FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET)

Announcement Type: ~~Initial Announcement~~ Modification 01
Funding Opportunity No. DE-FOA-0001199
CFDA Number 81.135

FOA Issue Date:	November 10, 2014
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, December 15, 2014
Submission Deadline for Concept Papers:	5 PM ET, December 22, 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 $10 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 $5 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	11/25/2014	• Updated Section Reference of "Applications Specifically Not of Interest," from I.F to I.E. See Section III.C.2 of the FOA.

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REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: ○ Concept Summary ○ Innovation and Impact ○ Proposed Work ○ Team Organization and Capabilities	Mandatory	IV.C	5 PM ET, December 22, 2014
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]	Mandatory	IV.D	5 PM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]	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.

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.

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 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.

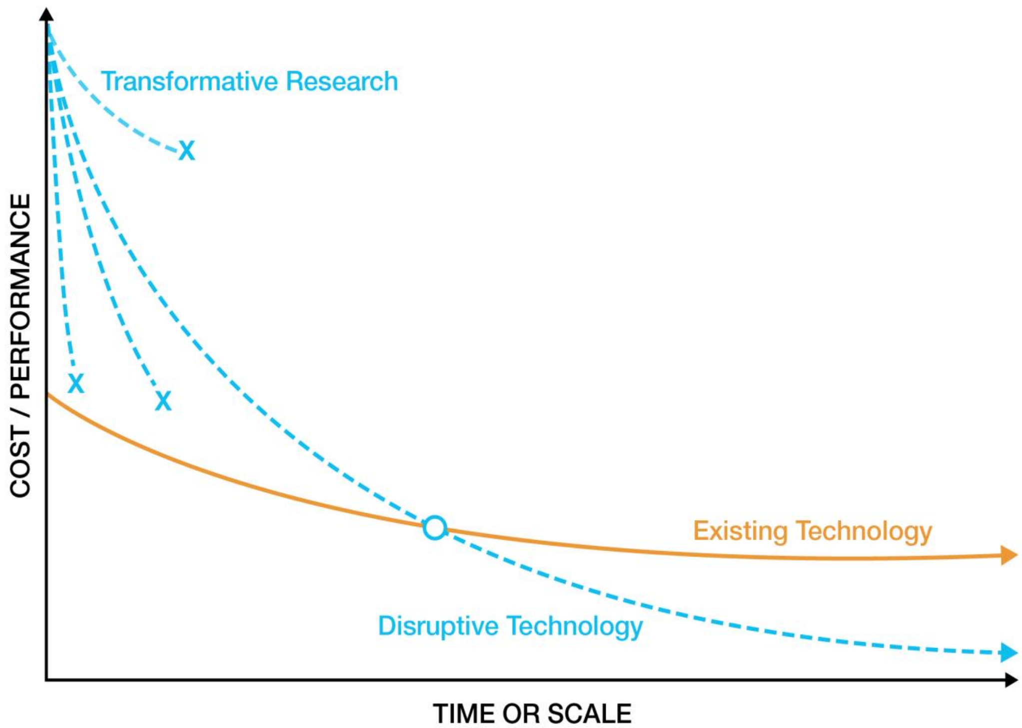

Figure 1: Description of transformational and disruptive technologies in terms of cost per unit performance versus time or scale. ARPA-E seeks to support research that establishes new learning curves that lead to disruptive technologies.

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

The Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET) program seeks solutions that minimize energy consumption in America's surface transportation network through the use of network control mechanisms that operate through personalized signals directed at individual travelers.

In 2013, the United States used more than 25% of its energy supply for the purpose of moving people and goods from one place to another, i.e., in the transportation sector.[1] Even modest improvements that reduce transportation energy consumption can reduce energy imports and greenhouse gas emissions, two of ARPA-E's primary goals. To date, technologies directed at transportation have focused primarily on the diversification of energy supplies (e.g., the production of alternative liquid fuels and electrification) or on improvements in vehicle fuel efficiency (e.g., combustion efficiency, weight reduction, and aerodynamic design).[2] The TRANSNET program takes an alternative, complementary approach through the development of technologies that target both the factors that drive energy consumption and the overall energy efficiency of personal transportation, without changing the mechanical efficiency of each mode (car, bus, train, etc.) within the network.

The time is ripe for this new approach. Today, personal transportation is entering a period of rapid change, enabled by the introduction of new technologies. Such technologies apply not only to the vehicles themselves (e.g., autonomous/semiautonomous vehicles, vehicle-to-vehicle (V2V)/vehicle-to-infrastructure (V2I) communications, and electric/natural gas fueled vehicles), but also to a number of approaches that enable transportation information to be collected and disseminated by wireless communication and the Internet (e.g., Waze, Uber, Zipcar, and Lyft, as well as social networks such as Facebook, Twitter, etc.). How can these innovative technologies be used to reduce energy use in transportation networks? The answer is not completely clear. But ARPA-E envisions significant opportunities for new and emerging technologies, with deliberate and thoughtful development, to create a framework for a practical system with real-time response to make energy efficiency an integral part of the optimized transportation network of the future.

In the context of this opportunity, several descriptive and common terms require accurate definitions, which may be found in the Technical Glossary in Section I.D of the FOA. Please review these definitions so that the intent of this funding opportunity is clear.

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[1] In 2013, the US consumed 97.534 quadrillion BTUs (Quads) of energy, 26.990 Quads of this were associated with transportation. Source: DOE/EIA-0035 (2014/07), U. S. Energy Information Agency, Monthly Energy Review, July 2014. 17 August 2014. http://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

[2] For example, see the ARPA E programs Electrofuels, BEEST, PETRO, REMOTE, RANGE, MOVE, and METALS. http://arpa-e.energy.gov/?q=arpa-e-site-page/view-programs

Summary of the Opportunity

ARPA-E believes that the transportation network can be made more efficient, without substantial investment in new infrastructure, improvements in modal efficiency, or perceptible reduction in either the quality-of-service or the reliability of the system. While the size of the impact is difficult to quantify precisely, given the human element, significant energy is wasted in personal transportation: Occupancy is only 40% of nominal capacity for passenger vehicles,[3] driving styles contribute to a 45% reduction in the on-road fuel economy (per driver),[4] and congestion (which is related to non-optimal route choice) increases the energy used in transportation up to 33%,[5] even before soft factors such as lost productivity and lower quality of life are accounted for.

Applicants are challenged to develop mechanisms for individual travelers that both signal and guide them toward improvement of the energy efficiency of the transportation network in multimodal urban areas. Because a purely experimental, complete analysis of the transportation network would be prohibitively expensive and time consuming, ARPA-E seeks the development of simulated network control models of energy use in personal transportation, based on real-world data, that incorporate personalized signaling and guiding mechanisms. A suitable model will need not only to describe the current state of the personal transportation network but also to predict the impact of changes to the network, both from travelers' choices, such as mode and departure time, and from network changes, such as those that result from incidents and lane closures. The model must also be robust with respect to inaccuracies that stem from incomplete and noisy sensor data. Optimization will require development of a high fidelity system model that allows guidance and control hypotheses to be tested, refined, or discarded in full view of this uncertainty. These hypotheses will be embodied through simulation to achieve ARPA-E's core objective, a control architecture that enables the practical network control through personalized guidance. The design of this control architecture defines the central challenge of the TRANSNET program.

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[3] The National Highway Transportation Survey reports average occupancy of 1.67 persons over all types of trips. The average number of seats is assumed to be 4.

[4] Sivak, M. & Schoettle, B."Eco-driving: Strategic, tactical, and operational decisions of the driver that influence vehicle fuel economy", Transport Policy 22 (2012) 96–99. See also LeBlanc, D., Sivak, M., and Bogard, S. "Using Naturalistic Driving Data to Assess Variations in Fuel Efficiency among Individual Drivers" University of Michigan Transportation Institute Report UMTRI-2010-34, December 2010.

[5] This is an approximation of the maximum effect. See Roughgarden, T., "The Price of Anarchy in Games of Incomplete Information", http://theory.stanford.edu/~tim/papers/inc.pdf.

Challenges in Signaling and Control Mechanisms

In today's transportation network, guidance and control mechanisms are, for the most part, impersonal. For example, in private vehicles, every traveler experiences speed limits, traffic signals, and tolls identically.[6] However, over the past ten years, digital technology has altered the landscape dramatically. Personal, wireless technologies combined with low-cost sensors are ubiquitous and these technologies possess an intrinsic transformational potential[7] to change how to move people from one place to another efficiently. Software advances complement these hardware and communications network technologies, fueling computational approaches that help process the data to both predict and influence the choices made by individuals.[8]

Here, we seek the development of a control architecture that acts to reduce energy use in transportation through personalized signaling, guidance, and control mechanisms. This architecture is subject to the physical constraints imposed by existing infrastructure (e.g., highways, arterials, rail lines, etc.). Because such a structure also needs to be practical for, and implemented by, travelers themselves, it must not reduce either the individual's quality-of-service or the network's system reliability.

Figure 2 shows energy use at the level of the individual traveler (expressed both as total energy consumed, in quadrillion BTUs or quads, and in consumer-friendly, miles-per-gallon-equivalent per traveler, MPGe). Personal transportation is dissected by mode, and plotted in order of increasing efficiency. We see that the least efficient choices, cars and trucks, consume most of the energy in personal transportation. Further, we see that, on a per person basis, all forms of road transportation are less efficient than air or rail; this is largely the consequence of occupancy, which is about 33% for cars and trucks, and 30-40% for city buses,[9] but exceeds 80% for commercial airlines. The relatively low occupancy of Amtrak (about 25%) is more than offset

[6] Note that even rudimentary differentiation by vehicle class can be a remarkably effective control mechanism. For example, the use of single-occupancy HOV lane stickers in California for alternative vehicles is considered to have been successful in reducing both emissions and congestion, with sticker-bearing Priuses valued thousands of dollars more than their sticker-free siblings.

[7] In 2014, the International Telecommunications Union reported that the cellular telephone market is approaching saturation, that is, one phone per person over the entire planet! [See http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.] In this same report, mobile broadband adoption appears to trail cellular adoption by about 10 years. Assuming these trends persist, nearly every person on the planet will be connected to the Internet via wireless devices within the next decade.

[8] Lohr, "Sizing Up Big Data, Broadening Beyond the Internet", New York Times Blog. August 23, 2014. http://bits.blogs.nytimes.com/2013/06/19/sizing-up-big-data-broadening-beyond-the-internet/ See also Thaler, R. H. & Sunstein, C. R. "Nudge: Improving Decisions About Health, Wealth, and Happiness", Penguin, 2009, and Ariely, D. "Predictably Irrational: The Hidden Forces That Shape Our Decisions", HarperCollins, 2008.

[9] The average occupancy of a city bus is about 9 (Table 2.12, Transportation Energy Data Book, Edition 33, 2014, http://cta.ornl.gov/data/index.shtml), the average capacity of a city bus is about 30 (seated).

by the extraordinary energy efficiency of rail,[10] a factor that is also captured in Light Rail efficiency.[11]

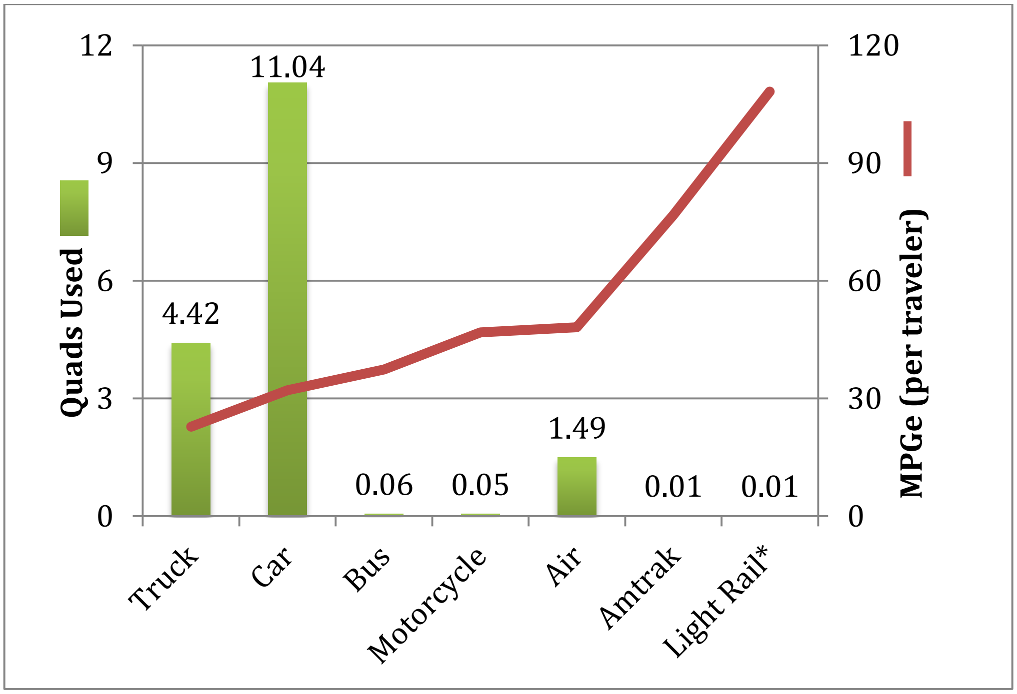

Figure 2: Energy used in personal transportation by mode and efficiency. For each mode, values are based on CY2011. Except for Light Rail, data is derived from USDOT RITA BTS "National Transportation Statistics", 2014 Tables 4-20, 4-21, 4-22, 4-24, and 4-26. MPGe is calculated based on the energy used and the energy content of gasoline, rather than the customary fuels used by each mode of transportation. *For Light Rail, value is derived from the National Transit Database (http://www.ntdprogram.gov/) as a ratio of total passenger miles to energy consumed, from Tables 17 and 19 respectively.

Of course, different modes are not ideal substitutes for one another, and mode choice is only one factor that influences transportation energy efficiency. For a large number of travelers, while shifting to mass transit would lead to energy savings, it also provides lower quality-of-service. Figure 2 also illustrates the importance, in energy terms, of targeting individual travelers. Today, travelers operate more or less independently under a control architecture comprised of uniformly displayed signals and controls and highly variable drivers. Cars and trucks are wasteful, but they are flexible modes that operate at low occupancy, addressing unique personal needs for transportation. In the TRANSNET program, we seek a way to leverage this feature of today's transportation network to provide both better control and improved network energy efficiency.

[10] This is derived from the limited access character of railroad, which results in fewer stops, and the low rolling friction of steel-on-steel. For more information, see the Association of American Railroads at https://www.aar.org/keyissues/Pages/Energy-And-Environment.aspx. The rolling resistance of automobile tires is approximately 15-fold higher than rail.

[11] For light rail, which is exclusively electric-powered, energy units were converted as 1 kWh = 3,412 Btu. This does not consider system losses in electrical generation; if those losses are considered, Light Rail efficiency drops to a less dramatic 34.9 MPGe.

Technologies based on significantly improved computational capabilities, personalized signals, and control mechanisms will be needed in order to realize this opportunity. The strategic advantage of network control architecture lies in its ability to adjust both the schedule and routing of individual elements, such that optimization becomes both possible and predictable. In transportation networks, the components of such a control architecture are already in place:

- Microscopic simulation models at different scales have been[12], or are being, developed[13] but dynamic, personalized signaling, guidance and control mechanisms have not been considered.

- The behavior of controlled dynamical systems can be predicted in advance of experiment using modern computational methods (Computational Fluid Dynamics, for example), so modeling and flow control in transportation networks needn't be a purely descriptive exercise.

- Model based network optimization is widely accepted practice, for example, in power systems and in air traffic control.

Consequently, ARPA-E believes that there are components in related fields of investigation that provide an opportunity for innovation, if these fields can be successfully integrated and the combined technology reduced to practice.

The first step is to develop a high fidelity system-level model of an urban multimodal network. This is expected to be a new effort that may build upon existing transportation models, which in many cases treat individual travelers as agents whose choices are independent, made largely before travel commences. The result of these uncorrelated choices is not optimal for the whole network, as first noted by economist A. C. Pigou in 1920.[14] The model must answer the central question: "What fraction of travelers must communicate directly, and in real time, both with each other and with a control network, to provide significant overall energy savings?" Such a model must not only take into account what happens when travelers communicate and the system is optimized based on personalized signaling and network control mechanisms, but also must be able to be grounded in (and tested by) real world data.

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[12] Treiber, M. & Kesting, A. "Traffic Flow Dynamics", Springer, 2013.

[13] There are a number of academic and private modeling efforts. See for example "POLARIS", https://www.tracc.anl.gov/index.php/polaris, a project under development at Argonne National Laboratories with funding from FHWA, and Zhang et al "Integrating an Agent-Based Travel Behavior Model with Large-Scale Microscopic Traffic Simulation for Corridor-Level and Subarea Transportation Operations and Planning Applications", J. Urban Plann. Dev. 2013.139:94-103.

[14] Pigou, A. C., *The Economics of Welfare*, Macmillan, 1920. A pithy, transportation-relevant treatment is given in Roughgarden, T. "Selfish Routing and the Price of Anarchy", MIT Press, 2005, Chapter 1.

As a second, more important step, personalized signaling and guidance strategies need to be embodied in a control architecture that reflects the incomplete and inaccurate sampling environment of the physical world. This architecture is intended to provide the basis for implementing personalized signaling and guidance in actual urban environments.

Challenges in Measurement

Particularly with the widespread deployment of low cost sensors, the energy used in transportation can certainly be measured with a high degree of accuracy—there is little technological challenge implicit in the development of new energy meters at the level of the mode (car, bus, train, etc.). In practice, however, energy use data is not collected effectively or at the level of the individual traveler, and conceptualizing the problem from the traveler's viewpoint exposes several technological shortfalls. The problem can be reduced to one of mapping the energy used by the mode to the energy used by the traveler.

To illustrate this problem, consider an individual commuter in the Washington (DC) metropolitan area, an area with many different transportation options. Suppose, for the purpose of illustration, that our traveler is a commuter who lives in the suburbs, but works downtown, and uses public transit to get to work. On a particular day, our traveler drives from home to the transit station, parks, rides the DC Metro rail system into work, attends a business lunch across town, and returns home by reversing the steps of the morning commute. During the first leg of the journey, our traveler drives (alone) from home to the train station. Modern automobiles have computer-controlled fuel injectors, such that the precise amount of fuel (and hence energy) used by the vehicle is readily measured, from data available on the On-Board Diagnostics (OBD-II) port that has been mandated in all new vehicles since 1996. During the second leg of the journey, our traveler boards the DC Metro. While the total amount of energy used by the train is certainly known, this data and the *occupancy* of the train is difficult to obtain by any individual traveler, especially in real time. The energy used by the traveler is, of course, the *pro rata* portion of the total energy used by the train, in other words, the total energy use for the mode divided by the occupancy. Next, our traveler arrives at work, ending the first part of the transportation day. Then, at lunch, our traveler has a cross-town business lunch and decides to take a taxi both ways. The OBD-II sensor in the cab can certainly provide precise energy use data to our traveler, with suitable connectivity, but there are additional unknowns. For example, how far away did the cab need to travel (without a passenger) to pick up our traveler?[15] Finally, the energy used in reversing each of these steps is not equivalent to that used in the forward steps, even though the distances traveled may be identical, due to factors such as modal occupancy, local traffic, and parking.

[15] Personalized controls may eventually seek to reward specific choices made by travelers who are also drivers, so, another question is, can the technology differentiate passenger and driver? Note that the traveler occupancy of the cab is 0 when it is not engaged. The traveler and the driver are separate in this case, unlike the first car trip. This example exposes data collection problems associated with vehicle to passenger/driver communication.

Collecting data at the level of the individual traveler is another part of this conceptually simple yet technically challenging problem, even though the overall answers are known: Average daily traffic speeds, fuel sales, vehicle miles traveled, transit ridership, and taxi trips are all tabulated (in principle). But, these data are not without issue: In the real world, sensor reliability and manual reporting reduces the quality of the data.[16] Personal data collection is, of course, treacherous due to privacy concerns,[17] such that it is unrealistic to expect the availability of a comprehensive data set to support any real world system model or control architecture. Fortunately, we believe that the proliferation of sensors in recent years will oversample the transportation network, and redundant data sources (from different sensors) will serve to mitigate at least some of the noise and inconsistency.[18] Regardless, the knowledge of aggregate numbers allows various models to be calibrated using real world data.

C. PROGRAM OBJECTIVES AND STRUCTURE

This funding opportunity solicits the development and testing of new network optimization approaches entirely in a simulation environment. The primary objectives are twofold: (1) To demonstrate that energy efficiency gains are possible through implementable control architectures, and (2) To identify key technology gaps that limit such implementation. A second phase program (if pursued) would involve real-world validation of the system model and trial implementation of the network control architecture developed in the initial phase of TRANSNET. **However, a second phase will only be considered if significant positive impact is demonstrated during the course of the awards made through this FOA.**

Each applicant must develop two interdependent modules: (1) a system model and (2) a control architecture. A system model is a fully parameterized model of a multimodal urban personal transportation network, and must functionally represent the real world. A control architecture is a detailed, comprehensive approach to network control and will be implemented within the system model in the same way it could be implemented in the real world, with the objective to reduce system level energy use by providing signals to individual travelers.

[16] See for example El Faouzi, NE et al. “Data fusion in intelligent transportation systems: Progress and challenges – A survey”, Information Fusion 12 (2011) 4–10

[17] For a transportation-related example, see de Montjoye, Y.-A., Hidalgo, C.A., Verleysen, M. & Blondel, V.D. “Unique in the Crowd: The privacy bounds of human mobility”. Sci. Rep. **3**, 1376.

[18] See for example, Bachmann, C. et al., “A comparative assessment of multi-sensor data fusion techniques for freeway traffic speed estimation using microsimulation modeling”, Transportation Research Part C 26 (2013) 33–48

The System Model

The system model must have two broad capabilities, (1) the ability to simulate a complete set of data that could be measured/obtained from the real world and (2) the ability to describe traveler behaviors and responses to guidance and control signals in a realistic way. The characteristics of system models that deliver these capabilities are provided in

Table 1. Applications should propose a model that addresses each of these characteristics; however, ARPA-E recognizes that flexibility in the model is required and that model development and refinement will continue during the course of the award.

Table 1.

Characteristics of the System Model		
DATA & DATA QUALITY		To be defined by applicant. Data must be based on the requirements of the control architecture. Applicants should estimate data accuracy and quality for each source to help with sensitivity evaluation of the model. Sources fall into three classes, public, private, and personal.
	Public:	These data will serve as the ground truth for the system model and must be comprehensive. Data outside the training set must also be available.
	Private:	If used, data providers must be involved, ideally with the data provider as a member of the project team. Privacy features must be incorporated up front, and should be highlighted, where necessary to protect both private and personal data.
	Personal:	It is assumed that individual wireless devices associated with each participating traveler will provide this data. Consequently, the applicant should clearly define what data is needed from each traveler and incorporate it into the system model. Real-world parameterization of this specification is expected. Personal data should be collected as needed, rather than as a continual stream, to minimize privacy and bandwidth concerns, but may include a zone around each traveler that is collected using peer-to-peer wireless technologies. See the Control Architecture section for further guidance.
REPORTING		In addition to energy use, other aggregate data, e.g., average vehicle speed and density on key highways and arterials, must be reported for model validation. These data are expected to closely approximate actual measurements, particularly during peak conditions. For transit, similar aggregate measures might include, for example, hourly ridership on public transit. Reporting should also include metrics of quality of service and system reliability (See Definitions).
MODEL PERFORMANCE		• Fast enough to support the testing of a real time control architecture, but need not be "real time" itself • Modular and developed under an open software standard[19] • Written in a widely-available computer language

[19] See for example http://opensource.org/osd

REGION OF INTEREST	US urban region of greater than 3 million inhabitants, based on the 2010 Census and metropolitan statistical areas defined the Office of Management and Budget[20] using a region that has robust multimodal options
DESCRIPTORS FOR PARTICIPANTS	Descriptors for both travelers and drivers should approximate the natural population. Models that employ individualized unique driver or probe data as descriptors will be strongly preferred. See Control Architecture section for suggested implementation of driver behavior in the absence of control.
Characteristics of the System Model (continued)	
VALIDATION AND SENSITIVITY ANALYSIS	Performance should be validated using historic data from anonymous sources (e.g., loop detectors) both during normal conditions and after actual incidents. Error rates and missing data parameters should be explicit.
CALCULATION OF ENERGY USED PER TRAVELER	Ability to calculate energy used by each traveler at any given time, and to re-calculate it dynamically as changes occur in traveler's choices and in the network.
CALCULATION OF AGGREGATE ENERGY USED	Aggregate energy use for travelers in the selected region should be calculated to within ±10% of overall estimates published by, or derived from, public sources such as the region's Metropolitan Planning Organization, as well as ±10% within each subcategory as defined by these sources.
DEMONSTRATION OF IMPACT	Determination of how energy reduction depends upon the fraction of participating travelers.
EXPANDABILITY	The model should be constructed to anticipate future technologies. These should be able to be incorporated in a modular fashion.

Supplementary Information:

Teams that expect to employ private data must explicitly involve data providers, with letters of support (at a minimum). Personal data should be assumed to be transmitted by individual wireless devices, but may include data that could be collected locally, including external sources (such as the automobile's OBD-II port) outside the devices themselves. Applicants may propose the use of additional data collection hardware in addition to smart phones and other personal wireless devices, but the applicant must discuss in detail the estimated cost and proposed deployment strategy for this data collection technology.

The system model must have the capability for sensitivity analysis, a process that is intended to simulate imperfections and uncertainties found in real world data, including erroneous, noisy, or missing data (for example, imperfect communications systems), as well as emergent situations such as road closures and traffic incidents.

The model must also report metrics associated with the traveler's quality-of-service and overall system reliability (see Definitions), such that no individual traveler or group of travelers is

[20] See http://www.whitehouse.gov/sites/default/files/omb/bulletins/2013/b13-01.pdf

forced to bear a disproportionate burden. The system model must identify and account for the measurement of difficult-to-measure aspects associated with individual participants, such as modal occupancy, openness to mode switching, and personal driving style.

The system model must also be a virtual test bed, capable of an authentic response to realistic personalized signals (see below). These signals will target participants to adjust behavior of travelers and drivers according to modern behavioral theories.[21] The description of both travelers and drivers in this model should thus explicitly factor in their human characteristics.

Model validation protocols are currently envisioned as a set of realistic scenarios (and extreme scenarios) that are intended to determine under what circumstances the system model "breaks". Tests will be designed in coordination with each awardee, to confirm that the model represents a fair and accurate test bed for the control architecture. Further, we anticipate that the system models may become useful tools either for transportation planners or for future transportation control simulations. Consequently, models that are modular and developed under public, open software standards, in commonly used computer languages are preferred. To facilitate this extension, once the program is underway, awardees that have similar approaches will be encouraged to collaborate on their system models, to provide added resources, perspectives, and robustness.

The system model and control architecture described below are strongly coupled. Because it may be easier for applicants to envision a control architecture that relies on a complete parameterized model of the transportation system, one approach is to construct a reduced complexity model based on sampling specific information from the system model. In this case, the development and validation of the reduced complexity model against the system model will be an important deliverable. Further, if this approach is taken, the control architecture and the reduced complexity model must be able to run concurrently with the system model itself, such that decisions and control outputs can be fed back into the high fidelity system model to evaluate the impact of the control architecture in a real-world, real-time setting.

[21] There are many examples of this type of approach, too numerous for this document. For a concise guide to possible approaches, see http://peec.stanford.edu/docs/energybehavior/Data Jam - 5 Behavioral Techniques Guide.pdf

The Control Architecture

The control architecture is a key deliverable. Developing a control architecture that interacts with the system model will allow ARPA-E to assess the usefulness of personalized control for energy savings in transportation. The control architecture should be scalable, thus capable of quantifying micro-, meso-, and macro-scale impacts of control on real-time reduction of energy use.

The characteristics of the control architecture are provided in Table 2. Applications should devise an architecture that addresses each of these characteristics; however, ARPA-E recognizes that the specifics of the architecture will evolve during the course of an award as tested via simulation using the model system.

Table 2.

Characteristics of the Control Architecture	
EVENT HORIZON	Successful controls will show statistically significant reduction in energy use based on predicted state, mode, and energy use of the system at least 15 minutes into the future.
PERSONALIZED DATA AND PARTICIPATION IN CONTROL STRUCTURE	Control scenarios should assume that only a small portion of those eligible participate, but may include a zone around each participant that utilizes peer-to-peer wireless technologies. The impact of the approach needs to be evaluated at varying degrees of technological penetration, so this is essentially a sensitivity analysis based on the number of control nodes in the network.
RESPONSE TO NETWORK CHANGES	Capable of rapid response to traffic incidents, providing relevant, wireless signals to travelers within 30 seconds of the time of the incident (and updated thereafter as the extent of the disruption caused by the incident becomes clearer). This constraint will affect data collection frequency and density.
DIMENSIONAL SCALES OF ENERGY EFFECTS	Micro-:[22] At this scale, individual travelers are observable as individuals, and naturalistic variations are evident. Meso-:[23] At this scale, traveler demand is aggregated across a region. Mesoscale zones should be no larger than 0.5 mile in radius. Microsimulated zones interact with one another in an open fashion, but interaction is limited to exchange of individual travelers between zones. Macro-:[24] This is the entire scale of the transportation simulation. Mesoscale zones interact with one another in a closed fashion to describe the entire region.

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[22] Hollander, Y. & Liu, R., "The principles of calibrating traffic microsimulation models", Transportation 35: 347-362 (2008)

[23] In mesoscale transportation systems, the statistical nature of local traffic can be used to develop a fluid-like conservation model of traveler flow, with average characteristics such as traffic velocity and vehicle density taking the place of individual travelers. See Horowitz, Roberto. (2003). Development of Integrated Meso/Microscale Traffic Simulation Software for Testing Fault Detection and Handling Algorithms in AHS: Final Report. California Partners for Advanced Transit and Highways (PATH). UC Berkeley: California Partners for Advanced Transit and Highways (PATH). Retrieved from: http://www.escholarship.org/uc/item/61z020hf

Characteristics of the Control Architecture (continued)	
QUALITY OF SERVICE	Based on travel time (with expected statistical uncertainty) for each traveler in the uncontrolled model, an increase in travel time upon control is never statistically significant ($p<0.05$)
SYSTEM RELIABILITY	Based on travel time (with expected statistical uncertainty) for all travelers in the uncontrolled model, the distribution of travel time upon control is never statistically broader ($p<0.05$)
WIRELESS DELIVERY OF SIGNALS	Required. Signals should be provided after an incident to affected travelers within 30 seconds.
INTENT	Patterns and historical data should be incorporated, but, for sensitivity analysis, applicants should assume that a variable fraction of the participants are willing to enter detailed trip information (e.g., destination).
CONTROL STRATEGIES	Applicants should employ individualized control strategies that are grounded in modern behavioral science, rather than those based on broad economic principles. Active control should influence energy use at the system level, and impact of control must be quantifiable in energy terms.
TRAVELER DECISION CRITERIA	In the absence of a control signal, model should assume that traveler decisions are essentially independent of all other travelers (i.e., a Nash equilibrium), based on anticipated total travel time. In the presence of a control signal, participants are expected respond in a probabilistic way, providing an alternative response when a personalized control signal is presented.
CAPABILITY FOR EXPERIMENTAL OPTIMIZATION	Personalized controls should incorporate intrinsic variables that can be adjusted to optimize participant responses when presented with a control signal. It is understood that each participant will not be individually predictable, but will instead show reproducible statistical tendencies are a population.
IDENTIFICATION OF KEY TECHNOLOGY GAPS	Applicants should identify key gaps in hardware of software that would be required to implement the proposed control architecture in the real world. Anticipated gaps in hardware and software might include: occupancy meters, driving style meters,[25] intent sensors (e.g., two-way turn signals), hands-free delivery of diverse personalized signals, traveler-to-traveler or traveler-to-infrastructure communication, and intent prediction algorithms.

Supplementary Information:

The control architecture should facilitate interactions with other micro- and mesoscale zones and routing infrastructure (e.g., traffic lights) and should query modes of transportation using a common protocol, where feasible. A personalized control architecture with partial adoption is important because, in contrast to today's dominant traveler control mechanisms (i.e., road signs, signals, etc.), new individualized controls are unlikely to be adopted immediately and

[24] The macroscale simulation is essentially the entire simulation described by the virtual test bed.
[25] See Progressive Insurance SnapShot, http://www.progressive.com/auto/snapshot-common-questions/

universally. Therefore, applicants must objectively assess the participation level for personalized guidance and control where they begin to have a measurable impact on energy use. This architecture must therefore use incomplete data sampled in a realistic way.[26] The control architecture should be designed to overcome bandwidth, privacy, and analysis issues generated by the now dominant "collect first, interpret later" strategy.[27] Further, the control architecture must assume that individual (personal) information will be available from a wireless app primarily from opt-in participants and thus will provide data only on an as needed basis, rather than as a continuous stream. This is not a rigid requirement: Simulations that rely on large amounts of largely anonymous (or anonymized) cell phone tower data are entirely appropriate and will be considered.[28] The intent is to provide for system-wide information acquisition from anonymous (or anonymized) data sources (which must be available today), supplemented and enhanced by personal data collected from a subset of participants, who will have opted both to provide more granular data and to be network control points. One approach to this is a query-response architecture that has direct or indirect access to data commonly collected by commercial transportation apps on a mobile device such as Google Maps and Inrix. Applicants should assume that data from all travelers would be fed into the control architecture through wireless communications.

Optimization algorithms should assume that the data, particularly from travelers, is of variable quality. The practical capacity to sample in the real world depends on the (limited) bandwidth of the network. Thus, while sampling of wireless sensors (as embodied in the wireless devices that individual travelers carry) will be limited both by penetration and bandwidth, the use of aggregate data streams based in the cloud (such as those available from the Google Maps "traffic" feature) is encouraged. Disproportional leverage by small groups of participating travelers is not unprecedented, since computational studies of congestion behavior show that the re-routing of only a few percent of the vehicles can lead to substantial reduction in congestion for all travelers.[29] For example, during periods of congestion, numerous analyses indicate that an improvement in efficiency is possible in theory through a more informed route selection: [30] The control architecture should attempt to quantify this expected improvement using practical personalized controls and real world data.

Unforeseen events such as traffic incidents, as well as foreseeable events such as road closures or anomalous traffic due to specific occasions, occur frequently, so the control architecture must lead to accurate and timely predictions of resulting changes in traffic patterns. The control

[26] For many examples, see Roughgarden, T. "Selfish Routing and the Price of Anarchy", MIT Press, 2005.
[27] See Bertolucci, J. "Big Data Fans: Don't Boil The Ocean", Information Week, May 12, 2014. http://www.informationweek.com/big-data/big-data-analytics/big-data-fans-dont-boil-the-ocean/
[28] See for example Wang, P., Hunter, T., Bayen, A.M., Schechtner, K. & Gonzalez, M.C. Understanding Road Usage Patterns in Urban Areas. Sci. Rep. **2**, 1001
[29] See for example Robert A. Johnston, Jay R. Lund, and Paul P. Craig (1995). "Capacity-Allocation Methods for Reducing Urban Traffic Congestion." *J. Transp. Eng.*, 121(1), 27–39.
[30] Wardrop, J. G.; Whitehead, J. I. *op cit*. For a more recent treatment that suggests even more improvement is possible, see Kerner, BS*, J. Phys. A: Math. Theor.* 44 (9) [2011].

strategy should predict changes in patterns as needed for control computation, but the system model should be able to represent/capture any non-nominal behaviors. Because the responsiveness to unforeseen events is crucial during periods of high volume, in particular, the model must be capable of rapid control and readjustment to enable rerouting of responsive travelers in a timely fashion.

Because the control architecture will be benchmarked against the system model also specified by the applicant, the two must be closely aligned. Key data needed for the control architecture must be gathered and processed in a timely fashion, both from the system model and in the real world. The control architecture will be evaluated as a predictable response of the system to differential, personalized controls.

ARPA-E seeks control strategies that are grounded in modern behavioral science.[30] The use of broad, non-personalized economic incentives as controls will not be considered adequate for this solicitation**.** Examples of these discouraged incentives include variable tolls tied to a group of travelers (rather than the individual traveler) and collective incentives such as preferential lanes.

Personalized signals should be targeted at selected participants, including both travelers and drivers, but these signals must intentionally influence energy-related transportation choices (e.g., mode, departure time, etc.) by travelers. Selection of these participants must be justified, where possible, through market adoption analysis based on the diversity and variation of Americans, rather than simply assuming statistically random participation. Thus, potential participants should be grouped based on their likelihood of adoption of the technology (e.g., a smartphone app combined with a particular personalized signal approach) and the probability of their affirmative response to a positive guidance and control signal—this can be approached essentially as a market segmentation exercise. Signals should not presume that the traveler is, or wishes to be, particularly energy aware or influenced by potential savings, either in energy or in cost. It will be more important to anticipate systemic energy reduction through personalized control signals than to make more participants aware of their energy choices.

Applicants will be asked to numerically estimate the impact of deployment of the proposed technology at various levels of participation and responsiveness and thereby determine, among other things, what fraction of participation is needed for impact. If implemented in the real world, signal strategies are expected to be refined experimentally (based on responsiveness and predictability), such that a direct feedback of the effectiveness of the signal must be implicit in the signaling architecture. Consequently, this control architecture must be designed to allow for trials and evaluation of different signal approaches to measure the effectiveness of different incentives strategies.

The response to a signal must be relevant to energy use by the traveler, e.g., changes in route, departure time, and mode, etc. While specific, punitive financial controls such as congestion pricing are excluded (as being known strategies), specific non-punitive financial controls such as coupons, tax relief, etc., will all be considered, provided they are personalized.
ARPA-E is interested in identifying key technology gaps allow that enable the control architecture to interact with the real world more effectively without extensive human input or interaction. In some instances, like the OBD-II connector mentioned previously, the essential technology is already deployed and Bluetooth® connectivity to wireless devices is already commercially available.[31] In other instances, however, technologies for measuring crucial parameters (such as modal occupancies) in a seamless, automatic fashion are more challenging. An applicant's concept may show significantly better performance when data that is currently unavailable from already-deployed sensors, either from modes or from personalized devices, becomes available. Applicants should identify both the new technologies (hardware or software) required and the data these will provide.

[31] See for example the OBDLink LX Bluetooth Scan Tool, http://www.scantool.net/obdlink-lx.html

D. TECHNICAL GLOSSARY

Participant	Either a traveler or a driver who opts-in voluntarily to participate in the control architecture
Traveler	The individual who has a need to move from one place to another
Driver	The individual who controls the mode. For the predominant mode, single-occupancy vehicles, the driver and the traveler are identical.
Mode	The specific transportation vehicle (car, bus, train, etc.) by which a traveler is moved
Route	The path by which the traveler moves. This is the traveler's personal choice.
Personal transportation network	The segment of the transportation sector that is involved in moving travelers in and around an urban center.
Personalized Signals	Information and incentives provided to individual travelers and drivers intended to affect their decisions while participating in the personal transportation network. *[Note: Only a limited number of* participants *will be available for personalized signaling.]*
Network Control	A predictable response of the personal transportation network to personalized signaling
New infrastructure	Deployment of additional resources, in the form of new roadways, new signals, or new sensor networks independent of personal mobile devices, as a prerequisite for real-world implementation.
Quality-of-service	Referenced to today's travel experience, primarily in terms of departure and arrival times. It is the overall measured or perceived performance of transit service from the traveler's point of view.[32] It has long been known that the efficiency of the transportation network during times of congestion is suboptimal (see Wardrop's Principles).[33] This can be framed as a shift from a selfish, Nash equilibrium (where individuals make independent choices that lead to a suboptimal solution) toward a more efficient system optimal equilibrium (where collaboration among individuals leads to a better situation for all).
System Reliability	The consistency of on-time arrival,[34] based on the expectation of the traveler. These are primarily related to travel time reliability: the consistency or dependability in travel times, as measured from day-to-day and/or across different times of the day.

[32] See: http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp100/part 3.pdf
[33] Wardrop, J. G.; Whitehead, J. I. (1952). "Correspondence. Some Theoretical Aspects of Road Traffic Research". *ICE Proceedings: Engineering Divisions* **1** (5): 767.
[34] See: http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Reliability_159.aspx

E. Applications Specifically Not of Interest

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.C 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 solely at discovery and/or 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.
- Applications that propose the following:
  - Applications that propose examining only a single transportation corridor or sub-region with limited population (< 3 million inhabitants).
  - Applications that focus primarily on freight demand and goods movements.

II. Award Information

A. Award Overview

ARPA-E expects to make approximately $10 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 5-10 awards under this FOA. ARPA-E may issue one, multiple, or no awards.

Individual awards may vary between $250,000 and $5 million.

The period of performance for funding agreements may not exceed 30 months. ARPA-E expects the start date for funding agreements to be August, 2015, or as negotiated.

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 plans to fully fund the negotiated budget at the time of award.

B. ARPA-E FUNDING AGREEMENTS

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[35] 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.[36]

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.

[35] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[36] The Prime Recipient is the signatory to the funding agreement with ARPA-E.

2. Funding Agreements with FFRDCs, GOGOs, and Federal Instrumentalities[37]

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 & Disclosures 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.

When a FFRDC is a *member* of a Project Team, ARPA-E generally 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 Prime Recipient under the Cooperative Agreement is the lead organization for the entire project, including all work performed by the FFRDC 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 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).

Non-DOE GOGOs and Federal agencies may be proposed as supporting project team members on an applicant's project. The Non-DOE GOGO/Agency support would be obtained via an Interagency Agreement between ARPA-E and the non-DOE GOGO/Agency, and provided as part of ARPA-E's standard substantial involvement in its funded projects.

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.

[37] DOE/NNSA GOGOs are not eligible to apply for funding, as described in Section III.A of the FOA.

A TIA is more flexible than a traditional financial assistance agreement. In using a TIA, ARPA-E may modify standard Government terms and conditions.

In general, TIAs require a cost share of 50%. See Section III.B.2 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 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 and Prime Recipients mutually 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 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.

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,[38] as the lead for a Project Team,[39] or as a member of a Project Team.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[40] 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.

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

[39] 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.

[40] 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.

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 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 & Disclosures Form, which is submitted with the Full Application. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. Consortium Entities

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

Unincorporated consortia must provide the Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This 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[41]

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

1. Base Cost Share Requirement

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement, the Prime Recipient must provide at least 20% of the Total Project Cost[42] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[43]

2. Increased Cost Share Requirement

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

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

3. Reduced Cost Share Requirement

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

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

- Small businesses – or consortia of small businesses - will provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the "Cost Share Grace Period"). If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80%, but less than 100%, of the total work under

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[41] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[42] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.
[43] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

the funding agreement (as measured by the Total Project Cost) the Project Team are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.

- 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.

- 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.

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[44] 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.

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

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

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

8. COST SHARE VERIFICATION

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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~~ I.E 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 in Section V.A.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 non-compliant.

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

Once ARPA-E completes its review of Full Applications and Replies to Reviewer Comments, it may, at the Contracting Officer's discretion, conduct a pre-selection clarification process and/or perform a "down-select" of Full Applications. Through the pre-selection clarification process or down-select process, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, 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. The Selection Official may select or not select a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

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

7. Mandatory Webinar

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

B. Application Forms

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424, Budget Justification Workbook/SF-424A, and Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures 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 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 formatting requirements:

- The Concept Paper must not exceed 4 pages in length including figures, footnotes and/or tables.

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

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.

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

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

1. Concept Paper

a. Concept Summary

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

b. Innovation and Impact

- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Discuss the concept in terms of each of the two main elements described in Section I.C of the FOA: The System Model (Table 1) and the Control Architecture (Table 2). In

particular, respond to the question, "How will the Control Architecture function in the real world, and what control strategies will be enabled and/or limited by this choice of architecture?"

c. PROPOSED WORK

- Describe the data sources, and simulation/modeling approaches that will be used in the proposed work. Provide supporting examples of precedents. Cite the scientific and technical literature as appropriate.

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

- Describe the nature of any significant technical challenges, the substance of key technical risks (whether or not they will be mitigated) and the limitations inherent in the proposed approach. [NOTE: ARPA-E expects that all successful proposals will contain significant technical uncertainty.]

- If applicable, describe any key technology gaps that are needed to enable the Control Architecture to function in the real world without extensive human input or interaction.

d. TEAM ORGANIZATION AND CAPABILITIES

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

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

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]

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 FEBRUARY/MARCH 2015]

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 FOA Targets* (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 compared to existing or emerging technologies;

- The extent to which the proposed concept is innovative and will achieve the program objectives defined in Section I.C of the FOA; 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 feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- The extent to which the Applicant proposes a sound technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches and how technical risk will be mitigated;
- The extent to which project outcomes and final deliverables are clearly defined;
- The extent to which the Applicant identifies techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; and
- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among team members supporting the proposed project.

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

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

2. Criteria for Full Applications

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015

3. Criteria for Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]

B. Review and Selection Process

1. Program Policy Factors

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]

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 FEBRUARY/MARCH 2015]

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. ARPA-E provides feedback in the notification letter in order to guide further development of the proposed technology.

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

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

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]

C. Reporting

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY/MARCH 2015]

VII. Agency Contacts

A. Communications with ARPA-E

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

During the "quiet period," Applicants are required to submit all questions regarding this FOA to ARPA-E-CO@hq.doe.gov.

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

- The rejection of a Concept Paper, Full Application, and/or Reply to Reviewer Comments;
- The termination of award negotiations;
- The modification, suspension, and/or termination of a funding agreement;

- The initiation of debarment proceedings, debarment, and/or a declaration of ineligibility for receipt of Federal contracts, subcontracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

D. RETENTION OF SUBMISSIONS

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

E. MARKING OF CONFIDENTIAL INFORMATION

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

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

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

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

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

F. Title to Subject Inventions

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

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

- All other parties: The Federal Non Nuclear Energy 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).

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 and FFRDCs.

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