technical challenges in creating localized cooling systems, submissions in this topic area are especially encouraged.

Appropriate team expertise for this FOA is a good understanding of basic human thermal physiology, thermal management, materials science, building heating and cooling systems, device fabrication, testing, and modeling. For wearable technologies, it is appropriate to have participation from designers and experts in consumer product adoption.

Below are the technical categories of interest, along with some representative example technologies of interest. However, approaches that are beyond these examples that meet the program metrics are equally encouraged.

CATEGORY 1: EXTENDED RANGE (> 1 M) WIRELESS ENERGY TRANSFER

This category seeks technologies that can uniformly heat or cool occupants remotely. The deliverable is a technology demonstration in a two-room, 6.1 m x 7.62 m floor area or equivalent building interior. This definition is intended to simulate both residential and small business office settings.

Examples of technologies of interest:

- Technologies that uniformly heat or cool the human body without substantially heating or cooling ambient air away from it and creating greater thermal asymmetry, including but not limited to directional energy transfer coupled with low cost tracking technologies;
- Technologies that can sense the human body temperature distribution and adjust the generation and transmission of energy to achieve optimum uniformity and comfort.

CATEGORY 2: NEAR RANGE (< 1 M) WIRELESS ENERGY TRANSFER

This category seeks technologies that are deployed to provide thermal comfort to building occupants who largely remain stationary, such as within an office environment. The deliverable is a technology demonstration, including both hardware and software, in a typical office setting composed of a desk and a chair.

Examples of technologies include:

- Cooling solutions for workstations without generating hot exhaust in occupied spaces;
- Low cost cooling solutions coupled with efficient heat storage;

- Physiological modeling coupled with experimental implementation of solutions that aid in minimizing cooling and/or heating requirements; and
- Office or home furnishings including chairs, desktop items, floor mats, bedding, and other ~~customary office~~ items.

CATEGORY 3: WEARABLE TECHNOLOGIES

This category seeks technologies that are wearable by building occupants to maintain thermal comfort within wider temperature setpoints of 66-79^{o}F. The deliverable is a device or completed wearable garment, shoes, and/or accessory.

Examples of potential technologies include:

- Wearable devices, shoes, apparels and accessories;
- Items that do not significantly impact aesthetics, such as shoe insoles, under garments, other wearable devices such as badges or small portable electronics devices such as mobile phones;
- Clothing with tunable insulation materials that control microstructure including porosity and thickness;
- Clothing with tunable emissivity and/or conductivity;
- Wearable items that create skin surface convection to promote cooling; and
- Wearable items that promote active cooling.

CATEGORY 4: COMBINATION OF CATEGORIES 1 TO 3

This category supports technologies that seek to synergistically utilize combinations of categories 1 through 3. Specifically, the category encourages submissions in:

- Combined technologies that achieve the desired thermal effect with increased effectiveness compared with individual technologies;
- Combined technologies that offer reduced cost and ease of installation in existing buildings.

E. TECHNICAL PERFORMANCE TARGETS

Definition of Thermal Envelope and Reference Building Environment

For the purpose of defining program metrics, ARPA-E defines a thermal envelope around the human body as a 1.83 m tall, 0.91 m diameter cylinder when the occupant is standing and a

1.22 m tall, 1.22 m diameter cylinder when the occupant is seated. While these representations of the human body are gross simplifications, they do enable the definition of the thermal transport problem. We also define the target building interior floor area to be a 6.1 m x 15.24 m made of two rooms of equal size, 6.1 m x 7.62 m.

In addition, regarding the thermal and cost targets: while DELTA has a *minimum* goal of achieving 4°F expansion of the building setpoint in each direction. Applicants are strongly encouraged to propose technologies that far exceed this goal. Consequently, the thermal and cost targets are set for a per degree expansion and a minimum expansion of 4°F.

Metrics for Categories of Interest

ARPA-E is interested in receiving proposals that address the below metrics in the following categories. A single technology that can address multiple categories is encouraged. However, if so proposed, the technology must address the metrics from all categories.

Applications are required to meet all of the Primary Metrics and a majority of the Secondary Metrics. Applications should provide the necessary analysis, modeling, and/or experimental results to justify how each of the metrics is addressed.

The summary table below (Table 1) contains key data specifications for DELTA that Applicants may find useful in preparing their applications.

Table 1. Selected data specifications for FOA calculations

Description	Specification
Baseline (Current) thermal neutral band	70°F-75°F
Expanded thermal neutral band	66°F-79°F
Optimal building relative humidity range	30-60 %
Human skin temperature	93°F
Average human heat generation	58.2 W/m^2
Average human surface area	1.8 m^2
Approximate human body occupancy volume as a cylinder – standing	H= 1.83 m, Dia.= 0.91 m
Approximate human body occupancy volume as a cylinder – seated	H= 1.22 m, Dia.= 1.22 m
Cooling needed to expand to 79°F	23 W/person
Heating needed to expand to 66°F	18 W/person
Average commercial office occupancy	18.6 m^2

Average residential occupancy	56.2 m^2
Average commercial office HVAC use	0.937 kW/person
Average residential HVAC use	2.44 kW/person
Demonstration building floor area	6.1 m x 15.24 m
Demonstration room floor area	6.1 m × 7.6 m
Household occupancy factor	2.55 people/home
Residential per capita annual heating and cooling expenditure	$352
Household annual apparel expenditure	$1740

CATEGORY 1: EXTENDED RANGE (> 1 M) WIRELESS ENERGY TRANSFER

Primary Metrics

ID	Property	Metric
1.1	Thermal Performance	Adaptively provide or remove > 6 W/°F [26] and > 23 W total from the defined thermal envelope without increasing undesirable thermal asymmetry on the occupant[27]
1.2	Minimum COP	0.35
1.3	Range of Motion	Entire building interior with tracking capable of following an occupant moving at 1 m/s
1.4	Cost	0.0375$/$ft^2$/°F and 0.15$/ft^2 if only heating or cooling is addressed (30$ per occupant with occupancy of 200 ft^2/person and a 4°F offset in a single direction; 60$ per occupant for 4°F offset in both directions).

[26] °F refers to per degree of setpoint expansion
[27] Undesirable asymmetry refers to an increased asymmetry vs a baseline

Secondary Metrics

ID	Property	Metric
1.5	Operability	Automated control by building with the option to be overridden by the occupant
1.6	Safety	Meet OSHA standards
1.7	Appearance	< 5% increase in visible light on occupant; <5% increase in noise

CATEGORY 2: NEAR RANGE (< 1 M) WIRELESS ENERGY TRANSFER

Primary Metrics

2.1	Thermal Performance	Adaptively provide or remove > 6 W/°F and > 23 W total from the defined thermal envelope without increasing undesirable thermal asymmetry on the occupant; for cooling solutions, air temperature in the thermal envelope has to be lower than ambient
2.2	Minimum COP	0.35
2.3	Range of Motion	A semicircle with a 0.61 m radius from the source of the energy supply[28]
2.4	Cost	60$/occupant annually for a 4°F offset in both directions, or 7.5$/°F of change.

Secondary Metrics

ID	Property	Metric
2.5	Operability	Automated control by building with the option to be overridden by the occupant

[28] This requirement is waived for concepts where end-users are intended to remain stationary while using the device, e.g., such as chairs or bedding.

2.6	Safety	Meet OSHA standards
2.7	Appearance	Compatible with common office environment

CATEGORY 3: WEARABLE TECHNOLOGIES

Primary Metrics

ID	Property	Metric
3.1	Thermal Performance	Adaptively provide or remove > 6 W/°F and > 23 W from the defined thermal envelope per occupant
3.2	Minimum COP	0.35
3.3	Range of Motion	Entire building interior
3.4	Cost	< 20$/person/year or < 10% of selling price increase over baseline apparel technology assuming a 4°F setpoint expansion in both directions. < 10$/person/year or < 10% of selling price increase over baseline is required assuming a 4°F setpoint expansion for technologies that only heat or cool.

Secondary Metrics

ID	Property	Metric
3.5	Operability	Fully autonomous but with optional capability to be overridden by the occupant and to communicate with the building
3.6	Safety	Meet OSHA standards
3.7	Durability	Meet ASTM standards of 50 washing and drying cycles

3.8	Appearance	Preferred to be detachable from current apparel Preferred to exhibit no visible surface change Preferred to exhibit no interference with consumer color or texture choices Preferred to require negligible power
3.9	Weight	< 10% increase over baseline apparel
3.10	Interaction with building	Preferred to provide temperature and humidity information to the building

CATEGORY 4: COMBINATION OF CATEGORIES 1 TO 3

Technologies proposed that use a combination of Category 1 to 3 technologies should meet the thermal and cost metrics as defined in the combined categories cumulatively. For example, if a variable insulation wearable technology can sustain a heat dissipation of 10 W, then a wireless energy transfer technology could provide the remaining 13 W needed to achieve the 23 W thermal power goal. In addition, technologies should meet the secondary metrics as defined in the categories appropriate for the combination.

F. APPLICATIONS SPECIFICALLY NOT OF INTEREST

- Installed systems that promote air movement with regular patterns without lowering air temperature, e.g, high efficiency fans.
- Technologies that increase the absolute indoor humidity.
- Technologies that require major change in common business and casual dress practices (for example, wearing hats indoors).
- Technologies that focus on zone control improvement by using better insulation between different zones (e.g, individual control for each room).

- Technologies that improve building thermal envelope and HVAC appliances that do not aim at creating a local thermal envelope around human body.

- Technologies that rely on human psychological effects (e.g., temporal allesthesia).

- Technologies that involve the intake of chemicals by the human body in any manner, including but not limited to: oral, transdermal, inhaling, or injection pathways.

The following types of applications will be deemed nonresponsive and will not be reviewed or considered (see Section III.C.2 of the FOA):

- Applications that fall outside the technical parameters specified in Section I.E of the FOA

- Applications that were already submitted to pending ARPA-E FOAs.

- Applications that are not scientifically distinct from applications submitted to pending ARPA-E FOAs.

- Applications for basic research aimed at discovery and fundamental knowledge generation.

- Applications for large-scale demonstration projects of existing technologies.

- Applications for proposed technologies that represent incremental improvements to existing technologies.

- Applications for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).

- Applications that do not address at least one of ARPA-E's Mission Areas (see Section I.A of the FOA).

- Applications for proposed technologies that are not transformational, as described in Section I.A of the FOA and as illustrated in Figure 1 in Section I.A of the FOA.

- Applications 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 (see Figure 1 in Section I.A of the FOA).

- Applications that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $30 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 12-18 awards under this FOA. ARPA-E may 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 in September 2014, or as negotiated.

ARPA-E encourages applications 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.

Applications requiring proof-of-concept R&D can propose a project with the goal of delivering on the program metric at the conclusion of the project period. These applications should 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, applications requiring proof-of-concept R&D can propose a project with the project end deliverable being extremely creative but partial solutions. 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 should 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 applications with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

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

ARPA-E may establish more than one budget period for each award and fund only the initial budget period(s). Applicants are not guaranteed funding beyond the initial budget period(s). Before the expiration of the initial budget period(s), ARPA-E may perform a down-select among different recipients and provide additional funding only to a subset of recipients.

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."[29] Accordingly, ARPA-E has substantial involvement in the direction of every project, as described in Section II.C below.

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[30]

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, GOGOS, AND FEDERAL INSTRUMENTALITIES[31]

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

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

[29] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[30] The Prime Recipient is the signatory to the funding agreement with ARPA-E.
[31] DOE/NNSA GOGOs are not eligible to apply for funding, as described in Section III.A of the FOA.

When a FFRDC or non-DOE/NNSA GOGO is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC or non-DOE/NNSA GOGO 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 or non-DOE/NNSA GOGO 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, and Federal instrumentalities (e.g., Tennessee Valley Authority) generally take the form of Interagency Agreements. Any funding agreement with a FFRDC or non-DOE/NNSA GOGO will have substantially similar terms and conditions as ARPA-E's Model Cooperative Agreement (http://arpa-e.energy.gov/arpa-e-site-page/award-guidance).

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.

If Applicants are seeking to negotiate a TIA, they are required to include an explicit request in their Full Applications. Please refer to the Business Assurances Form for guidance on the content and form of the request.

In general, TIAs require a cost share of 50%. See Section III.B.3 of the FOA.

4. GRANTS

Although ARPA-E has the authority to provide financial support to Prime Recipients through Grants, ARPA-E generally does not fund projects through Grants. ARPA-E may fund a limited number of projects through Grants, as appropriate.

C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

Generally, ARPA-E is substantially involved in the direction of projects (regardless of the type of funding agreement) from inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- ARPA-E does not limit its involvement to the administrative requirements of the ARPA-E funding agreement. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole. Project teams must adhere to ARPA-E technical direction and comply with agency-specific and programmatic requirements.

- ARPA-E may intervene at any time to address the conduct or performance of project activities.

- During award negotiations, ARPA-E Program Directors establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. Prime Recipients document the achievement of these milestones and deliverables in quarterly technical and financial progress reports, which are reviewed and evaluated by ARPA-E Program Directors (see Attachment 4 to ARPA-E's Model Cooperative Agreement, available at http://arpa-e.energy.gov/arpa-e-site-page/award-guidance. ARPA-E Program Directors visit each Prime Recipient at least twice per year, and hold periodic meetings, conference calls, and webinars with Project Teams. ARPA-E Program Directors may modify or terminate projects that fail to achieve predetermined technical milestones and deliverables.

- ARPA-E reviews reimbursement requests for compliance with applicable Federal cost principles and Prime Recipients' cost share obligations. Upon request, Prime Recipients are required to provide additional information and documentation to support claimed expenditures. Prime Recipients are required to comply with agency-specific and programmatic requirements. Please refer to Section VI.B.3-4 of the FOA for guidance on proof of cost share commitment and cost share reporting.

- ARPA-E works closely with Prime Recipients to facilitate and expedite the deployment of ARPA-E-funded technologies to market. ARPA-E works with other Government agencies and nonprofits to provide mentoring and networking opportunities for Prime Recipients. ARPA-E also organizes and sponsors events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E establishes collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

- ARPA-E may fund some projects on a fixed-obligation basis.

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,[32] as the lead for a Project Team,[33] or as a member of a Project Team.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[34] 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 are eligible to apply for funding as the lead organization for a Project Team or as a member of a Project Team, but not as a Standalone Applicant.

DOE/NNSA GOGOs are not eligible to apply for funding.

Non-DOE/NNSA GOGOs 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.

State and local 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. All

[32] A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.
[33] 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.
[34] 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.

work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (including U.S. territories). The Applicant may request a waiver of this requirement in the Business Assurances Form, which is submitted with the Full Application. Please refer to the Business Assurances 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 agreement binds the individual consortium members together and should discuss, among other things, 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[35]

Applicants are bound by the cost share proposed in their Full Applications. In the Business Assurances Form accompanying the Full Application, Applicants must provide written assurance of their cost share commitments. Please refer to the Business Assurances Form available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov) for additional guidance.

[35] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.

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, the Prime Recipient must provide at least 20% of the Total Project Cost[36] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[37]

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 by large businesses when selecting applications for award negotiations (see Section V.B.1 of the FOA).

The Prime Recipient may request the use of a Technology Investment Agreement (instead of a Cooperative Agreement) in the Business Assurances Form submitted with the Full Application (see Section II.B.3 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.

- 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, and/or FFRDCs 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) 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.

[36] 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, FFRDCs, and GOCOs.
[37] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

- 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 project period, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination. ARPA-E requires all recipients to contribute cost share in proportion with each submitted invoice over the life of the program.

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.

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 project period;

- 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[38] 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.

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 10 C.F.R. parts 600 and 603 for additional guidance on cost sharing, specifically 10 C.F.R. §§ 600.30, 600.123, 600.224, 600.313, and 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

Because FFRDCs and GOGOs are funded by the Federal Government, costs incurred by FFRDCs and GOGOs 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.

8. COST SHARE VERIFICATION

Applicants are required to provide written assurance of their proposed cost share contributions in their Full Applications. Please refer to the Business Assurances Form for guidance on the cost share information that must be included.

Upon selection for award negotiations, Applicants are required to provide additional information and documentation regarding their cost share contributions. Please refer to

[38] As defined in Federal Acquisition Regulation Section 31.205-18.

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.

ARPA-E will 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.

ARPA-E will 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 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 uploaded all required documents to ARPA-E eXCHANGE by the deadline stated in 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. Any "Applications Specifically Not of Interest," as described in Section I.F of the FOA, are deemed nonresponsive and are not reviewed or considered.

3. LIMITATION ON NUMBER OF APPLICATIONS

ARPA-E is not limiting the number of applications that may be submitted by 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. 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.1 of 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 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 30 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. ARPA-E reviews only compliant and responsive Full Applications.

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 noncompliant.

5. "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, perform a "down-select" of Full Applications. Through a down-select, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, 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 and site visits, nor will these costs be eligible for reimbursement as pre-award costs.

ARPA-E may select applications for funding 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. ARPA-E may select or not select a Full Application for award negotiations. ARPA-E 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, Budget Justification Workbook/SF-424A, Business Assurances Form, and Other Sources of Funding Disclosure Form. Sample responses to the Other Sources of Funding Disclosure Form and Business Assurances Form, and a sample Summary Slide, are also available on ARPA-E eXCHANGE. Applicants must 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 Technical Milestones and Deliverables - Instructions and Examples, the template for the Summary Slide, the template for the Summary for Public Release, and the template for the Reply to Reviewer Comments.

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 requirements:

- 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. Use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The Control Number 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.

ARPA-E will not review or consider noncompliant and/or nonresponsive Concept Papers (see Section III.C of the FOA).

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

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

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

SECTION	PAGE LIMIT	DESCRIPTION
Technology Description	2 pages maximum	• Applicants are required to describe succinctly: ○ The proposed technology, including its basic operating principles and how it is unique and innovative; ○ The proposed technology's target level of performance (Applicants should provide technical data or other support to show how the proposed target could be met); ○ The current state-of-the-art in the relevant field and application, including key shortcomings, limitations, and challenges; ○ How the proposed technology will overcome the shortcomings, limitations, and challenges in the relevant field and application; ○ The potential impact that the proposed project would have on the relevant field and application; ○ The key technical risks/issues associated with the proposed technology development plan; and ○ The impact that ARPA-E funding would have on the proposed project.
Addendum	2 pages maximum	• Applicants may provide graphs, charts, or other data to supplement their Technology Description. • Applicants are required to describe succinctly the qualifications, experience, and capabilities of the proposed Project Team, including: ○ Whether the Principal Investigator (PI) and Project Team have the skill and expertise needed to successfully execute the project plan; ○ Whether the Applicant has prior experience which demonstrates an ability to perform R&D tasks of similar risk and complexity; ○ Whether the Applicant has worked together with its teaming partners on prior projects or programs; and ○ Whether the Applicant has adequate access to equipment and facilities necessary to accomplish the R&D effort and/or clearly explain how it intends to obtain access to necessary equipment and facilities.

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

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 JULY 2014]

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;
- 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 State of the Art* (50%) - This criterion involves consideration of the following factors:

- The extent to which the proposed quantitative material and/or technology metrics demonstrate the potential for a transformational and disruptive (not incremental) advancement in one or more energy-related fields;
- The extent to which the Applicant demonstrates a profound understanding of the current state-of-the-art and presents an innovative technical approach that significantly improves performance relative to the current state-of-the-art; and
- The extent to which the Applicant demonstrates 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 factors:

- The extent to which the proposed approach is unique and innovative;
- The feasibility of the proposed work;
- The extent to which the Applicant proposes a sound technical approach to accomplish the proposed R&D objectives;
- The extent to which project outcomes and deliverables are clearly defined; and

- The extent to which the Applicant proposes a strong and convincing technology development strategy, including a feasible pathway to transition the program results to the next logical stage of R&D and/or directly into commercial development and deployment.

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 State of the Art	50%
Overall Scientific and Technical Merit	50%

2. CRITERIA FOR FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

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 JULY 2014]

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 reviewed or considered. 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. Due to the anticipated volume of applications, ARPA-E is unable to provide feedback on Concept Papers.

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 or the Applicant. 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 JULY 2014]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

Upon the issuance of a FOA, ARPA-E personnel 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.

- ARPA-E will post responses on a weekly basis to any questions that are received. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- ARPA-E will cease to accept questions approximately 5 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 posted to "Frequently Asked Questions" 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 Form and the Other Sources of Funding Disclosure 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. Applicants should not include confidential, proprietary, or privileged information in their Concept Papers, Full Applications, or Replies to Reviewer Comments unless such information is necessary to convey an understanding of the proposed project.

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 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 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.

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.

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. Such data should be clearly marked as described in Section VIII.E of the FOA. 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. ANNUAL COMPLIANCE AUDITS FOR FOR-PROFIT ENTITIES

[TO BE INSERTED BY FOA MODIFICATION IN JULY 2014]

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: Advanced Research Projects Agency-Energy.

Cost Share: The Prime Recipient share of the Total Project Cost.

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.

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

Key Participant: Any individual who would contribute in a substantive, measurable way to the execution of the proposed project.

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 or otherwise supporting work under an ARPA-E funding agreement.

R&D: Research and development.

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).