FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

NETWORK OPTIMIZED DISTRIBUTED ENERGY SYSTEMS (NODES)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0001289
CFDA Number 81.135

FOA Issue Date:	February 4, 2015
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, March 13, 2015
Submission Deadline for Concept Papers:	5 PM ET, March 20, 2015
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	5 PM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	TBD
Total Amount to Be Awarded	Approximately $30 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

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

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).

- 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.

TABLE OF CONTENTS

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).

REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: o Concept Summary o Innovation and Impact o Proposed Work o Team Organization and Capabilities	Mandatory	IV.C	5 PM ET, March 20, 2015
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN MAY 2015]	Mandatory	IV.D	5 PM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN MAY 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 (DOE), is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358) to:

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

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

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

ARPA-E funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have the clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

ARPA-E funds applied research and development. The Office of Management and Budget defines "applied research" as "systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met" and defines "development" as the "systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements."[1] Applicants interested in receiving financial assistance for basic research should contact the DOE's Office of Science (http://science.energy.gov/). Similarly, projects focused on the improvement of existing technology platforms along defined roadmaps may be appropriate for support through the DOE offices such as: the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy (http://fossil.energy.gov/), the Office of Nuclear Energy (http://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

Program Vision

The infrastructure that defines the U.S. electric grid is based largely on pre-digital technologies developed in the first part of the 20th century. Through subsequent decades, grid development has evolved through emphasis on safety, accessibility, and reliability to security and resiliency. But the evolution of the grid now faces significant challenges in flexibility if it is to integrate and accept more energy from renewable generation and other Distributed Energy Resources (DERs) (e.g. rooftop photovoltaic and home energy-storage). The addition of intermittent generation along with changing usage patterns (e.g. increased penetration of electric vehicles) is leading to greater uncertainty and variability in the electric grid that may have a significant impact on grid reliability. However, a potential opportunity exists for these changes to be utilized to the benefit of the grid, with the deployment of the right control and integration technologies.

The **N**etwork **O**ptimized **D**istributed **E**nergy **S**ystems (NODES) Program aspires to enable renewables penetration at the 50% level or greater, by developing transformational grid control algorithms and architectures that optimize the usage of flexible load and DERs. The challenge is to reliably manage, locally or globally, dynamic changes in the grid by leveraging these additional grid resources, while having minimal impact on customer quality of service (QoS). The expected system level benefits include net energy savings, reduction of CO_2 emissions in

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

power generation by directly offsetting load consumption by renewable energy production, and lowering required operating reserves. Additional savings are expected to be achieved by supporting higher penetration of Distributed Generation (DG) that is expected to reduce energy-delivery losses by delivering energy where it's needed, and when it's needed.

A significant reduction in fossil fuel consumption and CO_2 emissions may be realized through the NODES Program. A preliminary study of the impact of a NODES approach on flexible load and DERs integration was completed for the PJM market (~20% of US electricity market) with a simulated 50% penetration of renewable generation resources.[2] The results were extrapolated to represent the entire US market. Compared to a baseline scenario of no load or DERs flexibility, the curtailment of VERs was reduced from 21% to 6%, offsetting 3.3 quads of thermal generation and displacing 290 MT of CO_2 emissions. Additionally, 4.5 GW of spinning reserves could be replaced with flexible load and DERs, a value of $3.3B per year. However, all of these benefits are in addition to the ability to transition from current penetration of renewable energy (16% for PJM) to 50% penetration. This transition would have otherwise been limited due to the declining capacity factor of renewable generators as greater amounts are curtailed to maintain the base-load generation, leading to increased Levelized Cost of Energy (LCOE).[3]

The future U.S. electric grid requires real-time adaptation by advanced controls to enable an interconnected power system, with a high level of renewable generation and a large number of DERs with the ability to reliably integrate customer side assets while providing benefits to system users. Traditionally, hierarchical control architectures defined by time-scale separation have been the engineering approach of choice for control of complex dynamical systems, as it is reflected in the grid's current top-down management structure. More recently, distributed control architecture has been explored as an alternative solution for large-scale system control, where system decomposition presents the major challenge. Accordingly, the power systems community has recently began looking into alternative grid management architecture that would enable seamless integration of numerous DERs into the grid, leading to more efficient grid operation and reduced CO_2 emissions. Proposed grid control architecture solutions vary from having ISOs manage the entire grid top-to-bottom, to running grid as a network of micro-grids. The NODES Program aims to explore which architectures and corresponding resource aggregation approaches will allow consumers and grid operators to adapt their operations to achieve significant improvements in system-wide operational cost and energy efficiency. If successful, the NODES Program will leverage advances in computing and data communications to enable control of load and distributed generation and facilitate large-scale renewables integration.

[2] GE Energy Consulting, Jovan Bebic´, Gene Hinkle, Slobodan Matic´, and William Schmitt, "Grid of the Future: Quantification of Benefits from Flexible Energy Resources in Scenarios With Extra-High Penetration of Renewable Energy", Nov 2014.
[3] GE Energy Consulting, Jovan Bebic´, Gene Hinkle, Slobodan Matic´, and William Schmitt, "Grid of the Future: Quantification of Benefits from Flexible Energy Resources in Scenarios With Extra-High Penetration of Renewable Energy", Nov 2014.

This program will build on grid-wide sensing, and energy efficient building control improvements accomplished over the past decade that have broadened the number of grid edge assets that can be controlled. It will integrate benefits from other federal programs, including: the Department of Defense's Environmental Security Technology Certification Program (ESTCP)[4]; the DOE Office of Energy Efficiency & Renewable Energy's (EERE) SunShot initiatives[5] on distributed solar integration; flexible load programs in EERE's Building Technologies Office (BTO)[6]; and the DOE Office of Electricity's (OE) "Integration of Variable Renewable Generation using Demand Response" program.[7] By focusing on developing technologies that enable novel functionalities at the distribution level and facilitate seamless integration of flexible load and distributed energy resources into the grid, NODES will complement programs aiming to integrate renewables into the electric transmission system such as ARPA-E's Green Electricity Network Integration (GENI) Program[8] and OE's *Advanced Computational and Modeling Research for the Electric Power System.*[9]

Recent advances in sensing, communication, and asset control enable the creation of a new paradigm for grid operations that utilizes novel system architectures and active control of load side resources to provide additional reserves and grid balancing services. At high deployment levels, DERs can collectively become a valuable system asset if coordinated with system needs and control processes, as they are very fast acting, and are close to the loads. In addition, with improved load and generation forecasting, and the introduction of local control and coordination algorithms DERs could easily provide timely services to the grid and could be integrated into the current power grid. At the same time, these technologies will provide a vehicle for the long-term transformation to a future grid that equally benefits from all assets, regardless of their placement at the distribution or transmission level.

The NODES Program is intended to bring together different scientific communities, such as power systems, control systems, computer science, and distributed systems to accelerate the development of new technologies enabling active control of load and DERs in coordination with the grid, and engage with stakeholders who can drive these new operational approaches towards market adoption. ARPA-E strongly encourages teaming among experts from these interdisciplinary technical fields in responding to this FOA in order to have the sufficient

---

[4] ESTCP energy projects https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy.
[5] Funding awarded in response to DoE EERE FOA DE-FOA-0000479, https://eere-exchange.energy.gov/Default.aspx?Search=DE-FOA-0000479, announced in April 2011.
[6] BTO's load control strategies, http://energy.gov/eere/buildings/building-technologies-office-load-control-strategies.
[7] Lawrence Berkeley National Laboratory, http://emp.lbl.gov/projects/integration-variable-renewable-generation-using-demand-response.
[8] http://arpa-e.energy.gov/?q=arpa-e-site-page/view-programs
[9] Funding awarded in response to DoE FOA DE-FOA-0000729, https://www.fedconnect.net/FedConnect/PublicPages/PublicSearch/Public_Opportunities.aspx, announced in May 2012.

breadth of expertise necessary to achieve the targeted advances in the management and control of the electric grid.

Current Grid Management

The dominant paradigm for delivering electricity in the U.S. consists primarily of bulk electricity generation at central power plants (coal, Natural Gas Combined Cycle (NGCC), nuclear - and more recently - wind farms and centralized solar), followed by transport across the U.S. electrical grid via Transmission and Distribution (T&D) networks, and finally delivery to the end-user. This energy generation paradigm is complemented by peaking energy generation that provides additional capacity during peak use hours, as well as other ancillary services[10] such as operational reserves, voltage regulation, load following, contingency reserves, etc.[11] At any given time, power generation must match the load to maintain grid reliability.

Currently, 87% of the 4058 Billion kWh of electric energy used annually in the U.S. comes from the central-station thermal generation fleet.[12] Historically, the primary benefit of this centralized approach to power generation has been that energy conversion is more efficient and cost effective at scale.[13] The centralized energy generation system generates more than 2 billion tons of CO_2 emissions annually.[14] The average conversion efficiency of the US fleet is 32.5% for coal and nuclear, and 42.4% for gas[15] utilizing a blend of combined cycle and simple cycle plants. In addition, the total T&D losses are 6%.[16]

Over the course of each day, the central-station generation fleet is committed (brought on-line) and dispatched (brought to a desired output) to follow the system load. Currently power plant dispatching is based on system load forecasting and is performed at various time horizons subject to control area's transmission system size and constraints. The unit commitment process ensures that the committed generation hour-by-hour has adequate margin to serve the

---

[10] FERC defined ancillary services as those "services necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system."
[11] U.S. Federal Energy Regulatory Commission (FERC), "Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities", Docket RM95-8-000, 1995.
[12] U.S. Energy Information Administration, "What is U.S. electricity generation by energy source?" http://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3, accessed: 2014-10-23.
[13] "Catalog of CHP Technologies," U.S. Environmental Protection Agency Combined Heat and Power Partnership (2008).
[14] U.S. Energy Information Administration, http://www.eia.gov/tools/faqs/faq.cfm?id=77&t=11.
[15] "Average Operating Heat Rate for Selected Energy Sources," http://www.eia.gov/electricity/annual/html/epa_08_01.html, accessed: 2014-10-23.
[16] "How much electricity is lost in transmission and distribution in the United States?" http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3, accessed: 2014-10-23.

load according to North American Electric Reliability Corporation (NERC) standards.[17] Transmission constraints can be determined by either thermal limits or voltage/transient stability limitations depending on the timeframe of the problem being addressed. These limits are most often a consequence of system security and reliability requirements, such as adequate system recovery after disturbances, which are stipulated by NERC planning standards (TPL-001-0.1, TPL-002-0b, TPL-003-0b, and TPL-004-0a.[18] [19] [20] [21]

Notably, the NERC planning standards consider the load as non-dispatchable and unable to contribute to dynamic system recovery. These practices give rise to two major areas for improvement in operation of the central station fleet: the proactive shaping of load over all relevant time horizons, and reducing the effect of transmission limits due to the potential ability of load and DERs to positively contribute to dynamic system recovery.

Current Limitations of Renewable Energy on the Grid

The installation of renewable electricity generators such as solar and wind is a growing trend in the United States,[22] driven in part by the rapidly falling cost of renewable generation technologies,[23] renewable portfolio standards (RPS) in 27 states, and net metering policies or other efficiency incentives in 43 states.[24] Because their fuel is free, renewable sources of energy typically exhibit very low marginal costs and are most often operated at their maximum available output, which makes them non-dispatchable. Additionally, due to the intermittency of solar and wind energy, the available output magnitude for renewables typically changes in a continuous manner, hence these are termed Variable Energy Resources (VERs). Today,

[17] North American Electric Reliability Corporation, "United States Mandatory Standards Subject to Enforcement," http://www.nerc.com/pa/stand/Pages/ReliabilityStandardsUnitedStates.aspx?jurisdiction=United%20States, accessed: 2014-10-23.
[18] NERC Transmission Planning Reliability Standard TPL-001-0.1, "System Performance Under Normal (No Contingency) Conditions (Category A)", http://www.nerc.com/files/TPL-001-0_1.pdf, May 2009.
[19] NERC Transmission Planning Reliability Standard TPL-002-0b, "System Performance Following Loss of a Single Bulk Electric System Element (Category B)", http://www.nerc.com/files/TPL-002-0b.pdf, October 2011.
[20] NERC Transmission Planning Reliability Standard TPL-003-0b, "System Performance Following Loss of Two or More Bulk Electric System Elements (Category C)", http://www.nerc.com/pa/Stand/Reliability%20Standards/TPL-003-0b.pdf, June 2013.
[21] NERC Transmission Planning Reliability Standard TPL-004-0a, "System Performance Following Extreme Events Resulting in the Loss of Two or More Bulk Electric System Elements (Category D)", http://www.nerc.com/pa/Stand/Reliability%20Standards/TPL-004-0a.pdf, June 2013.
[22] U.S. Energy Information Administration, "Annual Energy Review," http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf, Figure 8.2a, 2011.
[23] Galen Barbose, Samantha Weaver, and Naïm Darghouth, Lawrence Barkley National Laboratory (LBNL), "Tracking the Sun IIV: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2013", September 2014.
[24] http://www.dsireusa.org/documents/summarymaps/net_metering_map.pdf.

renewables penetration is limited (less than 30%, PJM Report[25]) because these technologies lack the ability to reliably and affordably manage their dynamic variability.

To maintain reliability, system operators must continuously match the demand for electricity with supply on a second-by-second basis. Historically, the Independent System Operator (ISO) directed thermal, controllable power plant units to move up or down with the instantaneous or variable demand. Demand has always been variable and system operators have always been required to match these variations with controllable resources (mostly dispatchable thermal generation). However, studies have shown that with high levels of non-dispatchable VERs, matching generation and demand in the grid becomes more difficult[26] because system operators must directly control resources to match both variable demand and variable supply.

Installation of variable, intermittent, and non-dispatchable generation technologies, such as solar photovoltaic and wind turbines, poses fundamental challenges to centralized power system management practices due to the variability and unpredictability they introduce into the system. Traditionally, most of the grid support services required to maintain system stability were provided by bulk power generation resources that could be quickly dispatched and ramped-up to generation levels required to maintain system balance. To maximize renewables and DERs integration in the future, all grid generators and flexible loads are expected to address and support system stability in accordance with their resource characteristics and technical capabilities. However, net-load control schemes would need to address various challenges in order to have significant effect on grid services and achieve prevalent industry adoption. These challenges include: coordinated management of large numbers of heterogeneous types of loads and DERs with various behavioral characteristics, guaranteed availability of negotiated Level-of-Service (LOS), and automated adaptation to real-time variability in the LOS required by the system and flexibility limits of loads.

One problem of matching generation and demand with high penetration of VERs is clearly illustrated by current and projected curves for net load as a function of time during the day, as shown for California ISO area in Figure 1 below. Net load is the difference between the forecasted load and the expected electricity production from VERs. The “duck curves” for future scenarios with high solar penetration illustrate the potential for over-generation during peak solar production hours and the need for very fast ramping from thermal generation to meet peak demand later in the day, following the peak of solar production.

[25] PJM, “Renewable Integration Study Report”, https://www.pjm.com/committees-and-groups/task-forces/irtf/pris.aspx, 2014.
[26] R. Masiello, et al., “Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid,” prepared for the California Energy Commission (CEC-500-2010-010) (2010).

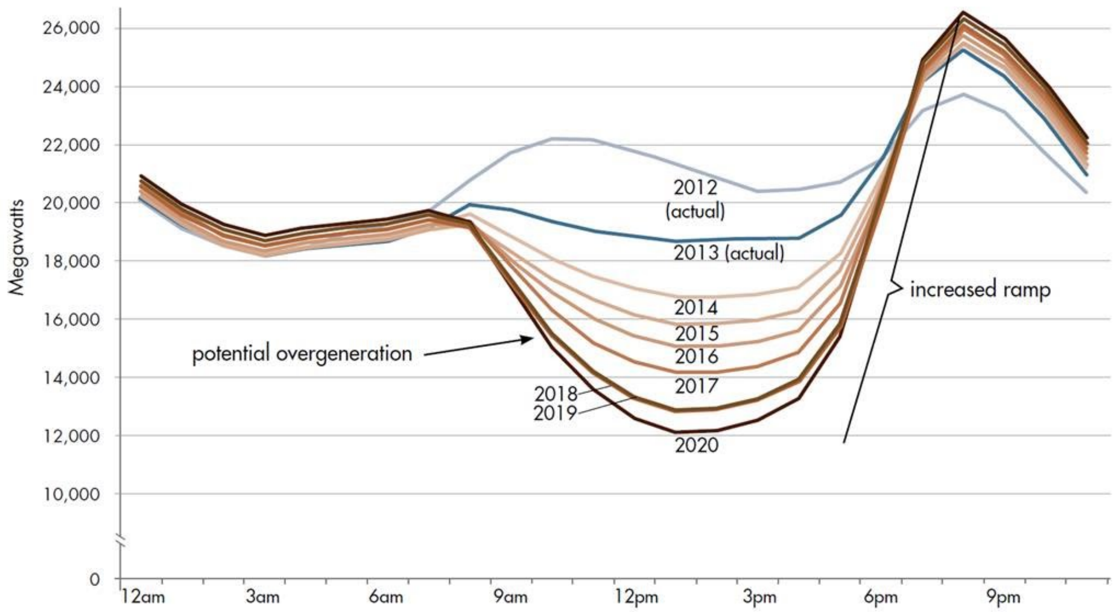

Figure 1: Net load curve for California, from 2012 to 2020, showing the difference between forecasted load and expected electricity production from variable renewable sources in a 24-hour cycle[27]

Balance of supply and demand directly affects system frequency. Thus, to ensure grid reliability, system frequency must be managed in a very tight band around the system's design frequency of 60 Hz. When an unexpected event occurs that disrupts the supply-demand balance, such as a loss of a generator or transmission line, frequency is impacted. These events do not allow time for manual response and balance is maintained through automated equipment. Conventional generation resources include frequency-sensing equipment, or governors, that automatically adjust electricity output within seconds in response to frequency to correct out-of-balance conditions. Figure 2 below shows the Under-Frequency Load Shedding (UFLS) threshold, frequency nadir, and settling frequency points during a frequency excursion caused by a loss of generation event.

Renewable generators are not currently required to include automated frequency response capability (i.e. no frequency reserve) and are operated at full output (i.e. they cannot increase power). Thus, as renewables begin to displace conventional generation, the total system inertia decreases, and additional contingency reserves are required to restore the system frequency to the reference value after contingency events. Even more problematic are renewable resources connected at the distribution level that have historically been required to trip offline during relatively small frequency excursions, meaning that a loss-of-generation event could be exacerbated by a sudden loss of all of the renewable DG resources within a

[27] California ISO, http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

control area[28]. This combination of factors makes the system more vulnerable to blackouts when generation or transmission outages occur.[29]

Recent studies have shown the short-term response of the power-system frequency to large mismatches between generation and load, and showcase how frequency nadir and settling frequency change in different scenarios.[30] Inadequate balancing reserves and/or transmission resources have already led to curtailment of renewable power in both the Electric Reliability Council of Texas (ERCOT) and the Bonneville Power Administration's (BPA) system.[31] Introduction of new grid control and optimization algorithms taking advantage of DG and load flexibility in the U.S. could directly contribute to the grid reliability and could have additional potential benefits, such as the reduction of renewables curtailment, peak load, T&D congestion, and grid vulnerability, in addition to improving power quality.

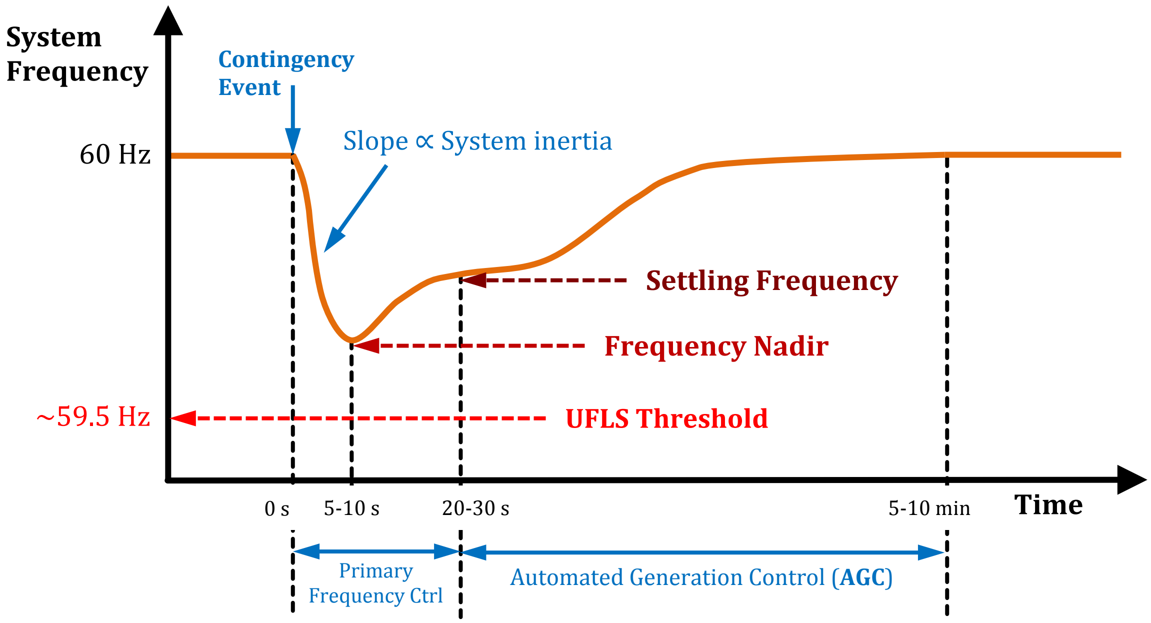

Figure 2: System frequency control following a loss-of-generation contingency event.

Deployment of VERs present operational challenges at the distribution level of the electric grid as well. Currently, the majority of distribution systems are predominantly radial networks (feeders) delivering grid-supplied power to customer's premises. With significant penetration of

[28] This issue is being addressed in new revisions of VER interconnection standards such as IEEE 1547. However, even with these changes, a large amount of legacy equipment will remain on the system that was compliant with older versions of the standard and could exhibit the mass-tripping behavior described here.
[29] N. Miller, M. Shao, S. Pajic, and R. D'Aquila, "Eastern Frequency Response Study," GE Energy, Tech. Rep. NREL/SR-5500-58077, May 2013.
[30] N. Miller, M. Shao, S. Pajic, and R. D'Aquila, "Eastern Frequency Response Study," GE Energy, Tech. Rep. NREL/SR-5500-58077, May 2013.
[31] R. Wiser and M. Bolinger, "Wind Technologies Market Report," http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf, 2011.

DERs distribution systems are facing a new demand to interconnect multiple feeders together in order to accept customer-generated power and be able to balance generation and demand on individual feeders with DERs available in surrounding feeders. In the future, distribution systems are likely to play two major roles; delivering power to or among customers and aggregating DERs to provide benefits to customers and the grid. The new structure and roles of distribution systems will require development of advanced distribution circuits and substations allowing bi-directional power flows, new protection schemes, and new control paradigms. Additionally, development of new technologies to enable DERs to provide Volt/VAR control resources are of great benefit to the grid given the importance of Volt/VAR optimization to achieving better asset utilization and improve distribution efficiency.[32] [33]

Grid Operating Reserves

Grid operators manage the variability of demand and generation on the system through reserves that are operated for diverse purposes across multiple timescales. Different amounts and types of operating reserves are secured in order to serve load reliably and keep the system frequency stable. Operating reserves (NREL report[34]) are defined as the real power capability that can be given or taken in an operating timeframe to assist in generation and load balance and frequency control. Systems also require reactive power reserves to provide voltage support. Finally, systems require certain targets for installed capacity that are often referred to as the planning reserve.

Operating reserves can be subdivided into five types: (1) frequency response reserves, (2) regulating reserves, (3) ramping reserves, (4) load following reserves, and (5) supplemental reserves, as summarized in Table 1 below. During normal system operation, regulating reserve (seconds) and load following reserve (minutes) are used. During contingencies, frequency response reserves (seconds) and supplemental reserves (minutes) are used for longer timescale events. Supplemental reserves are effectively used to replenish the faster responding reserves when these are insufficient to protect the system from the next event.

In addition to categorization by response time, reserves are classified by the physical capabilities needed of the responding participant. For instance, some reserves are required to be generating at part load to provide spinning reserve, others require Automatic Generation Control (AGC), and still others require portions of their reserve to be directly responsive to frequency deviations. According to NERC, the difference between spinning and non-spinning

[32] K. Mamandur and R. Chenoweth, "Optimal control of reactive power flow for improvements in voltage profiles and for real power loss minimization," Power Apparatus and Systems, IEEE Transactions on, vol. PAS-100, no. 7, pp. 3185–3194, July 1981.
[33] Michael J. Krok and Sahika Genc, "A Coordinated Optimization Approach to Volt/VAr Control for Large Power Distribution Networks" American Control Conference, June 2011.
[34] E. Ela, M. Milligan, B. Kirby, "Operating Reserves and Variable Generation", National Renewable Energy Laboratories technical report NREL/TP-5500-51978, August 2011.

reserves is that spinning reserves must be synchronized to the system while non-spinning reserves are not necessarily synchronized.[35]

Both NERC and its sub-regions detail how much a balancing area of the grid will require of each type of operating reserve on its system.[36] For instance, the NERC BAL-002 standard requires that a balancing authority or reserve-sharing group maintain at least enough contingency reserve to cover the most severe single contingency. Regions typically require at least half of the contingency reserve to be spinning. Unlike contingency reserve, regulating reserves usually do not have explicit, pre-determined requirements on the amount of reserve that must be procured. Instead, balancing areas will maintain sufficient regulating reserves so that they meet their NERC Controlled Performance Standards (CPS1 and CPS2).

	Frequency Response Reserves	**Regulating Reserves**	**Ramping Reserves**	**Load Following Reserves**	**Supplemental Reserves**
Purpose of Reserve	Provide Initial Frequency Response to major disturbance	Maintain area control error due to random movement in a time frame faster than energy markets clear	Respond to events that occur over longer time frames than a contingency, but shorter than standard load following (e.g. wind forecast error, wind ramps)	Maintain area control error and frequency due to non-random movements on a slower time scales than regulating reserves	Replace faster reserve to restore pre-event level reserve
Other Names	Governor response, primary control	Frequency Control	Variable Generation event Reserve, forecast error reserve, balancing reserve		
Response Timescale	sec	sec	min-hrs	min	min-hrs
Spinning Reserve	✔	✔	✔	✔	✔
Non-Spinning Reserve			✔	✔	✔

Table 1: Summary of Reserve Types[37]

[35] "Average Operating Heat Rate for Selected Energy Sources," http://www.eia.gov/electricity/annual/html/epa_08_01.html, accessed: 2014-10-23.
[36] "How much electricity is lost in transmission and distribution in the United States?" http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3, accessed: 2014-10-23.
[37] Michael Milligan et al, NREL, "Operating Reserves and Wind Power Integration: An International Comparison", NREL/CP-5500-49019, October 2010

Increasing Grid Edge Functionality by Active Net-Load Control: The Potential for Greater use of Renewables

The challenges associated with centralized grid management by dispatching power generation as described above indicate the potential for direct control of DERs and load to be a complementary and beneficial strategy for affordable and reliable power delivery.

As noted above, generation and load must be balanced instantaneously and continuously to keep the power system stable and operating. Controllable reserves must be available to respond to variations in load and supply. From a reliability perspective, it does not matter if these reserves are provided by generation, demand response, or storage resources as long as they respond with the speed, accuracy, and magnitude that is required. At higher levels of renewables penetration, the available instantaneous renewable power output may surpass the system load, which makes curtailment inevitable unless there is flexibility available on the load side. The flexibility can be provided by energy storage or by scheduling system load to correlate its consumption with the availability of renewable energy.

While it is widely recognized that active participation from the load and DERs can improve dynamic behavior of the system, studies to date have generally considered only the correlation between technology features and dynamic recovery of frequency or voltage. Most notably, a recent study[38] that explored the technical and economic impacts of 30% renewable integration into the PJM interconnection assumed only traditional flexibility from the load (demand response).

To support high peak demand, utilities need to build very capital-intensive power plants and lines. Peak demand happens just a few times a year, and according to the Demand Response (DR) Smart Grid Coalition, 10%–20% of electricity costs in the United States are due to peak demand during only 100 hours of the year.[39] Current DR schemes are implemented with large and small commercial and residential customers, often through the use of dedicated control systems to shed loads in response to a request by a utility based on slow market price conditions (day-ahead or hour-ahead). Services (lights, machines, air conditioning) are reduced according to a pre-planned load prioritization scheme during the critical time frames. DR is a way for utilities to reduce the need for large capital expenditures by shedding some non-critical loads at peak times, and thus keep rates lower overall. However, there is a limit to such reductions because consumers will not tolerate too much real - or perceived - loss of quality of

[38] GE Energy Management, "PJM Renewable Integration Study - Project Review (Task 3a)," http://www.pjm.com/~/media/committees-groups/committees/mic/20131028-impacts/20131028-pjm-renewable-integration-study.ashx, March 2014.
[39] E. Ela, M. Milligan, B. Kirby, "Operating Reserves and Variable Generation", National Renewable Energy Laboratories technical report NREL/TP-5500-51978, August 2011.

service. Thus, it is misleading to only look at the cost savings that DR can produce without also considering what the consumer forfeits in the process.

This program anticipates net-load functionality beyond the current load DR scenarios that could increase the benefits of DERs as an affordable, complementary technology for integrating renewables with the grid without loss of Quality of Service (QoS) to the consumer. Consumer QoS involve several factors including; electricity delivery reliability (based on SAIDI[40] and SAIFI[41]), cost of electricity, and load QoS to the consumer. Load QoS to consumer is inversely proportional to the magnitude of deviation from user-defined parameters (e.g. room temperature in the case of HVAC systems or water quality in the case of pool pumps) or mandatory system performance constraints (e.g. building ventilation requirements in the case of HVAC fans) caused by external load control mechanisms.[42] Several load types could likely be controlled with no net reduction in consumer quality of service or utility. While many flexible load resources can simply be switched off or cycled, other kinds of end-uses are capable of providing finer-grained control, such as reducing dimmable lighting levels or adjusting set-points on thermostats.[43] These flexible load resources can be directly controlled using automated DR to provide varying behaviors and response times.

Two major areas for improvement in operation of the power grid enabled by net-load flexibility are: the proactive shaping of load profiles over all relevant time horizons and geographical localities (home, neighborhood, city, and region); and leveraging the ability of load and DERs to provide dynamic response and positively contribute to dynamic system recovery, reducing the restrictions introduced by transmission and distribution network constraints. Shaping of load temporal profiles should include not only load shedding, but also aligning the flexible part of consumption with availability of renewable energy, directly contributing to increase in the grid efficiency, and CO_2 emission reduction.

C. PROGRAM OBJECTIVES

The overall objective of the NODES Program is to develop innovative and disruptive technologies to enable real-time management of T&D networks by large-scale active load control and system-wide coordination of DERs. Such technological advances would facilitate the utilization of net-load control to provide low-cost ancillary services to the electric grid at different time-scales and to improve grid operational reliability, efficiency, and resiliency.

NODES focuses on two major approaches to facilitate the integration net-load flexibility control

[40] System Average Interruption Duration Index (SAIDI)
[41] System Average Interruption Frequency Index (SAIFI)
[42] Yue Chen, Ana Busic, and Sean Meyn, "Individual Risk in Mean Field Control with Application to Automated Demand Response", IEEE Conference on Decision and Control, December 2014, Los Angeles, California, USA.
[43] David S. Watson et el. (LBNL), Karin Corfee el. (KEMA), "Fast Automated Demand Response to Enable the Integration of Renewable Resources", June 2012.

in the electric grid's ancillary services.

The first approach is to alter the paradigm of grid operations by creating new functionality in various DERs that will provide net-load automated frequency response capability needed to overcome frequency stability limitations at higher renewable energy penetration levels.

The second approach is to develop advanced load shaping strategies, which make adjustments to load shapes over both short and long time horizons. This is a direct extension of traditional DR, which curtails the load to avoid using the most expensive peaking units. Short-term magnitude variation and time shifting of fast acting loads or distributed generation resources would facilitate large-scale coordinated control of net-load in order to provide fast acting synthetic regulation and contingency reserve services to the grid while minimally affecting customer quality of service. Long-term magnitude variation and time shifting of loads or DERs that are capable of responding to grid reserve signals within minutes, and maintaining the required net-load magnitude targets for few hours, would facilitate large-scale coordinated rescheduling of net-load in order to provide fast acting synthetic ramping reserve services to the grid.

Both approaches require building intelligence into distribution system components (distribution substations, distribution feeder circuits, transformers, and protection systems) to allow automatic reconfiguration and integration of DERs and to maintain acceptable voltage at all points along the feeder.

D. TECHNICAL CATEGORIES OF INTEREST

NODES is focused on supporting research and development of technologies that can enable reliable and affordable approaches to utilize net-load flexibility to provide operational reserve services to the grid, in one or more of the following three categories:

CATEGORY 1: Synthetic Frequency Response Reserves

A study analyzing year 2020 33% renewables scenario, conducted by CAISO, indicated that in times of low load and high renewable generation, as much as 60% of the energy production would come from VERs that displace the power output of conventional generation without providing inertial response.[44] Under such operating conditions, the study results showed that the frequency could drop below the acceptable UFLS threshold because the system did not have sufficient inertial response to be able to prevent frequency decline following the loss of a large conventional generator or transmission asset. Figure 3 below shows the effect of declining grid inertia within ERCOT interconnection from 2006 to 2010. This situation arises because

[44] Nicholas W. Miller, Miaolei Shao, Sundar Venkataraman, "California ISO (CAISO) Frequency Response Study", GE Energy, Technical Report, November 2011.

renewable generators are not currently required to include automated frequency response capability. Therefore, they usually cannot increase their output power either because they are operated at maximum output or lack the control capability necessary to respond to system frequency regulation requirements. This decrease in available inertial response capacity leaves the system increasingly exposed to blackouts when generation or transmission outages occur.

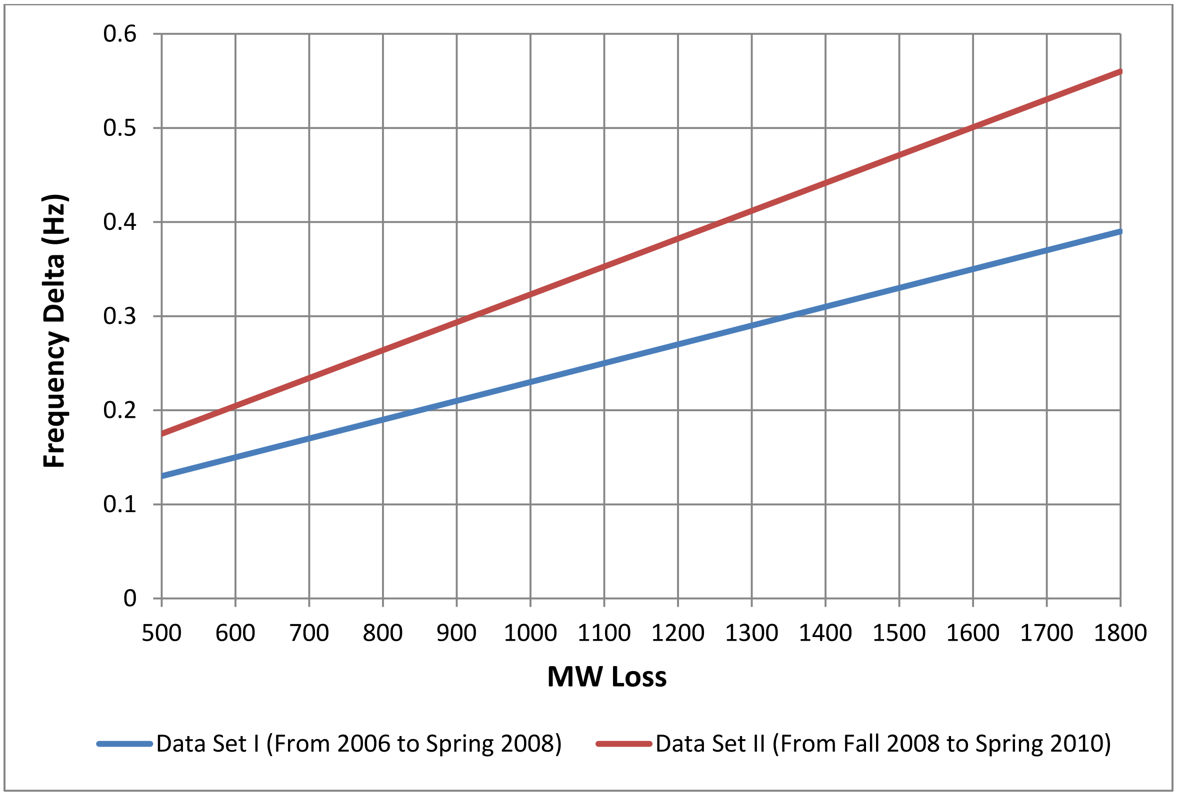

Figure 3: Declining grid inertia within ERCOT interconnection from 2006 to 2010.[45] System frequency decline is shown as a function of power loss in the system, with the red curve illustrating the loss of system inertia as a result of increased penetration of renewables.

Approximately 44% degradation in frequency response has been observed for the case with about 30% of the generation participating in governor control.[46] One way to address this is to require renewable generators to operate at lower-than-maximum output and thus enable their participation in providing reserves; however, this would not be cost effective for renewable generation plants under current energy market rules. This pre-emptive curtailment has a financial penalty in that it reduces the utilized renewable energy. An alternative is to provide frequency response by energy storage and loads. The frequency events in the power system typically last less than 20 seconds; therefore, partial participation of loads in response to system frequency could be fully automated and would not cause noticeable changes in most

[45] ERCOT Concept Paper, "Future Ancillary Services in ERCOT", Version 1.0, 2013
[46] N. Miller, M. Shao, S. Pajic, and R. D'Aquila, "Eastern Frequency Response Study," GE Energy, Tech. Rep. NREL/SR-5500-58077, May 2013.

settings.

This category focuses on the development of technologies to enable the net-load automated frequency response capability needed to overcome frequency stability limitations at higher VER penetration levels. If the dynamic load response can be provided using only the inherently available system frequency signal as input, the deployment of dynamically responsive load controls would not be contingent on the availability of a high-speed, high-cost communication channel to send state and control signals. Autonomous local control actions are more likely to result in faster frequency response time.

Examples of potential technologies of interest for this category include, but are not limited to:

- Decentralized control algorithms that:
    - Have a sufficiently fast response that they can provide a reliable replacement for generator inertial and governor response;
    - Are able to discern between events that require load response and those that do not, based on local measurements only;
    - Are sufficiently adaptive to remain effective as loads, generation and the system configuration change;
    - Are able to provide a coordinated response to system events under all loading conditions;
    - Properly coordinate a handoff from responsive loads back to generators during the frequency recovery period; and
    - Provide high levels of visibility and predictability to system operators.
- Centralized control algorithms that:
    - Integrate responsive load into grid inertial and governor response mechanisms, thereby reinforcing the system's own inertial response;
    - Are sufficiently adaptive to automatically remain effective as the system changes over time;
    - Minimize communication requirements and costs; and
    - Provide system operator visibility and predictability.
- Dynamic and robust load operational models (e.g., energy consumption patterns, responsiveness, and user utility).
- Techniques that account for the distribution network topology and variable constraints (e.g., line flow limits, transformer overload ratings) that can restrict the ability of connected loads or DERs to participate in a net-load management scheme. For example, a sudden adjustment in distribution-connected loads or DERs in response to a frequency event cannot result in distribution feeder voltage swinging beyond the acceptable range.
- Techniques that account for transmission network constraints that can be affected by active control of DERs.

<u>Note: All technology examples provided in this FOA are only meant to illustrate principles, and they are *not* meant to prescribe or limit the technical approaches proposed under the NODES program.</u>

CATEGORY 2: Synthetic Regulating Reserves

Significant integration of VERs into the grid requires the use of dispatchable, quick-ramping generators (spinning) that provide the regulating reserves necessary to smooth the variability and hedge against the uncertainty within a "balancing region." Spinning reserve units are required to be synchronized to the grid and able to rapidly increase or decrease their output on a short time scale (seconds to minutes, faster than energy markets react, but slower than AGC or inertial response) to provide contingency, regulation, and flexibility reserves. While operating in spinning reserve mode, these units are consuming fuel, producing emissions, and experiencing wear and tear, all while operating at very low power output levels at which the generators tend to be less efficient.[47] They also tend to be the more expensive units that could replace more cost effective resources because of the market reserve requirements. Additionally, generation based reserve units are only capable of providing "upward" reserves when they are operating at their minimum generation points. The need for "downward" reserves becomes more important at high renewable penetration when conventional thermal generators are operated at or near their minimum levels.[48]

This category focuses on developing enabling technologies that could facilitate large-scale coordinated control of net-load in order to provide fast acting synthetic regulating reserve services to the grid. Submissions to this category should focus on short-term magnitude variation and time shifting of fast acting loads or distributed generation resources that are capable of responding to grid reserve signals within seconds and ramp up/down to required magnitude targets within a few minutes.

"Synthetic Regulating Reserves" is the term being used in this FOA to describe the desired reserve service timing and magnitude characteristics. System operators may use a number of different types of reserves to meet the system need for this response. Additionally, different ISOs or RTOs use slightly different or overlapping definitions for the different types of operating and contingency reserves. Applications in this category could target technologies that can enable responsive loads or DERs to provide any type of reserve service that enables the system to handle short-term variability in the VERs' output.

<u>Examples of potential technologies of interest for this category include, but are not limited to:</u>

[47] Marissa Hummon, Paul Denholm, Jennie Jorgenson, and David Palchak, National Renewable Energy Laboratory, "Fundamental Drivers of the Cost and Price of Operating Reserves", NREL/TP-6A20-58491, 2013.
[48] Marissa Hummon, Paul Denholm, Jennie Jorgenson, and David Palchak, National Renewable Energy Laboratory, "Fundamental Drivers of the Cost and Price of Operating Reserves", NREL/TP-6A20-58491, 2013.

- Methods and architectures to optimally schedule and control local energy resources (flexible loads, distributed generation, storage) at the level of home or building based on user utility, weather forecast, and grid reserve and price signals.
- Methods and architectures to aggregate and coordinate controllable net-load resources at the distribution level and integration with transmission market and control structures effectively creating a "virtual power plant" from aggregated responsive loads.
- Real-time hierarchical or consensus-based distributed control methods, market models, and system architectures to actively manage very large number of loads to guarantee convergence while satisfying global (transmission), regional (distribution), and local operational constraints and objectives.
- Approaches that mitigate distribution system problems induced by variable net-load (voltage sags/surges, flicker, voltage rise …)
- Techniques that account for the distribution network topology and variable constraints (e.g., line flow limits, transformer overload ratings) which can restrict the ability of connected loads or DERs to participate in net-load control and aggregation schemes providing ancillary services to the bulk grid.
- Techniques that account for transmission network constraints that can be affected by active control of DERs.

Note: All technology examples provided in this FOA are only meant to illustrate principles, and they are *not* meant to prescribe or limit the technical approaches proposed under the NODES program.

CATEGORY 3: Synthetic Ramping Reserves

Some U.S. utilities, particularly in California, Hawaii and Texas, are beginning to experience a lack of sufficient ramping reserve generation due to high penetrations of VERs. "Ramping reserve" is usually considered to be generation reserve that is able to handle infrequent events that are more severe than those handled by regulating reserves, but less severe than contingency reserve.[49] Examples of situations in which VERs can cause events requiring ramping reserve would be:

- Sudden, unforeseen decrease in wind leads to a loss of wind generation and an error in net forecast load, or
- Late-day load pickup that is coincident with the decrease of PV output as the sun goes down. The combination of load pickup and loss of PV generation leads to what appears from the utility perspective to be an uptake in demand that increases as the PV penetration level rises (the "duck curves" in Figure 1).

[49] E. Ela, M. Milligan, B. Kirby, "Operating Reserves and Variable Generation", National Renewable Energy Laboratories technical report NREL/TP-5500-51978, August 2011.

These events may lead to large errors between actual and forecast net-load, meaning that a balancing authority may be required to call on contingency reserves or other standby generation to cover this load forecast error, leaving the system vulnerable to contingencies or other events that now cannot be covered by the generation used to supply the ramping reserve. Even if the event is predicted, and the likelihood of the event is known to be high, utilities must request additional reserve resources which is more expensive and increases emissions.

The main strategies available to mitigate this problem today are to add fast-ramping generation capacity, and as a last resort, initiate Conservation Voltage Regulation (CVR) or load shedding schemes.[50] None of these mitigation strategies is desirable. It is widely thought that responsive load can make a significant contribution to meeting this need, and responsive load would potentially have very significant cost advantages over either spinning or non-spinning ramping reserve. However, there is a significant challenge due to the fact that the load response will be required over a period of 30 min up to 2 hours. It is highly unlikely that any single flexible load could maintain a useful response over that entire time-period without disrupting service required by the end customer. Thus, there is a need for aggregation, coordination and dispatch algorithms that cause the widely dispersed aggregated load to have the desired ramp rate response characteristics and maintain them over the required time period (very much like the “virtual power plant” concept).

This category focuses on developing enabling technologies that would facilitate large-scale coordinated rescheduling of net-load in order to provide fast acting synthetic ramping reserve services to the grid. Projects in this category would focus on long-term magnitude variation and time shifting of loads or distributed generation resources that are capable of responding to grid reserve signals within minutes and maintain the required net-load magnitude targets for few hours.

“Synthetic Ramping Reserves” is the term being used in this FOA to describe the desired reserve service timing and magnitude characteristics. System operators may use a number of different types of reserves to meet the system need for this response. As previously mentioned, different ISOs or RTOs use slightly different or overlapping definitions for the different types of operating and contingency reserves. This is especially applicable in this category because “ramping reserve” is not yet a clearly defined term across the industry. Submissions to this category should target technologies that can enable responsive loads or DERs to provide any type of reserve service that enables a system with high penetrations of VERs to better follow high net-load ramp rates.

Examples of potential technologies of interest for this category include, but are not limited to:

[50] Irradiance and wind forecasting are also being developed to help in solving this problem, but these technologies are outside the scope of the present FOA.

- Quantitative assessments of the responsive load resource and its adequacy for providing slower, non-spinning type reserves. This includes quantification of load types' flexibility capacity as well as real-time forecasting of load flexibility capabilities.
- Responsive load control and aggregation systems that are able to provide predictable and consistent synthetic ramping reserves over a period of few hours, without degrading the quality of service to the end user.
- Statistical modeling of the responsiveness of various populations of controlled loads in response to various reserve control signals.
- Utilization of data analytics and machine learning techniques to develop aggregated net-load behavior and response models from large-scale sensory measurements (thermostat data, smart meters, µPMUs …) and weather forecast.

Note: All technology examples provided in this FOA are only meant to illustrate principles, and they are *not* meant to prescribe or limit the technical approaches proposed under the NODES program.

E. Technical Performance Targets

Proposed technical plans must show a well-justified, realistic potential for the technology to meet or exceed all of the Primary Technical Performance Targets described below by the end of the period of performance for the proposed project.

1. Primary Technical Performance Targets

The Primary Technical Performance Targets for the different project categories of this FOA are stated below, with time-sensitive performance metrics illustrated in Figure 4 below.

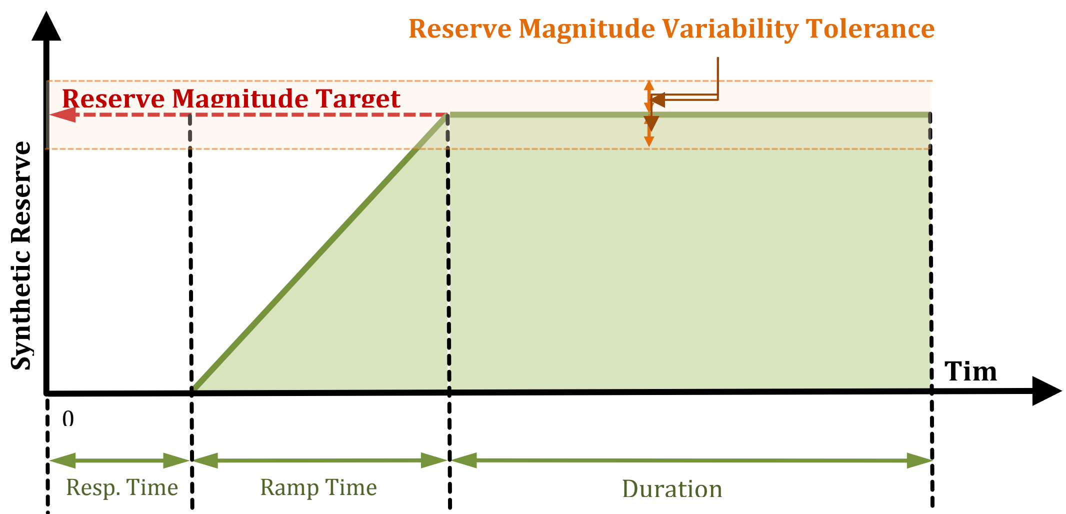

Figure 4: Schematic illustration of the timing performance metrics for synthetic reserves. Specific values for each timing metric are given for each of the three technical categories of interest: Synthetic Frequency Response Reserves, Synthetic Regulating Reserves, and Synthetic Ramping Reserves.

CATEGORY 1: Synthetic Frequency Response Reserves

ID	Performance Metric	Target Value
1.1	Initial Response Time	< 2 seconds
1.2	Reserve Magnitude Target (RMT, % of load)	> 2 %
1.3	Reserve Magnitude Variability Tolerance (RMVT)	< +/- 5%
1.4	Ramp Time	< 8 seconds
1.5	Duration	> 30 seconds
1.6	Availability	> 95 %
1.7	Cascaded Contingency Support	> 2

Supplemental Explanation of Category 1 Performance Targets

1.1 The *Initial Response Time* is the time between reception of a request for services (for centrally-controlled architectures) or initiation of the system-level event triggering a need for services (for architectures with distributed control) and the availability of the candidate system to provide the required reserve service.

1.2. The *Reserve Magnitude Target* (RMT) quantifies the amount of synthetic frequency regulation reserve provided to the grid through the aggregated active control of flexible load and VERs. It is expressed in terms of the percentage of system load within a given balancing area, at the time of the event triggering the need for this type of reserve service. The value of 2% is based on the magnitude expected to be required to make a significant positive contribution to the transient response of a typical balancing area.

1.3. The *Reserve Magnitude Variability Tolerance (RMVT)* quantifies the maximum tolerated deviation from the RMT after the initial ramping interval.

1.4 The *Ramp Time* is the time required to go from 0% activation to 100% of the RMT provided by the responsive load and VERs used in a candidate system.

1.5. *Duration* is the length of time over which the candidate system must be able to maintain RMT and stay within the tolerated variability envelope (deviation < RMVT) to satisfy system reserve services.

1.6. *Availability* is defined in this context in the same way as it is for generation resources; it is the fraction of time during which the aggregated responsive loads or DERs control system is able to provide its specified ancillary service to the grid.

1.7. The *Cascaded Contingency Support* parameter describes the number of cascaded contingencies (contingencies occurring one after another, spaced by no more than 15 seconds) that the candidate technology must be able to support. The purpose of this parameter is to ensure that a candidate technology providing Synthetic Inertial Response is prepared to assist the system in the event that a first contingency (e.g., loss of a major tie line) leads within a few seconds to a second contingency (e.g., mass tripping of VER or loss of other generation), which is a common occurrence that can lead to a cascade system failures. This parameter requires that the candidate technology be able to support no fewer than the specified number of contingency events involving the largest contingency elements within the balancing area, and should maintain effectiveness regardless of whether the contingencies involve loss of generation or load.

CATEGORY 2: Synthetic Regulating Reserves

ID	Performance Metric	Target Value
2.1	Initial Response Time	< 5 seconds
2.2	Reserve Magnitude Target (RMT, % of load)	> 5 %
2.3	Reserve Magnitude Variability Tolerance (RMVT)	< +/- 5%
2.4	Ramp Time	< 5 minutes
2.5	Duration	> 30 minutes
2.6	Availability	> 95 %

Supplemental Explanation of Category 2 Performance Targets

2.1 See 1.1 above.
2.2 See 1.2 above.
2.3. See 1.3 above.
2.4. See 1.4 above.
2.5. See 1.5 above. This value is based on historical data from balancing areas with high wind penetrations (ERCOT, SPP).
2.6. See 1.6 above.

CATEGORY 3: Synthetic Ramping Reserves

ID	Performance Metric	Target Value
3.1	Initial Response Time	< 10 minutes
3.2	Reserve Magnitude Target (RMT, % of load)	> 10 %
3.3	Reserve Magnitude Variability Tolerance (RMVT)	< +/- 5%
3.4	Ramp Time	< 30 minutes
3.5	Duration	> 3 hours
3.6	Availability	> 95 %
3.7	Recovery Time	< 4 hours

Supplemental Explanation of Category 3 Performance Targets

3.1 See 1.1 above.
3.2 See 1.2 above.
3.3. See 1.3 above.
3.4. See 1.4 above.
3.5. See 1.5 above. This value is based on worst-case values seen in balancing areas with heavy solar penetration (CAISO, HECO).
3.7 The *Recovery Time* is the time required by the candidate technology to become prepared to support a second ramping event, after having supported a first event. The value in the table is driven by experience with ramping events associated with wind farms. Ramping reserve to support high PV penetration levels (the "duck curve") might

be able to tolerate a longer recovery time as these events are anticipated at most twice per day, at sunup and sundown.

2. Additional Technical Objectives

The Additional Technical Objectives provided below apply to all technical categories of interest.

a. ***Validation***

- Quantitative validation of proposed solutions is required of all projects. Due to the wide range of different system designs that could potentially meet the technical performance targets described above, each team's specific testing and evaluation plan is expected to be different.
- *Hardware-In-The-Loop Testing:* It is critical to test new control and aggregation schemes with a minimum of 100 actual hardware devices (representing 10s of customers/prosumers). This could take the form of testing diverse devices in a laboratory environment, a commercial building, a group of utility customers in a controlled experimental test platform, or a campus with controlled devices (e.g. electric vehicles charge stations, micro-grids.) In all cases, applicants should have a plan for demonstrating the effectiveness and convergence of their proposed solutions in this "hardware-in-the-loop" test environment.
- *Large-Scale Simulations:* Beyond testing the effectiveness of algorithms with actual hardware, large-scale, realistic simulations of the proposed flexible load and DERs control and aggregation schemes are also critically important for validating the robustness and scalability of the proposed solutions. During their projects, all NODES program teams are expected to prove the ability of their proposed solutions to control large-scale dynamical test systems. In order to ensure simulations are as realistic as possible, the datasets and models used for simulations should be provided by grid operators or utilities whenever possible.
- Applicants should provide a high level overview of their testing plan in the Concept Paper.

b. ***Renewable Penetration***

- Beyond testing the scalability of system concepts, large-scale simulations should also be used to quantify the role that the proposed control solutions can play in enabling the cost effective integration and management of intermittent, non-dispatchable renewable generation with penetrations of at least 50% on an energy basis (kWh of total). In these simulations, at least 15% of the renewable generation should be assumed to come from distributed generation resources. For example, project teams may choose to evaluate the avoided costs of additional balancing reserves for managing intermittency that would be necessary without the technologies involved in the project.

c. Consumer QoS

- o Load/DERs control and aggregation technologies should demonstrate that they have minimal to no impact on the customer's QoS from the load and the electric grid, including:
  - No negative impact on the reliability of electricity delivery to customers, as measured by indices such as SAIDI and SAIFI.
  - No increase in the cost of energy to customers by showing that they do not increase the monthly energy bill for all customers.
  - Minimal impact on the user QoS from the load by showing that they cause minimal deviation from user-defined load-utility parameters and/or mandatory system performance constraints. QoS performance parameters should be defined for each type of load under control and validation that the mean absolute percentage error (MAPE) in such parameters resulting from the introduction of the control approach is less than 2% should be provided.

d. Failsafe Designs

- o System control architectures should address or *resolve* the sensing, communications, computational, and actuation (ramp and dispatch) challenges for implementation in "real-time" markets under normal, stressed, and degraded conditions.
- o Control solutions should be designed so that a failsafe operation occurs in the event of local or wide-area failure or attack.
- o The control approach should demonstrate graceful degradation under major system failures or blackouts as well as gradual and stable recovery from such failures.

e. Cost Effectiveness

- o System control technologies must be cost effective, e.g., they must be at least competitive in cost with the incumbent reserves they seek to replace. The cost analysis should consider control systems' one-time fixed cost components, such as installation and commissioning cost, amortized over the expected system lifetime. It should also account for incremental operational cost to manage and maintain the system.

F. 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.E of the FOA
- Applications that have been submitted in response to other currently issued ARPA-E FOAs.
- Applications that are not scientifically distinct from applications submitted in response to other currently issued 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 for proposed technologies that are not transformational, as described 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.
- Applications that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.
- Applications that propose any of the following:
  - Sensor development;
  - Computation hardware development;
  - Simulation only based validation of algorithms for Categories 1 and 2; or
  - Development of communication protocols or standards.

G. TECHNICAL GLOSSARY

AGC	Automatic Generation Control. Refers to the speed controller (governor) and field current controller (exciter) that control a generator's output real and reactive power.
Ancillary Services	Services necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system
CAISO	California Independent System Operator.
CHP	Combined Heat and Power. A device that provides both electric energy and usable heat to a single or multiple buildings.
CVR	Conservation Voltage Regulation. CVR involves a deliberate reduction of the distribution voltage in an attempt to moderate demand.
DERs	Distributed Energy Resources. Similar to DG, except that DER specifically includes such things as energy storage or responsive loads that are not generation
DG	Distributed Generation. Typically refer to generation resources connected at the distribution level of the system.
Distribution system	The part of the electric grid traditionally used to distributed electric power (typically at <100kV) from the high-voltage transmission system to the end-user.
ERCOT	Electric Reliability Council of Texas.

Extra-high penetration of renewable energy	A level of penetration resulting in significant number of hours where instantaneous power output from variable renewable sources added to the power output from base-load nuclear fleet surpasses the instantaneous power consumption by the load.[51]
FERC	Federal Energy Regulatory Commission.
Frequency Nadir	Minimum frequency reached during a frequency excursion event. It is a direct measure of how close a system has come to interrupting the delivery of electricity to customers after a generation loss event.
ISO	Independent System Operator
LCOE	Levelized Cost of Energy
LOS	Level-of-Service
MAPE	Mean Absolute Percentage Error
NERC	North American Electricity Reliability Corporation.
Net-Load	The electric load minus the electricity production from VERS.
NODES	Network Optimized Distributed Energy Systems
QoS	Quality of Service
Quad	1 quadrillion (10^{15}) BTU
RMT	Reserve Magnitude Target
RMVT	Reserve Magnitude Variability Tolerance
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
Settling Frequency	Refers to the point during a loss-of-generation disturbance when the frequency stabilizes following a frequency excursion. It represents the interconnected system frequency at the point after the frequency stabilizes due to governor action but before the contingent balancing authority takes corrective AGC action.
UFLS threshold	Under-frequency load shedding threshold.
VERs	Variable Energy Resources. These are generation sources that: (1) are renewable; (2) cannot be stored by the facility owner or operator; and (3) have variability that is beyond the control of the facility owner or operator. This includes, for example, wind, solar thermal and photovoltaic, and hydrokinetic generating facilities.[52]

[51] GE Energy Consulting, Jovan Bebic', Gene Hinkle, Slobodan Matic', and William Schmitt, "Grid of the Future: Quantification of Benefits from Flexible Energy Resources in Scenarios With Extra-High Penetration of renewable Energy", Nov 2014.

[52] FERC Docket No. RM10-11-000; Order No. 764 "Integration of Variable Energy Resources" http://www.ferc.gov/whats-new/comm-meet/2012/062112/E-3.pdf

II. Award Information

A. Award Overview

ARPA-E expects to make approximately $30 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 12 to 15 awards under this FOA. ARPA-E may issue one, multiple, or no awards.

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

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be December 2015, or as negotiated.

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

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

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

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

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

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

B. ARPA-E Funding Agreements

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[53] 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.[54]

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

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

2. Funding Agreements with FFRDCs, GOGOs, and Federal Instrumentalities[55]

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 or non-DOE/NNSA GOGO is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC or non-DOE/NNSA GOGO and a single, separate Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple

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

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 on non-DOE/NNSA GOGO will have substantially similar terms and conditions as ARPA-E's Model Cooperative Agreement (http://arpa-e.energy.gov/arpa-e-site-page/award-guidance).

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.

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

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

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 negotiated 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,[56] as the lead for a Project Team,[57] or as a member of a Project Team.

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

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[58] 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, local, and tribal government entities are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

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

3. FOREIGN ENTITIES

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. 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

[57] 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.
[58]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.

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[59]

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

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime Recipient must provide at least 20% of the Total Project Cost[60] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[61]

[59] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[60] 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.
[61] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

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")[62]. 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 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.[63]
- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs are required to provide at least 5% of the Total Project Cost as cost share.
- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80%, of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity

[62] Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards).
[63] See the information provided for footnote number 62 above.

(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 <u>not</u> 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[64] to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment Agreements.

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

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

Applicants may wish to refer to 2 C.F.R. Parts 200 and 910, and 10 C.F.R Part 603 for additional guidance on cost sharing, specifically 2 C.F.R. §§ 200.206 and 910.130, and 10 C.F.R. §§ 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

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.

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

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 SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploaded all required documents to ARPA-E eXCHANGE by the deadline stated in the FOA.

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments, including Replies submitted through other means and Replies submitted after the applicable deadline. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information due to server/connection congestion. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

2. Responsiveness Criteria

ARPA-E performs a preliminary technical review of Concept Papers and Full Applications. Any "Applications Specifically Not of Interest," as described in Section I.F of the FOA, are deemed nonresponsive and are not reviewed or considered.

3. Limitation on Number of Applications

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

IV. Application and Submission Information

A. Application Process Overview

1. Registration in ARPA-E eXCHANGE

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

2. CONCEPT PAPERS

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

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.C of the FOA. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria 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 all or part of a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

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

7. Mandatory Webinar

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

B. Application Forms

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424, 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 may use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the template for the Summary Slide, the template for the Summary for Public Release, 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 graphics, figures, and/or tables.
- The Concept Paper must be submitted in Adobe PDF format.
- The Concept Paper must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11 inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator's Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.

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

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

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

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

- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the technical performance targets in Section I.E of the FOA for the appropriate Technology Category in Section I.D of the FOA.

c. Proposed Work

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

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

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

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

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

- Provide a high-level overview of testing plan to demonstrate the effectiveness of the proposed technology in achieving the program objectives and technical performance targets:
    - Category 1:
      Hardware-In-The-Loop (HiL) Validation
        - Testing setup description for real-time testing with a minimum of 100 actual hardware devices (representing 10s of customers/prosumers).

      Large-Scale Simulation (Optional)
        - Simulation test plan description to demonstrate the robustness and scalability of the proposed solution using large-scale dynamical test systems.
        - A tentative plan to obtain the datasets and models used for simulations provided by grid operators or utilities.
    - Category 2:
      Hardware-In-The-Loop (HiL) Validation
        - Same as Category 1.

      Large-Scale Simulation
        - Same as Category 1.
    - Category 3:
      Hardware-In-The-Loop (HiL) Validation (Optional)
        - If HiL testing platform of the type listed above for Categories 1 and 2 is not available, it could be replaced by a small to medium scale simulation testing involving similar numbers of devices and/or customers.

      Large-Scale Simulation
        - Same as Category 1.

d. TEAM ORGANIZATION AND CAPABILITIES

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

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

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

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

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2015]

E. Content and Form of Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN MAY 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 MAY 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 technical performance targets defined in Section 1.E of the FOA for the appropriate technology Category in Section I.D 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 MAY 2015]

3. Criteria for Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2015]

B. Review and Selection Process

1. Program Policy Factors

[TO BE INSERTED BY FOA MODIFICATION IN MAY 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 MAY 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 MAY 2015]

B. Administrative and National Policy Requirements

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2015]

C. Reporting

[TO BE INSERTED BY FOA MODIFICATION IN MAY 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. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. § 783.

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. REGULATIONS APPLICABLE TO RESULTING AWARDS

Effective December 26, 2014, this FOA and any awards made under it will be governed by 2 C.F.R. Part 200, the Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards, as modified by 2 C.F.R. Part 910, the Department of Energy Financial Assistance Rules.

J. 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, FFRDCs, and GOCOs.

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