

**FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT**



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

**GENERATING ELECTRICITY MANAGED BY INTELLIGENT
NUCLEAR ASSETS (GEMINA)**

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0002174
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	Wednesday, October 2, 2019
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, Friday, November 1, 2019
Submission Deadline for Concept Papers:	9:30 AM ET, Wednesday, November 13, 2019
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	9:30 AM 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 \$35 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between \$250,000 and \$10 million.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov/Registration.aspx>). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.H.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.
- For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 through III.C.4 of the FOA.

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

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REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	<ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • Concept Summary • Innovation and Impact • Proposed Work • Team Organization and Capabilities • Appendix: Digital Twin and/or Cyber-Physical Systems Diagram (Optional for concepts falling under Category A). The Appendix must not exceed one page for a Concept Paper overall total of 5 pages. 	Mandatory	IV.C	9:30 AM ET, Wednesday, November 13, 2019
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]	Optional	IV.E	5 PM ET, TBD

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I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

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

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

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

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

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

ARPA-E funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from

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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 an “original investigation undertaken in order to acquire new knowledge...directed primarily towards a specific practical aim or objective” and defines “experimental development” as “creative and systematic work, drawing on knowledge gained from research and practical experience, which is directed at producing new products or processes or improving existing products or processes.”¹ Applicants interested in receiving financial assistance for basic research should contact the DOE’s Office of Science (<http://science.energy.gov/>). Office of Science national scientific user facilities (<http://science.energy.gov/user-facilities/>) are open to all researchers, including ARPA-E Applicants and awardees. These facilities provide advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. Projects focused on early-stage R&D for the improvement of technology along defined roadmaps may be more appropriate for support through the DOE applied energy offices including: the Office of Energy Efficiency and Renewable Energy (<http://www.eere.energy.gov/>), the Office of Fossil Energy (<http://fossil.energy.gov/>), the Office of Nuclear Energy (<http://www.energy.gov/ne/office-nuclear-energy>), and the Office of Electricity Delivery and Energy Reliability (<http://energy.gov/oe/office-electricity-delivery-and-energy-reliability>).

B. PROGRAM OVERVIEW

1. SUMMARY

The aim of this ARPA-E program is to make a transformational change to the current state-of-the-art and improve advanced reactor (AR)² designs with operations and maintenance (O&M) in mind. Advances in autonomous, efficient, and low-cost systems O&M are occurring in many industrial sectors, largely powered by artificial intelligence (AI), advanced data analytics, distributed computing, powerful physics simulation tools, and other technical breakthroughs. To date, little of this advancement has been adopted by the nuclear energy industry. There is a

¹ OMB Circular A-11 (https://www.whitehouse.gov/wp-content/uploads/2018/06/a11_web_toc.pdf), Section 84, pg. 3.

² Advanced reactor designs include classes of reactors that are being planned but are not currently deployed. This includes designs that use as heat transfer media: gas, lead (or lead-bismuth alloy), molten salt, sodium, heat pipes, supercritical water, supercritical CO₂, and light water; and as nuclear fuel types: ceramic oxides, nitrides, metal, triso clad, silicon carbide clad, metal clad, and liquid eutectic.

crucial need to design and execute extremely robust and low-cost operations and maintenance procedures for ARs.

Most analysts conclude that the low-carbon electricity grids of the future will be most easily and economically achieved by including firm low-carbon resources such as nuclear energy.³ However, existing light water nuclear power plants are facing the significant challenge of having comparatively high fixed O&M costs⁴ and new builds of large light water reactors (LWRs) have historically been drastically over schedule and budget in the U.S. and Western Europe.⁵ Advanced reactors offer a compelling solution option as they can provide enhanced flexibility, a range of power generation outputs, lower capital costs and shorter construction schedules, high temperatures for industrial heating use, and strong safety cases. For a decarbonized future, we need to ensure that AR construction and operating costs are competitive and the plants are flexible to operate.

To accomplish this goal, ARPA-E seeks interdisciplinary teams to develop digital twins (DTs),⁶ or a technology with similar capability, for an AR design as the foundation of the team's O&M strategy. The digital twins (or equivalent) and associated O&M approaches the teams will develop will include diverse technologies that are driving efficiencies in other industries, such as AI, advanced control systems, predictive maintenance, and model-based fault detection. Because ARs are still in design phases, with no physical units operating, teams working on core operations will also develop cyber-physical systems (CPS)⁷ that simulate advanced reactor plant operating dynamics using a combination of non-nuclear experimental facilities (e.g., flow loops) and software. Teams will use these systems as the "real asset," a surrogate upon which developers can test their DT platforms for operations and maintenance. CPS may also provide validation data for regimes for conditions with high uncertainty. Teams focusing on activities outside the reactor core are encouraged to identify appropriate test systems and data. ARPA-E will also support research for filling specific technical gaps to enable the O&M strategies. This program lays the basis for a future where ARs operate with a staffing plan and fixed O&M costs more akin to that of a combined cycle natural gas plant than that of the legacy LWR fleet.

Beyond providing lower fixed O&M costs, development of DTs for ARs has multiple other benefits. In particular, ARPA-E sees DT development contributing to the following areas:

³ Jenkins, Jesse D., and Fernando J. de Sisternes, and Richard K. Lester. "The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation." *Joule*, vol. 2, no. 11, 2018, pp. 2403-2420.

⁴ U.S. Energy Information Administration. "Electric Power Annual. Table 8.4. Average Power Plant Operating Expenses for Major U.S. Investor-Owned Electric Utilities, 2007 through 2017 (Mills per Kilowatthour)." July 1, 2019.

⁵ McMahon, Jeff. "Reasons Nuclear Power Plants are More Expensive in the West (It's Not Regulation)." *Forbes*, Oct 1, 2018.

⁶ Shaw, Keith, and Josh Fruhlinger. "What is a digital twin? [And how it's changing IoT, AI and more]." *NetworkWorld*, January 1, 2019.

⁷ Ptolemy Project. *Cyber-Physical Systems*. UC Berkeley EECS Dept. <https://ptolemy.berkeley.edu/projects/cps/>. Accessed Aug. 2019.

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- **Reactor design.** Detailed designs and operational frameworks for ARs are under active development, meaning that there is an especially rich opportunity to develop the technologies for low-cost and efficient operations and maintenance right now. Insights from O&M strategies can inform design-related improvements to enhance system reliability and flexibility, streamline or eliminate maintenance procedures, and reduce the amount of operator input. ARPA-E anticipates many opportunities for cost reduction and performance improvement to be identified through the use of DTs. Timely development of optimal O&M strategies is critical so they can be incorporated into the designs of these long-life (40+ yr.) systems, and significantly increase long-term viability.
- **Regulatory efficiency.** Development of simulated operations can potentially result in enhanced understanding of reactor behavior, leading to an improved knowledge set for regulator evaluation of advanced reactors. This may shorten licensing timelines and costs.
- **De-risking market adoption challenges.** Presently, most ARs base O&M cost estimates on reference points rooted in LWRs, which feature different materials, operating temperatures, and fuels than proposed ARs. The absence of AR-specific operating cost data inhibits pro-forma assessments of overall reactor operating costs. This program can provide more specific and concrete detail for cost estimation so utility companies and investor groups can create robust estimates of levelized cost of electricity (LCOE) to ultimately drive investment decisions. Cost models also help identify the key elements of the supply chain that must be developed for manufacturing scale up.
- **Standards.** Compliance with a multiplicity of standards is a critical cost driver in LWRs and will likely be so in ARs. Information from this program could help inform the development of technically-based, risk-based NQA-1 standards (nuclear quality assurance standards) as they apply specifically to ARs. Developing these standards now will provide certainty so developers can design to the standards instead of having to perform rework in the future.
- **Training.** When ARs near deployment, tools and training platforms will be required to teach operators how to run the asset under realistic conditions and aid regulators in their certification processes. The DTs developed here could contribute to that training.

2. BACKGROUND AND MOTIVATION

The existing fleet of nuclear reactors have high fixed O&M costs compared to other forms of electricity generation, rendering them uncompetitive in some markets.⁸ Much of the recent focus for advanced reactor development has been on avoiding principal challenges for large LWR designs, such as construction cost and schedule overruns. Much less attention has been given, however, to the O&M costs that are important once the reactor has been constructed and is under operation. Indeed, some analysts expect that ARs may be slightly less expensive to

⁸ Nuclear Energy Institute. "Nuclear Costs in Context," October, 2018. <https://www.nei.org/resources/reports-briefs/nuclear-costs-in-context>

operate than plants in the existing LWR fleet, but economic competitiveness in markets with low-cost natural gas, solar, and wind resources remains a significant question.⁹

O&M is different for nuclear plants than other electricity sources such as natural gas, coal, and biomass. Because nuclear fuel is about 100 million times more energy dense than combusted fuels, nuclear reactors do not consume much fuel and fuel use is not a large cost driver; conversely, fuel is a major cost driver in these other electricity sources. Nuclear reactors, however, have a much larger staff—giving nuclear reactors high fixed O&M costs and low variable O&M costs. While nuclear reactors of the future may vary electrical output instead of operating at a constant power as is done today, it is expected that variable O&M will remain a small fraction of O&M cost. As a result, fixed O&M is the primary focus of this program, though ARPA-E encourages teams to consider whether variable O&M and system optimization warrant some focus.

U.S. nuclear operators have decades of experience operating LWRs, resulting in exceptionally high asset utilization—but this body of experience is not directly translatable to AR systems with different physics, operating temperatures, degradation modes, fuel cycles, etc. Economic viability dictates that AR developers and prospective owners must climb up the AR learning curves with urgency in order to attain operational efficiency promptly. For example, new reactors may undergo refueling on much longer time scales (5-30 years) than today, creating vastly different maintenance paradigms than those centered around 18-month LWR refueling schedules. Operating cost profiles for LWRs are locked in via nuclear quality assurance procedures, but these haven't yet been developed for advanced reactors. Finally, ARs will likely need to operate more flexibly by varying the dispatch of their electrical output (either directly or with thermal or electrochemical energy storage) in the future, which may require more operational actions and maintenance considerations. Rethinking the O&M paradigm for ARs is needed and doing so now provides time for filling technology gaps, design changes, and thoughtful regulator engagement before these are established suboptimally.

There are many AR designs currently in development, each with a different combination of materials, sizes, and operating regimes that may affect O&M needs and choices:¹⁰

- **Electrical output:** Microreactors may be 1-10 MWe, small modular reactors are often 50-300 MWe, and large reactors are on the order of 1 GWe.
- **Power conversion system:** Most ARs plan to use a steam Rankine cycle, but some are planning for CO₂ Brayton cycles.

⁹ Energy Innovation Reform Project. "What Will Advanced Nuclear Power Plants Cost?" July 1, 2017.

<https://www.innovationreform.org/2017/07/01/will-advanced-nuclear-power-plants-cost/>

¹⁰ Milko, John et al. "Keeping Up with the Advanced Nuclear Industry," February 8, 2018.

<https://www.thirdway.org/graphic/keeping-up-with-the-advanced-nuclear-industry>

Freed, Josh et al. "Advanced Nuclear 101," December 1, 2015. <https://www.thirdway.org/report/advanced-nuclear-101>

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- **Heat transfer medium:** light (regular) water, sodium, gas (usually He), lead (or lead-bismuth alloy), molten salt (fluorides, chlorides, or nitrides), heat pipes, supercritical water, organics, and supercritical CO₂ are all options.
- **Fission operating regime:** fission reactors use neutrons to split unstable isotopes. The energy of the neutron causing fission can be near the energy they are born, “fast” (on the order of MeV), or in thermal equilibrium with the system, “thermal” (on the order of meV).
- **Fuel form:** ceramic oxides, nitrides, metal, triso clad, silicon carbide clad, metal clad, liquid eutectic are all options.
- **Operating Temperature:** LWRs have a core outlet temperature of ~285-330 °C, while many non-LWRs will operate around 650 °C or even 1000 °C.
- **Operating Pressure:** some reactors operate at atmospheric pressure, many operate in the range of 7 to 17 MPa, while the highest pressure systems are 25 MPa.

State of the Art Industrial Operations and Maintenance

A range of companies from startups to large, established corporations are developing technologies such as asset performance management (APM), predictive maintenance (PDM), automation, autonomous risk detection, and autonomous control to disruptively improve the performance of industrial processes.¹¹ Applying APM to a utility-scale wind farm reduced under-forecasting to deliver a 1-3% annual energy production gain.¹² A nuclear plant implemented PDM and saved \$540,000 in operating costs in two months.¹³ Use of DTs on an oil platform is projected to reduce inspection costs from \$12M to \$3M,¹⁴ and automation technologies are expected to reduce staffing levels on an oil rig from 25 to five.¹⁵ All of these technologies use sensors on the asset, data aggregation across assets, and DTs to assess the performance of each piece of equipment and to make predictions of its future performance. For many technologies, the predictions allow for suggestions for future actions, alarms, etc. to enable optimal equipment performance. In some cases, the DT systems are integrated with the system controls and can recommend and carry out control actions. When and how to use information from these advanced O&M platforms are relevant questions.

Many of the O&M technologies being developed use DTs to drive future control actions and decision making. A DT is a software representation of a physical asset (a piece of equipment or a system) that assists designers and operators in understanding the state and performance of

¹¹ Pariyani, Ankur. “Maximizing Uptime, Efficiency, and Safety of Industrial Operations through Early Risk Detection.” AiChE Annual Meeting, 28 Oct. – 2 Nov. 2018, David L. Lawrence Convention Center, Pittsburgh, PA.

¹² GE. “Predix: The Industrial IoT Application Platform.” 2018.

https://www.ge.com/digital/sites/default/files/download_assets/Predix-The-Industrial-Internet-Platform-Brief.pdf

¹³ Aveva. “Predictive Asset Analytics for Nuclear Equipment Reliability.” Industry Solution. 2019.

<https://pdfs.semanticscholar.org/dd70/70ea70b09bc8d72c4be6f9ac8925479fa805.pdf>

¹⁴ Akselos. “Predictive Digital Twins for Structural Integrity Management.” Phone meeting with ARPA-E, 2018.

¹⁵ Newman, Nicholas. “Robots are Taking Over Oil Rigs,” July 6, 2017.

https://www.eniday.com/en/technology_en/robots-are-taking-over-oil-rigs/

their designs. A DT is not simply a single model or type of model—it is a collection of relevant models that are combined to compute or derive outputs of interest. The constituent models may be physics-based, data-driven, or include both representations. The DT must evolve along with the real system as it ages and as its performance changes over time. Much of the work in DT development is in defining what can go wrong on various timescales and how to quantify the predictive performance of DTs. Modeled responses can be as fast as the timescale required for system control, or much slower, and the DT can potentially detect previously unknown unknowns.¹⁶

New O&M technologies use sensor data to understand the current state of an asset, with many moving to a level of complexity where historical data can be used to predict future asset performance and, consequently, the need for particular operational actions or maintenance activities. While more and better sensor data is always desired, there are tradeoffs. Key considerations include how sensors will be maintained, the cost of sensors, what data is really needed, and sensor uncertainty and reliability. Sophisticated techniques have been developed to use simulation and implicit data to create “virtual sensors,” to anticipate sensor failures and compensate for missing data, and to auto-calibrate sensors.

Digital Twins for ARs

ARPA-E is interested in supporting teams of engineers and technologists to develop new O&M frameworks for future AR designs. Specifically, ARPA-E would like teams to leverage the ideas being applied in other industries to radically improve and reduce the costs of O&M activities. ARPA-E is interested in solutions focusing on operating and maintaining the reactor core, the balance of plant (BOP), or the entire reactor plant system (including both the reactor core and BOP). The tools and strategies needed for semiautonomous reactor operations (controlling the reactor itself) are not yet fully developed and are likely to require significant further innovation. Ideas for O&M in the BOP may require additional modifications that assure reliability, materials compatibility, or safe operation in radiation environments, etc. compared to the systems used in other industrial sectors.

Because operating ARs do not currently exist in the U.S., an AR DT will reflect a combination of experimental data, where available,¹⁷ and physics-based simulations, combined with assumptions of prospective reactor performance. For technologies more focused on the BOP, data from relevant industries may be utilized. ARPA-E expects selected teams will develop, test, and use information from DTs to establish efficient and low-cost AR O&M strategies. ARPA-E recognizes that not all of the required data, tools, or capabilities exist to implement some of the best O&M strategies and will therefore fund targeted efforts to “fill in” crucial technology gaps.

¹⁶ We do not always know all of the edge or corner cases that might occur in the operation of a given technology a priori. Using a DT offers the possibility to uncover system problems or vulnerabilities that were missed by the designers.

¹⁷ For reactor operations this includes separate effects tests or full reactor operations, e.g., the Experimental Breeder Reactor II at Idaho National Laboratory; the Molten Salt Reactor Experiment conducted at Oak Ridge National Laboratory; or commercial operation from the Fort St. Vrain Generating Stations.

For DT use, there is a need to answer fundamental questions such as: What specific applications require DTs? What level of modeling fidelity is needed for which operational conditions? What information from reactor sensors, balance of plant, and environmental conditions are needed, and at what accuracy? How can AI and information from reactor operation procedures be used to guide operator actions? How will synthetic data, dynamic simulation resolution, and uncertainty be handled? Should the DT ever be allowed to take direct control of the process? If so, when, and for what purpose? These answers can form the basis of an operational paradigm that increases the safety basis of the plant and reduces the staff size needed for safe and efficient operation. Many of these questions are not unique to the nuclear energy industry, but they need to be answered specifically for the nuclear case because of the complexity of the physics involved, the harshness of the physical environment, and the overriding importance of reliability.

Testing and validating the DTs will be an important component of this program. For reactor core operations, ARPA-E would like teams to develop cyber-physical systems (CPS) to function as the “real asset” to use in the development of DTs for ARs. Cyber-physical systems are hybrid digital-physical representations of underlying real systems. Also known as hardware-in-the-loop systems, CPS integrate computation, networking, and physical processes with feedback loops where physical processes affect computations and vice versa. For the reactor core operation of ARs, the digital component may include elements such as a simulated reactor core, with the physical system comprising actual coolant flow loops working at temperatures and/or pressures similar to those of the proposed reactor design. By using the combination of real system response and simulation, a more realistic system representation is attained compared to simulation alone. This is particularly true because limited operational data exist for most ARs. These CPS are the most effective simulation tool that can be used in advance of system integration test facilities and commercial deployment to gather operational data for the highest risk subsystems and to enhance the foundational data that underpins the DTs.

For proposals focused on the BOP, either physical systems or cyber-only systems may be more appropriate to use with DTs since more existing data is available for use. Because the reactor core and BOP are closely coupled, ARPA-E also welcomes solutions for the entire reactor plant.

C. PROGRAM OBJECTIVES

ARPA-E aims to develop the tools and cost basis for ARs to achieve fixed O&M costs of \$2/MWh without shifting costs to other parts of LCOE. ARPA-E intends this program to be iterative in nature, where designs and tools are improved as new information is gained, research questions are answered, and costs are estimated. Representatives from selected Project Teams will be required to attend periodic working group meetings with other GEMINA teams and external stakeholders, including the Nuclear Regulatory Commission, to address common questions and

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issues associated with DT development and use.¹⁸ To achieve the GEMINA goals, awardee teams will develop the following for one or more of the most promising AR designs:

- **Digital twins for advanced reactor systems.** The DTs will leverage appropriate physics codes and experimental data, supplementing with first principles calculations or approximations where necessary. The DTs may focus on reactor operations, plant maintenance, or a combination thereof.
- **Relevant cyber physical systems.** For reactor core control, teams will use existing non-nuclear flow loops or experimental facilities, combined with relevant physics software and control systems, to create a CPS of an AR to serve as the “real asset” to be matched with the relevant DT. For BOP O&M, ARPA-E is interested in seeing as much realism as possible.
- **O&M approaches for advanced reactors.** ARPA-E intends for teams to use the DTs and CPS (or equivalent) to develop and test novel O&M procedures and ideas, leveraging the best existing ideas when appropriate, to create an economic, reliable, and flexible O&M platform for at least one AR design.
- **Cost models and design updates.** ARPA-E intends for the tools developed in this program, in conjunction with capabilities existing outside the program, to inform O&M costs and practices in AR systems. ARPA-E would also like to emphasize designing for maintenance. Teams should use their developed tools to make design choices to ensure that equipment is easy to maintain and the plant can be operated to reduce maintenance cost and complexity.

D. TECHNICAL CATEGORIES OF INTEREST

There are many different reactor designs in development and it is unclear which will ultimately be deployed. For both categories below, we encourage teams to think about how their ideas could have the broadest impact by doing work that can be applied to or adapted easily for multiple reactor types.

1. CATEGORY A: OPTIMAL OPERATIONS AND MAINTENANCE FOR ARs

Currently, AR O&M frameworks are poorly defined and cost estimates are based on rough assessments. To create low-cost and well-defined O&M strategies, ARPA-E would like teams to build DTs of advanced reactor designs and to develop and demonstrate their use for optimal operations and maintenance. Applications of interest will consist of interdisciplinary teams that propose to:

¹⁸ Travel to working groups will be reimbursed by ARPA-E; teams will not be required to share any confidential information at working group meetings.

1. Build a digital twin (following the definition from Section I.B) for an advanced reactor system and use it to develop and test advanced O&M framework and associated cost reduction strategies. Proposals that include or present a pathway towards experimental demonstration are of interest. Applicants may propose development of DTs geared towards reactor core operation activities, BOP systems, or ideally, given that these categories can be tightly coupled, a combination of the two. Tasks to be conducted include:
 - a. Clearly specifying personnel requirements and identifying opportunities for automation and for autonomy.
 - b. For the reactor core, practicing control operations with injected signals for scenarios such as startup, shutdown, and transients. Research into autonomous controls is of interest.
 - c. Evaluating what measured data are essential and developing inference methods to reduce required instrumentation. Optimizing sensor sets by balancing the tradeoffs between abundant instrumentation (yielding a rich data-stream) and the associated costs (sensors are expensive and must be maintained, etc.).
 - d. Designing for maintenance (component accessibility, systems compatibility for APM and PDM, etc.).
 - e. Gaining validation data for nuclear software.
2. Develop a techno-economic analysis to concurrently drive decision making, optimizing for cost, reliability, and flexibility.
3. Examine the results, try out different ideas, and feed the learning back into the system design.
4. Support regulator engagement, standards development and adoption, and training platforms using the developed tools.

Teams should note that many of the existing algorithms and frameworks for O&M typically require large data sets to be stored and accessed from the cloud. Special consideration must be given for how to handle this in the nuclear plant context. Current nuclear reactors are air-gapped, sensors are often analog, and data are either transmitted by wires or recorded by hand. The next generation of reactors will not need to have the same constraints, but very strong physical and cyber security protocols will be required. It may be possible to connect to remote computing in a “data out only” structure. ARPA-E expects teams to explicitly consider this issue throughout the program but will not fund topics developing cyber security solutions as the primary focus.

2. CATEGORY B: TARGETED O&M TOPICS

Technical gaps may exist that prevent the O&M solutions developed in this program from being fully usable, such as a lack of suitable data necessary for modeling or simulation, insufficient essential sensors, or inability to execute specific maintenance tasks. Progress toward sophisticated O&M may be accelerated through the development of smaller, more specific, and focused technology-oriented research programs to address these gaps. Proposers in this

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category must identify the specific issue they are addressing and justify why it is essential for the O&M goals. ARPA-E seeks to address the following areas:

1. Data generation. The novelty of advanced reactors potentially poses a range of data gaps that must be resolved in order to create effective DTs, operational requirements, and management plans. These may include, for instance, materials behaviors in the relevant reactor environment, fission product behavior in salt eutectics, structural mechanics impacts for flexible operations, etc.
2. Sensor development. Strategies and technologies for sensing reactor and system states may need to be developed. ARPA-E will consider funding the development of sensors that are needed now to substantially advance O&M activities such as self-calibrating sensors or detectors, molten salt flow meters, or virtual sensor strategies specifically for AR applications. These must be technologies for which DOE-NE has not already committed resources.
3. Maintenance task execution. Some advanced reactor designs will have maintenance activities that may be too hazardous, challenging, error prone, or expensive for humans to conduct routinely. Autonomy may be enhanced through the development of systems that can reduce or even eliminate the need for humans to perform O&M tasks. Areas of interest related to this topic include but are not limited to: radiation-hardened electronics and instrumentation for robots, virtual reality solutions for remote operations, and algorithm development for autonomous operations.
4. Other. Applicants may propose alternate R&D areas, hardware or software, which are critical enablers of optimal O&M technologies for ARs.

E. TECHNICAL PERFORMANCE TARGETS

Because of the wide breadth of technologies and use cases addressed in this FOA, it is impractical to provide well-defined technical targets for all topics of interest. Instead, qualitative targets and general discussion are provided below to elucidate the desired outcomes of successful projects. However, Applicants are asked to quantitatively address these selection criteria in their applications, specifying the technical performance targets required for the proposed work to have transformative impact in the areas of interest. For the Concept Paper, Applicants are expected to identify measures of success and the data requirements for the proposed approach. At the Full Application stage, a greater level of detail and specificity will be required. In addition, Applicants will need to clearly specify their technology to market plan at the Full Application stage.

1. CATEGORY A: OPTIMAL OPERATIONS AND MAINTENANCE FOR ARS

1. Digital twin targets and metrics:
 - Reactor core operations: DTs must be capable of emulating AR system startup, shutdown, power change, and relevant transient operating scenarios.

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- Relevant system and measurement timescales must be clearly identified, as well as the data required to make reliable control decisions and recommendations, including associated uncertainties.
- Operational envelopes for system parameters as a function of time must be defined for scenarios of interest. The accuracy and efficacy of autonomous control systems will be assessed according to their ability to (1) classify the scenario correctly and (2) recommend and simulate corrective control actions that keep the system within the defined operational envelopes.
- Uncertainty quantification will be an important research component—handling sensor and data uncertainty, identifying simulation fidelity requirements for various tasks, etc.

2. Economic impact:

- To underscore the scale of innovation necessary to promote economic viability of the AR fleet, a grand challenge of levelized fixed O&M of \$2/MWh is presented as a target for future AR plants.

2. CATEGORY B: TARGETED O&M TOPICS

1. *Data generation.* Applicants should clearly identify what additional data at what quality are needed to impact operations software tools and/or advanced maintenance strategies for AR plants (e.g., filling in gaps in parameter space, reducing uncertainties, etc.).
2. *Sensor development.* Applicants should clearly identify the need for the development of new and/or improved instrumentation (i.e., what monitoring and/or control capabilities will the new instrumentation enable?) as well as the requisite performance targets (accuracy, resolution, survivability in harsh environments, etc.).
3. *Maintenance task execution.* Applicants should clearly identify why remote and/or autonomous handling is strictly required for the proposed tasks; or if not, how it would either significantly reduce the O&M cost in AR plants or why the benefits outweigh the cost of implementation.
4. *Other.* Similarly, Applicants must justify R&D projects in alternate or adjacent technical areas of interest to future AR development by quantifying the benefits of the proposed technology.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately \$35 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 10-15 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

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

The period of performance for funding agreements may not exceed 42 months. ARPA-E expects the start date for funding agreements to be August 2020, or as negotiated.

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

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

Applicants proposing projects for which some initial proof-of-concept demonstration already exists 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 submissions with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

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

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

B. RENEWAL AWARDS

At ARPA-E's sole discretion, awards resulting from this FOA may be renewed by adding one or more budget periods, extending the period of performance of the initial award, or issuing a new

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award. Renewal funding is contingent on: (1) availability of funds appropriated by Congress for the purpose of this program; (2) substantial progress towards meeting the objectives of the approved application; (3) submittal of required reports; (4) compliance with the terms and conditions of the award; (5) ARPA-E approval of a renewal application; and (6) other factors identified by the Agency at the time it solicits a renewal application.

C. ARPA-E FUNDING AGREEMENTS

Through cooperative agreements, other transactions, 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."¹⁹ Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, 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.²⁰

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

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

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

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

When a FFRDC/DOE Lab (including the National Energy Technology Laboratory or NETL) is the

¹⁹ U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

²⁰ The Prime Recipient is the signatory to the funding agreement with ARPA-E.

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

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

Funding agreements with DOE/NNSA FFRDCs take the form of Work Authorizations issued to DOE/NNSA FFRDCs through the DOE/NNSA Field Work Proposal system for work performed under Department of Energy Management & Operation Contracts. Funding agreements with non-DOE/NNSA FFRDCs, GOGOs (including NETL), and Federal instrumentalities (e.g., Tennessee Valley Authority) will be consistent with the sponsoring agreement between the U.S. Government and the Laboratory. Any funding agreement with a FFRDC or GOGO will have similar terms and conditions as ARPA-E's Model Cooperative Agreement (<https://arpa-e.energy.gov/?q=site-page/funding-agreements>).

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

3. OTHER TRANSACTIONS AUTHORITY

ARPA-E may use its "other transactions" authority under the America COMPETES Reauthorization Act of 2010 to enter into an other transaction agreement with Prime Recipients, on a case-by-case basis.

ARPA-E may negotiate an other transaction agreement when it determines that the use of a standard cooperative agreement, grant, or contract is not feasible or appropriate for a project.

In general, an other transaction agreement would require a cost share of 50%. See Section III.B.2 of the FOA.

D. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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

- Project Teams must adhere to ARPA-E's agency-specific and programmatic

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requirements.

- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- ARPA-E may, at its sole discretion, modify or terminate projects that fail to achieve predetermined Go/No Go decision points or technical milestones and deliverables.
- During award negotiations, ARPA-E Program Directors and Prime Recipients mutually establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. In addition, ARPA-E will negotiate and establish “Go/No-Go” milestones for each project. If the Prime Recipient fails to achieve any of the “Go/No-Go” milestones or technical milestones and deliverables as determined by the ARPA-E Contracting Officer, ARPA-E may – at its discretion - renegotiate the statement of project objectives or schedule of technical milestones and deliverables for the project. In the alternative, ARPA-E may suspend or terminate the award in accordance with 2 C.F.R. §§ 200.338 and 200.339.
- ARPA-E may provide guidance and/or assistance to the Prime Recipient to accelerate the commercial deployment of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits to provide mentoring and networking opportunities for Prime Recipients. ARPA-E may also organize and sponsor events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E may establish collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

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III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

This FOA is open to U.S. universities, national laboratories, industry and individuals.

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,²¹ as the lead for a Project Team,²² or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits²³ that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

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

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

U.S.-incorporated subsidiaries of foreign entities, whether for-profit or otherwise, are eligible to apply for funding under this FOA as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team, subject to the requirements in 2 C.F.R. §

²¹ A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.

²² A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.

²³ 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.

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910.124, which includes requirements that the entity's participation in this FOA's Program be in the economic interest of the U.S. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate.

Entities not incorporated in the U.S., whether for-profit or otherwise, are not eligible to apply for funding, but may be proposed by an Applicant as a member of a Project Team.

All work under an ARPA-E award must be performed in the U.S. The Applicants may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at <https://arpa-e-foa.energy.gov/>. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

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

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

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;
- Provisions for members' cost sharing contributions; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

B. COST SHARING²⁴

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

²⁴ Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.C.1 of the FOA). Under a Cooperative Agreement, the Prime Recipient must provide at least 20% of the Total Project Cost²⁵ as cost share, except as provided in Sections III.C.2 or III.C.3 below.²⁶

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 an “other transaction” agreement, the Prime Recipient must provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this cost share requirement, as appropriate.

3. REDUCED COST SHARE REQUIREMENT

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

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is not required to provide cost share.
- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs/DOE Labs/Federal agencies and instrumentalities (other than DOE) are not required to provide cost share.
- Small businesses – or consortia of small businesses – may provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the “Cost Share Grace Period”).²⁷ 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.

²⁵ 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.

²⁶ Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

²⁷ 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>). Applicants that are small businesses will be required to certify in the Business Assurances & Disclosures Form that their organization meets the SBA’s definition of a small business under at least one NAICS code.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) 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.²⁸
- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.
- Projects that do not meet any of the above criteria are subject to the base 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, or ensuring payment of, the entire cost share. The Prime Recipient's cost share obligation is expressed in the funding agreement as a static amount in U.S. dollars (cost share amount) and as a percentage of the Total Project Cost (cost share percentage). If the funding agreement is terminated prior to the end of the period of performance, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

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

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 of the FOA.

²⁸ See the information provided in previous footnote.

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

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

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

In addition, Project Teams may not use independent research and development (IR&D) funds²⁹ to meet their cost share obligations under Cooperative Agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under “other transaction” 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. §§ 200.306 and 910.130, and 10 C.F.R. §§ 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCs AND GOGOS

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

²⁹ As defined in Federal Acquisition Regulation SubSection 31.205-18.

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

8. COST SHARE VERIFICATION

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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

Full Applications are deemed compliant if:

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

Full Applications found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Full Applications, including Full

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

Applications submitted through other means, Full Applications submitted after the applicable deadline, and incomplete Full Applications. A Full Application is incomplete if it does not include required information and documents, such as Forms SF-424 and SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

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

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

2. RESPONSIVENESS CRITERIA

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

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Submissions for proposed technologies that are not transformational, as described in Section I.A of the FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress.

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

- Submissions that are not distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by any other office within Department of Energy.
- Submissions that are not distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by other government agencies or the private sector.
- Submissions that do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

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

- Technologies primarily focused on Gen II and Gen III LWRs.
- Plant security systems. While ARPA-E recognize that security represents a large portion of O&M costs, technologies intended to only address cyber or physical security at plants are not of interest.
- “Paper reactors” or proposed reactor systems that have relatively little design and/or relative commercial maturity.
- Developing O&M for industrial facilities without a direct application to nuclear energy.
- Category A strategies for single components, e.g., a digital twin for a pump.
- Methods or software development only for physics simulations codes.

4. LIMITATION ON NUMBER OF SUBMISSIONS

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

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

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

2. CONCEPT PAPERS

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

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria and program policy factors in Sections V.A.1 and V.B.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 submission that is unlikely to be selected for award negotiations. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. Unsuccessful Applicants should continue to submit innovative ideas and concepts to future FOAs.

3. FULL APPLICATIONS

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

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

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

4. REPLY TO REVIEWER COMMENTS

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

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

5. PRE-SELECTION CLARIFICATIONS AND “DOWN-SELECT” PROCESS

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

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

6. SELECTION FOR AWARD NEGOTIATIONS

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

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

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

B. APPLICATION FORMS

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

C. CONTENT AND FORM OF CONCEPT PAPERS

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

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

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

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

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

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

1. CONCEPT PAPER

a. CONCEPT SUMMARY

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

b. INNOVATION AND IMPACT

- Clearly identify the problem to be solved with the proposed technology concept.
- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Explain the concept's potential to be disruptive compared to existing or emerging technologies.
- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the Technical Performance Targets in Section I.E of the FOA 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.

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

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.

e. APPENDIX: DIGITAL TWIN AND/OR CYBER-PHYSICAL SYSTEMS DIAGRAM

- This one page appendix is optional for concepts falling under Category A. It is not permitted for concepts falling under Category B.
- Category A teams may include a diagram of their DT plan, their CPS plan, or both, as appropriate:
 - The digital twin diagram should illustrate system inputs, outputs, and constituent components such as physics codes and software frameworks.
 - The cyber-physical systems diagram should similarly illustrate information flow and also delineate which components will be represented by virtual or physical components.

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]

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 JANUARY 2020]

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

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 Applicant 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 may not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications may 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;

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

- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the “Submit” button in ARPA-E eXCHANGE by the deadline stated in the FOA;
- Uploading the wrong document(s) or application(s) to ARPA-E eXCHANGE; and
- Uploading the same document twice, but labeling it as different documents. (In the latter scenario, the Applicant failed to submit a required document.)

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

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

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

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

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

1. **CRITERIA FOR CONCEPT PAPERS**

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

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

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

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

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

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 JANUARY 2020]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

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

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

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

- III. **Synergy of Public and Private Efforts.**
 - a. Avoids duplication and overlap with other publicly or privately funded projects;

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- b. Promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer; or
 - c. Increases unique research collaborations.
- IV. **Low likelihood of other sources of funding.** High technical and/or financial uncertainty that results in the non-availability of other public, private or internal funding or resources to support the project.
- V. **High-Leveraging of Federal Funds.** Project leverages Federal funds to optimize advancement of programmatic goals by proposing cost share above the required minimum or otherwise accessing scarce or unique resources.
- VI. **High Project Impact Relative to Project Cost.**

2. ARPA-E REVIEWERS

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

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

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

3. ARPA-E SUPPORT CONTRACTOR

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

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

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

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES
[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]

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

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

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

2. CONCEPT PAPER NOTIFICATIONS

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

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

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

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN JANUARY 2020]

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

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

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

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

- ARPA-E will post responses on a weekly basis to any questions that are received that have not already been addressed at the link above. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- ARPA-E will cease to accept questions approximately 10 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted approximately one business day in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- Responses are published in a document specific to this FOA under “CURRENT FUNDING OPPORTUNITIES – FAQs” on ARPA-E’s website (<http://arpa-e.energy.gov/faq>).

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

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

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

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

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.

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

VIII. OTHER INFORMATION

A. 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 Prime Recipients/Subrecipients elect to retain title, they must file a patent application in a timely fashion, generally one year from election of title, though: a) extensions can be granted, and b) earlier filing is required for certain situations (“statutory bars,” governed by 35 U.S.C. § 102) involving publication, sale, or public use of the subject invention.
- All other parties: The Federal Non-Nuclear Energy Research and Development Act of 1974, 42 U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below*).
- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues “class patent waivers” under which large businesses and foreign entities that meet certain stated requirements, such as cost sharing of at least 20%, may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.
- GOGOs are subject to the requirements of 37 C.F.R. Part 501.
- Determination of Exceptional Circumstances (DEC): DOE has determined that exceptional circumstances exist that warrant the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to maximize the manufacture of technologies supported by ARPA-E awards in the United States. The DEC, including a right of appeal, is dated September 9, 2013 and is available at the following link: <http://energy.gov/gc/downloads/determination-exceptional-circumstances-under-bayh-dole-act-energy-efficiency-renewable>. Please see Section IV.D and VI.B for more information on U.S. Manufacturing Requirements.

B. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

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

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

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.

C. RIGHTS IN TECHNICAL DATA

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

- Background or “Limited Rights Data”: The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.
- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be

protected from public disclosure for a reasonable time in order to allow for filing a patent application.

D. 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).

E. 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>.

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

F. 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.

G. 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.

H. 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.

I. 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.

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

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.

J. COMPLIANCE AUDIT REQUIREMENT

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

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

IX. GLOSSARY

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

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

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

Cost Sharing: is the portion of project costs not paid by Federal funds (unless otherwise authorized by Federal statute). Refer to 2 C.F.R. § 200.29.

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

DOE: U.S. Department of Energy.

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

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

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

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

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

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

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.

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

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

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).