FINANCIAL ASSISTANCE
NOTICE OF FUNDING OPPORTUNITY

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

GRID RELIABILITY WITH AUTOMATIC DAMPING AND INERTIA FOR ELECTRICAL NETWORKS AND TRANSMISSION SYSTEMS SBIR/STTR (GRADIENTS SBIR/STTR)

Announcement Type: ~~Initial Announcement~~ Modification 01
Notice of Funding Opportunity No. DE-FOA-0003555
Assistance Listing Number 81.135

Mod. No.	Date	Description of Modifications
01	2/6/2025	• Clarified the meaning of the Program Policy Factors in Section V.C

- All modifications to the Notice of Funding Opportunity (NOFO) are highlighted in yellow in the body of the NOFO.

NOFOs 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 NOFO 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 NOFO. It is recommended that you register as soon as possible after release of the NOFO to ensure that you receive timely notice of any modifications or other announcements.

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

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BASIC INFORMATION

KEY DATES:	
Notice of Funding Opportunity (NOFO) Issue Date:	January 15, 2025
Deadline for Concept Paper Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, February 4, 2025
Submission Deadline for Concept Papers:	9:30 AM ET, February 14, 2025
Anticipated Date for Encourage/Discourage Notifications:	5 PM ET, April 3, 2025
Deadline for Full Application Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	9:30 AM ET, TBD
Expected Reviewer Comment Release Date:	5 PM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Anticipated Timeframe for Selection Notifications:	July 2025
Anticipated Timeframe for Award:	October 2025
Anticipated Period of Performance:	October 2025 – October 2028

BASIC INFORMATION:	
Total Amount to Be Awarded	Approximately $30 million, subject to the availability of appropriated funds to be shared between NOFOs DE-FOA-0003555 and DE-FOA-0003554.
Anticipated Number and Value of Awards	ARPA-E anticipates making approximately 6-15 awards between NOFOs DE-FOA-0003555 and DE-FOA-0003554. ARPA-E may issue one, multiple, or no awards under this NOFO. The Federal share of awards under this NOFO may vary between $314,363 and $4,505,859.
Agency Contact Information	• Questions and answers (Q&As) about ARPA-E and this specific NOFO: http://arpa-e.energy.gov/faq. • Send other questions about the NOFO to: ARPA-E-CO@hq.doe.gov. • Send questions about use of ARPA-E eXCHANGE to: ExchangeHelp@hq.doe.gov. Upon the issuance of a NOFO, only the Grants Officer via ARPA-E-CO@hq.doe.gov may communicate with Applicants. This "quiet period" remains in effect until ARPA-E's public announcement of project selections. Emails sent to other email addresses will be disregarded.

The power grid is currently undergoing a large-scale transformation, including a significant reduction of conventional synchronous generators, a high penetration of inverter-based resources, substantial load growth, and a concerning vulnerability to contingencies and extreme weather. The GRADIENTS program seeks to develop disruptive solutions to drastically improve grid reliability and controllability under these conditions. With the goal of avoiding blackouts and cascading failures, the program will provide new solutions to system operators to facilitate greater controllability and coordination capabilities to stabilize the system under undesired dynamic interactions and extreme weather events.

The GRADIENTS program is composed of three technical categories: (1) Flexible renewable generation, (2) Intelligent automatic relays, and (3) Wide-area real-time control co-design.

The flexible renewable generation category (Category 1) shall develop inverter-based renewable generators that include (1) inverters that can seamlessly and on-demand transition from grid-following to grid-forming mode and vice-versa, (2) some form of battery-less short-term energy storage for a few

seconds at rated power, and (3) advanced control solutions to improve grid controllability and coordination in real-time.

The intelligent automatic relays category (Category 2) shall develop advanced relays that include under-frequency/under-voltage load-shedding capabilities for emergency operation smart sensors and algorithms for automatic contingency prediction, small-signal impedance estimation, stability assessment, and incipient fault detection.

The wide-area real-time control co-design category (Category 3) shall develop new real-time control and optimization solutions for energy (inertia) allocation, control authority (damping) allocation, and load-shedding capability allocation across different regions of the grid. These algorithms would be implemented in central/regional control rooms and would interact with the intelligent generation nodes developed under Category 1 and the intelligent relays developed under Category 2.

To effectively respond to this NOFO, expertise and teaming of engineers and scientists from different organizations, disciplines, and technology sectors are expected, especially of those from electrical and mechanical engineering, control engineering, optimization, storage, mathematics, physics, artificial intelligence, and other relevant fields.

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), as further amended by the Energy Act of 2020 (P.L. 116-260):

"(A) to enhance the economic and energy security of the United States through the development of energy technologies that—
(i) reduce imports of energy from foreign sources;
(ii) reduce energy-related emissions, including greenhouse gases;
(iii) improve the energy efficiency of all economic sectors;
(iv) provide transformative solutions to improve the management, clean-up, and disposal of radioactive waste and spent nuclear fuel; and
(v) improve the resilience, reliability, and security of infrastructure to produce, deliver, and store energy; and
(B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies."

ARPA-E issues this Notice of Funding Opportunity (NOFO) under its authorizing statute codified at 42 U.S.C. § 16538. The NOFO and any cooperative agreements or grants made under this NOFO are subject to 2 C.F.R. Part 200 as supplemented by 2 C.F.R. Part 910.

ARPA-E funds research on, and the development of, transformative science and technology solutions to address the energy and environmental missions of the Department. The agency focuses on technologies that can be meaningfully advanced with a modest investment over a defined period of time in order to catalyze the translation from scientific discovery to early-stage technology. For the latest news and information about ARPA-E, its programs and the research projects currently supported, see: http://arpa-e.energy.gov/.

ARPA-E funds transformational research. Existing energy technologies generally progress on established "learning curves" where refinements to a technology and the economies of scale that accrue as manufacturing and distribution develop drive improvements to 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. In 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 better than that of the incumbent technology. 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 funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

ARPA-E funds applied research and development (R&D). 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 (defined by the Office of Management and Budget as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts")[1] 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 and Carbon Management (https://www.energy.gov/fecm/office-fossil-energy-and-carbon-management), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity (https://www.energy.gov/oe/office-electricity).

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 can propose a project with the end deliverable being an extremely creative, but partial solution.

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

B. SBIR/STTR PROGRAM OVERVIEW

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are Government-wide programs authorized under Section 9 of the Small Business Act (15 U.S.C. § 638). The objectives of the SBIR program are to (1) stimulate technological innovation in the private sector, (2) strengthen the role of Small Business Concerns in meeting Federal R&D needs, (3) increase private sector commercialization of innovations derived from Federal R&D activities, (4) foster and encourage participation by socially and economically disadvantaged and women-owned Small Business Concerns, and (5) improve the return on investment from Federally funded research and economic benefits to the Nation. The objective of the STTR program is to stimulate cooperative partnerships of ideas and technologies between Small Business Concerns and partnering Research Institutions through Federally funded R&D activities.[2]

ARPA-E administers a joint SBIR/STTR program in accordance with the Small Business Act and the SBIR and STTR Policy Directive issued by the U.S. Small Business Administration (SBA).[3] ARPA-E provides SBIR/STTR funding in three phases (Phase I, Phase II, and Phase IIS).

Applicants must apply for a Combined Phase I/II Award or a Combined Phase I/II/IIS Award. Combined Phase I/II and I/II/IIS Awards are intended to develop transformational technologies with disruptive commercial potential. Such commercial potential may be evidenced by (1) the likelihood of follow-on funding by private or non-SBIR/STTR sources if the project is successful, or (2) the Small Business Concern's record of successfully commercializing technologies developed under prior SBIR/STTR awards. Phase IIS awards are a "sequential" (i.e., additional) Phase II award, intended to allow the continued development of promising energy technologies. Combined Phase I/II/IIS awards may be funded up to $4,505,859. Funding amounts will be consistent with the Phase I and Phase II limits posted on SBIR.gov website.[4]

ARPA-E reserves the right to select all or part of a proposed project (i.e., only Phase I, or only Phase I and Phase II). In the event that ARPA-E selects Phase I only or Phase I/II only, then the maximum award amount for a Phase I award is $314,363 and the maximum amount for a Phase I/II award is $2,410,111.

[2] Research Institutions include FFRDCs, nonprofit educational institutions, and other nonprofit research organizations owned and operated exclusively for scientific purposes. Eligible Research Institutions must maintain a place of business in the United States, operate primarily in the United States, or make a significant contribution to the U.S. economy through the payment of taxes or use of American products, materials, or labor.

[3] See 88 Fed. Reg. 19704 (May 3, 2023) or SBIR.gov file at SBIR and STTR Policy Directive - May 2023.

[4] For current SBIR and STTR Phase I and Phase II funding amounts, see https://legacy.www.sbir.gov/about. Phase IIS funding amounts are equal to Phase II funding amounts for both SBIR and STTR awards.

C. PROGRAM OVERVIEW

1. SUMMARY

The Grid Reliability with Automatic Damping and Inertia for Electrical Networks and Transmission Systems (GRADIENTS) program will support the development of disruptive grid assets and control solutions enabling renewable energy systems to provide and improve services traditionally supported by large conventional synchronous generators.[5] At present, existing renewable energy systems without ancillary services can deteriorate grid stability. This program aims to use real-time control co-design (RT-CCD) to transform that problem into a solution, specifically creating intelligent inverter-based resources (IBRs) that improve grid controllability and coordination. The RT-CCD methodology uses control engineering principles throughout the design process rather than considering control design as a subsequent process.[6] By co-optimizing assets for power delivery and controllability, this design methodology can achieve improvements in grid stability that are not otherwise possible without prohibitive capital expenses. Projects in this program will cover technologies in three categories: flexible renewable generation, intelligent automatic relays, and wide-area RT-CCD. GRADIENTS technologies based on dynamic metrics that quantify grid stability and controllability in terms of rate of change of frequency (RoCoF), nadir, decay ratio, and recovery time, and the program will also include a techno-economic metric for synergy margin evaluation.

The program will drive advancements in grid resilience, efficiency, and adaptability. By addressing and coordinating resources that can provide inertia (energy) and damping (control) with fast frequency regulation across the grid, GRADIENTS will improve reliability in high-renewable penetration scenarios, mitigating blackout risks, reducing potential curtailment of renewables, lowering operational costs, and maximizing economic viability.[7] The program will also foster technological innovation by developing intelligent relays and fault-tolerant protection systems, improving fault detection, adaptability, and response capabilities tailored for IBRs. Furthermore, its scalable and flexible approach to distributed control supports a wide range of applications from large regional grids to localized microgrids with customization for diverse energy mixes and regulatory requirements. Collectively, these advancements will modernize grid infrastructure, promote renewable energy integration, improve grid dynamics, and support a sustainable energy future.

[5] The RoCoF, which is the slope or “gradient” of the change of frequency after a contingency, is a fundamental parameter to improve the grid reliability, hence the use of the GRADIENTS acronym.
[6] Garcia-Sanz, Mario. "Control Co-Design: an engineering game changer." *Advanced Control for Applications: Engineering and Industrial Systems* 1, no. 1 (2019): e18.
[7] Muir, A., and J. Lopatto. "Final report on the August 14, 2003 blackout in the United States and Canada: causes and recommendations." (2004).

2. TECHNICAL CHALLENGES

The GRADIENTS program aims to address several grid challenges associated with high penetration of IBRs (Figure 1).

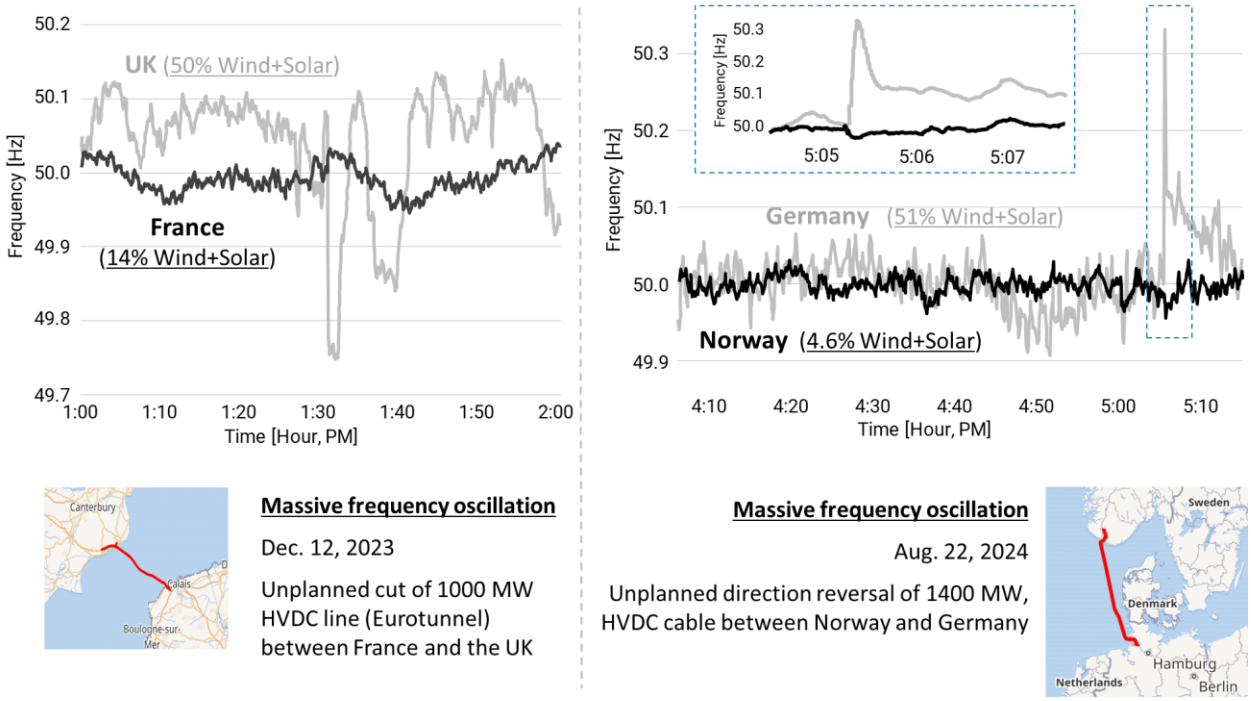

Figure 1. Electrical contingencies between (a) the United Kingdom and France and (b) Germany and Norway.[8,9] Larger frequency oscillations are observed in grids with higher IBR penetration.

- **Lack of inertia and damping to manage frequency fluctuation.** In conventional grids, large rotating synchronous generators provide inertia (associated to the kinetic energy stored in the rotors) and damping (related to the damper windings of the machines). Both aspects help reduce oscillations and stabilize the grid during disturbances.
    - IBRs lack rotating mass and damper windings, increasing the grid's susceptibility to frequency fluctuations and potential blackouts.
    - IBRs are typically designed to inject the maximum power harnessed from the renewable resource, usually wind or solar, using a grid-following mode. When the grid frequency deviates significantly from the setpoint (60 Hertz [Hz]), IBRs may limit their output or disconnect rather than contribute to frequency regulation, hindering primary control.[10]

[8] GridRadar, UCTE, UKTSOA (https://gridradar.net/en/blog/post/interconnector-trip-fr-uk).
[9] Hybrid Greentech. NordLink (https://montelnews.com/news/fcd122d7-8d87-4da8-a0ce-7b126c448ad1/norway-germany-cable-1-4-gw-returns-online-after-failure).
[10] Ahmadyar, Ahmad Shabir, Shariq Riaz, Gregor Verbič, Archie Chapman, and David J. Hill. "A framework for assessing renewable integration limits with respect to frequency performance." IEEE Transactions on Power Systems 33, no. 4 (2017): 4444-4453.

  - The existing control of IBRs follows a slow response to accommodate existing secondary control time-frames. While advanced control algorithms can emulate inertia and damping, their effectiveness depends on factors like inverter control type, virtual response speed, and coordination among IBRs. Poorly optimized or unsynchronized algorithms can result in slower or less effective responses.

- **Lack of integration of voltage regulation capabilities.** Voltage ride-through operation is critical to maintain the grid's voltage profile and prevent instability or equipment failure.[11] As grids become more distributed and increasingly rely on IBRs, grid coordination becomes essential to ensure resources operate together without conflict and load-share to meet demands.
  - IBRs can typically provide voltage regulation, but these capabilities are not yet integrated into the system-level operations yet.
  - Interoperability is also an issue, as the lack of standardized control systems and protocols means IBRs with different characteristics may not function seamlessly as a cohesive system.
  - During under-frequency and under-voltage events, traditional grid protection mechanisms, which are designed for synchronous generators, do not work as effectively in systems with high IBR penetration.[12,13]

- **Lack of effective market mechanisms.** Market design is increasing in complexity with high IBR penetration. New market mechanisms are needed to integrate renewable generation's variability and flexibility, including ancillary services markets for frequency regulation, voltage control, and reactive power support, which are traditionally provided inherently by synchronous generators. This will require new methodologies for cost-based dispatch and flexible grid operation, as well as the integration of these markets into tertiary control.

This program also aims to support the development of new protection schemes and decentralized, fast-acting relay systems that can dynamically react to faults and disturbances in real time. The grid must become more flexible to handle the variability and intermittency of renewable resources, which can cause difficulties in balancing supply and demand in real time.[14] GRADIENTS will support the development of advanced control co-design solutions based on three categories (Section I.D), along with more sophisticated market mechanisms to ensure grid reliability, stability, and efficiency in a world that is increasingly utilizing variable renewable

[11] Li, Chang, Yaqian Yang, Yijia Cao, Lei Wang, and Frede Blaabjerg. "Frequency and voltage stability analysis of grid-forming virtual synchronous generator attached to weak grid." IEEE Journal of Emerging and Selected Topics in Power Electronics 10, no. 3 (2020): 2662-2671.
[12] Delfino, Bruno, S. Massucco, A. Morini, P. Scalera, and F. Silvestro. "Implementation and comparison of different under frequency load-shedding schemes." In 2001 Power Engineering Society Summer Meeting. Conference Proceedings (Cat. No. 01CH37262), vol. 1, pp. 307-312. IEEE, 2001.
[13] Laghari, J. A., H. Mokhlis, A. H. A. Bakar, and Hasmaini Mohamad. "Application of computational intelligence techniques for load shedding in power systems: A review." *Energy conversion and management* (2013): 130-140.
[14] Li, Chang, Yaqian Yang, Yijia Cao, Lei Wang, and Frede Blaabjerg. "Frequency and voltage stability analysis of grid-forming virtual synchronous generator attached to weak grid." IEEE Journal of Emerging and Selected Topics in Power Electronics 10, no. 3 (2020): 2662-2671.

energy resources and experiencing dramatic increases in load growth.

GRADIENTS fills a specific technological gap to ensure that IBRs can provide new and improved grid services such as the control co-design of the system with virtual inertia, damping, frequency regulation, and control authority allocation in a distributed, decentralized manner.[15,16] The program complements broader efforts in decarbonizing the energy sector while also supporting the expansion of the grid.

3. PROGRAM MOTIVATION

The urgency to address energy leadership and grid resilience is becoming more critical, with governments, utilities, and corporations setting aggressive load growth requirements and decarbonization goals. These targets require large-scale integration of renewable energy systems, which must happen smoothly and without compromising grid reliability. Renewable energy sources like solar and wind are typically connected through inverter-based systems with grid-following control strategies.

Recent advances in power electronics, control algorithms, and communication technologies have opened new possibilities for real-time, decentralized control of IBRs, including new grid-forming control solutions. These technologies make it possible to create more intelligent, autonomous control systems capable of managing large fleets of distributed inverters, allowing IBRs to mimic and improve the stabilizing effects of traditional generators. Technologies like wide-area monitoring systems, fast communication networks, and smart sensors are now available to provide the real-time data needed for improved grid management.[17,18] Additionally, advances in machine learning and artificial intelligence can be leveraged to create predictive and adaptive control systems for IBRs.

As the occurrence and severity of extreme weather events such as hurricanes, wildfires, and heatwaves increase, grid resilience is becoming more critical. The 2021 Texas winter storm and recent California wildfires are stark reminders of the vulnerabilities of traditional grid systems and the importance of developing more flexible and resilient solutions.[19,20] A decentralized,

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[15] Cheng, Yunzhi, Lingling Fan, Jonathan Rose, Shun-Hsien Huang, John Schmall, Xiaoyu Wang, Xiaorong Xie et al. "Real-world subsynchronous oscillation events in power grids with high penetrations of inverter-based resources." *IEEE Transactions on Power Systems* 38, no. 1 (2022): 316-330.

[16] Markovic, Uros, Ognjen Stanojev, Petros Aristidou, Evangelos Vrettos, Duncan Callaway, and Gabriela Hug. "Understanding small-signal stability of low-inertia systems." IEEE Transactions on Power Systems 36, no. 5 (2021): 3997-4017.

[17] Hong, Qiteng, Mazaher Karimi, Mingyu Sun, Seán Norris, Oleg Bagleybter, Douglas Wilson, Ibrahim F. Abdulhadi, Vladimir Terzija, Ben Marshall, and Campbell D. Booth. "Design and validation of a wide area monitoring and control system for fast frequency response." IEEE Transactions on Smart Grid 11, no. 4 (2020): 3394-3404.

[18] Peng, Zefeng, Qiao Peng, Yingmin Zhang, Huachun Han, Yue Yin, and Tianqi Liu. "Online inertia allocation for grid-connected renewable energy systems based on generic ASF model under frequency nadir constraint." IEEE Transactions on Power Systems 39, no. 1 (2023): 1615-1627.

[19] https://www.ercot.com/news/february2021.

[20] https://www.fire.ca.gov/incidents.

inverter-based grid with robust real-time control can improve resilience by ensuring that local resources can operate autonomously or in coordination with the larger grid even in the face of widespread grid failures.

The GRADIENTS program transforms and reimagines the role of IBRs. By enhancing the intelligence of IBRs, the program seeks to transform existing challenges into assets that strengthen system stability, reliability, and resilience. This involves co-designing IBRs with storage systems and embedded autonomous decision making, developing intelligent and cooperative relay technologies for fault-tolerant protection, and integrating these capabilities into advanced wide-area control tools. The GRADIENTS program disrupts the traditional methodology of prioritizing optimal power output and retroactively addresses reliability issues without costly capital expenditures and increased reliance on synchronous generators. In doing so, the program leverages the growth of renewables to enhance grid reliability and empowers renewables to actively participate in emerging ancillary services markets, supporting the evolution of a more flexible and sustainable energy grid.

4. TECHNICAL DESCRIPTION

The key equation in power system stability analysis is the rotational inertia equation (swing equation), which describes the effect of the imbalance between the electromagnetic output torque and the mechanical input torque of individual rotating machines.[21] In stability studies for the power grid, the mechanical characteristics of the synchronous generator are represented by parameters such as the moment of inertia and damping. The swing equation, described by second-order dynamics of a synchronous generator, can be represented by the transfer function $P(s)$ between the angular position (θ) of the rotor and the difference between the mechanical input torque (T_m) supplied by the prime mover and the electrical output torque (T_e) of the generator (see equation 1, where J is the moment of inertia of the rotor in [kgm^2], D is the damping coefficient [*Nms/rad*], and K is the synchronizing power coefficient [*Nm/rad*]). The kinetic energy ($E_{stored} = E_{kinetic}$) in a synchronous generator is stored in its rotating mass (rotor) and plays a critical role in power system dynamics and stability. It is calculated based on the moment of inertia (J) and the angular speed of the rotor ($\omega = d\theta/dt$) (see equation 2). The inertia constant (H) is commonly used to characterize the stored energy in a synchronous generator, representing the time the generator can supply rated power (P_{rated}) from its stored kinetic energy, which is typically a few seconds (see equation 3).

$$\frac{\theta(s)}{T_m(s)-T_e(s)} = P(s) = \frac{1}{J\,s^2+D\,s+K} \quad (1)$$

$$E_{stored} = E_{kinetic} = 0.5\,J\,\omega^2 \;\; [Jul] \quad (2)$$

$$H = \frac{E_{stored}}{P_{rated}} \;\; [seconds] \quad (3)$$

[21] Prabha Kundur, "Power System Stability and Control", McGraw-Hill, New York, 1994.

These two characteristics (inertia and damping) help stabilize the grid frequency during sudden disturbances or power imbalances. IBRs, on the other hand, do not have a rotating mass or damper windings and typically do not provide these stabilizing effects, making the grid more susceptible to frequency fluctuations and potential blackouts. GRADIENTS tackles stability challenges in power grids with high penetration of IBRs by enhancing both inertia (energy buffer) and damping (control capabilities).

As an example, Figure 2 shows the simulation of the swing equation of a synchronous machine, modeled as a second order system, with three cases that represent various inertia and damping parameters. The figure shows that increasing inertia (J) improves M1 (reducing the normalized RoCoF and nadir) but deteriorates M2 (increasing the normalized decay ratio and recovery time). Improving both dynamic characteristics requires not only more inertia (J), but also more damping (D), as is shown in Case 3. More information about the M1 and M2 variables can be found in Section I.E.1.

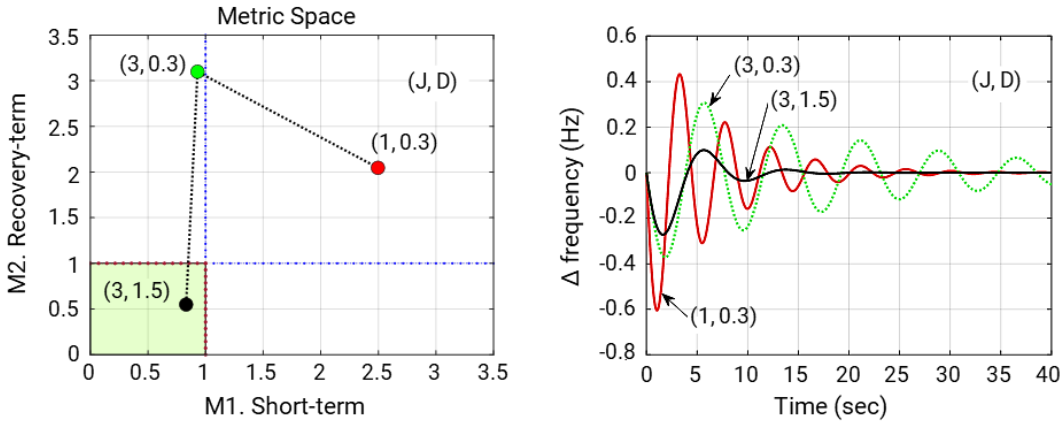


Figure 2. Results of three cases: Case 1 (J = 1, D = 0.3), Case 2 (J = 3, D = 0.3), and Case 3 (J = 3, D = 1.5). Figure (a) represents M1, or short-term metric (normalized RoCoF and nadir), versus M2, or recovery-term metric (normalized decay ratio and recovery time), and Figure (b) shows the frequency oscillation over time with these three cases.

D. PROGRAM OBJECTIVES

The overall objective of the GRADIENTS program is to develop innovative and disruptive technologies that enable real-time power grid management via flexible renewable generation, intelligent and automatic relays, and system-wide real-time control solutions. The program is composed of three categories (Flexible Renewable Generation, Intelligent Automatic Relays, and Wide Area RT-CCD) that, taken together, can address ARPA-E's statutory goals to improve the resilience, reliability, and security of infrastructure to produce, deliver, and store energy; reduce energy-related emissions; and improve the energy efficiency of all economic sectors.

The GRADIENTS program aims to increase grid stability, improve resilience (specifically, the SAIDI and SAIFI metrics in the U.S.), and provide expanded and advanced grid controls that do not exist today.[22]

The intended impacts of GRADIENTS are illustrated in Figure 3, demonstrating potential program outcomes.

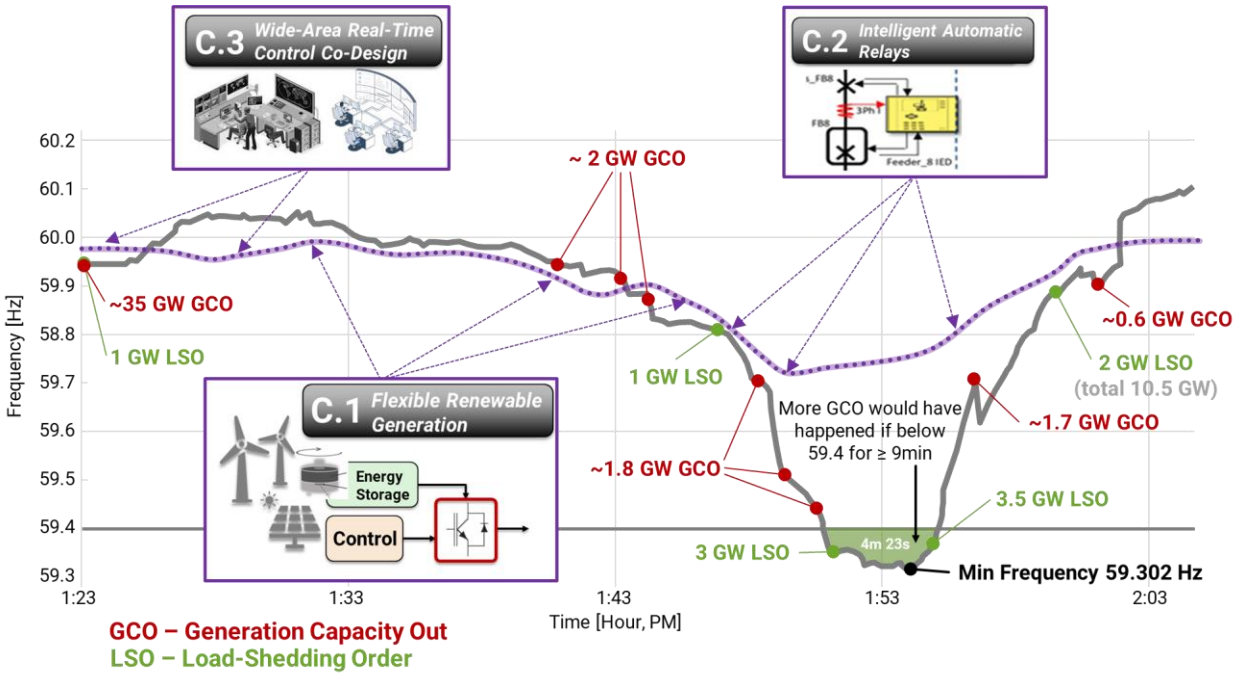


Figure 3. Illustration of the intended impacts of GRADIENTS on achieving system stability, with a focus on mitigating issues like those experienced during the 2021 Texas blackout.[23] The gray solid line shows the frequency oscillation of the Texas blackout. The purple dashed line shows the intended results after applying the potential outcomes of the three program categories (here C.1, C.2, and C.3).

It is also critical that the U.S. maintains a technological lead in developing and deploying advanced energy technologies. Other countries have started to experiment with inertia markets and manage IBR penetration, and a successful GRADIENTS program will ensure that the U.S. does not fall behind in developing technologies to enhance both our security and leadership in energy.

[22] The System Average Interruption Duration Index (SAIDI) measures the total duration (in hours) an average customer experiences non-momentary power interruptions in a one-year period. The System Average Interruption Frequency Index (SAIFI) measures the frequency of interruptions in number of occurrences.

[23] Busby, Joshua W., Baker, Kyri, Bazilian, Morgan D., et. al., "Cascading risks: Understanding the 2021 winter blackout in Texas", Energy Research & Social Science, Volume 77, https://doi.org/10.1016/j.erss.2021.102106.

E. TECHNICAL CATEGORIES OF INTEREST

The GRADIENTS program is comprised of three technical categories to support the program objectives outlined in Section I.C. Those categories are depicted in Figure 4.

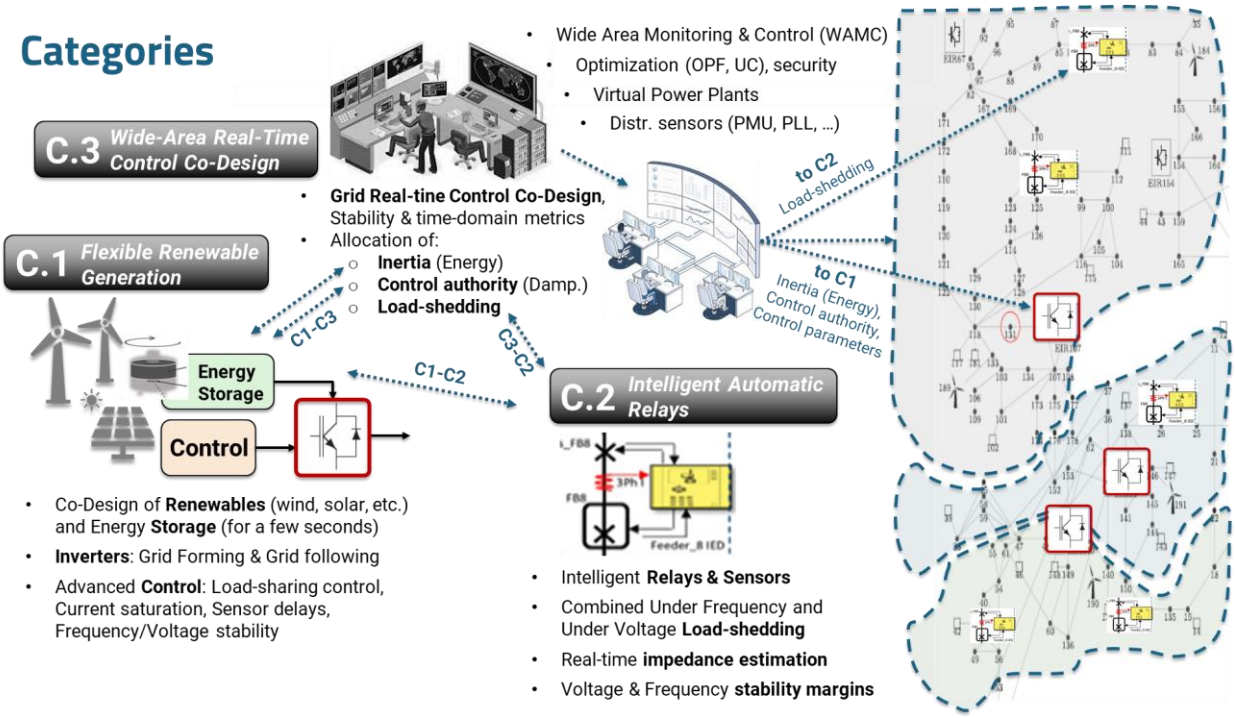


Figure 4. GRADIENTS Program Categories.

Teams are encouraged to work together to improve the efficacy of GRADIENTS. In the future, once the new solutions are deployed in the grid, it is expected that Category 3 technologies that continuously control co-design in real-time (RT-CCD) will be sending inertia and damping allocation commands to systems developed by Category 1, and load-shedding allocation commands to systems developed by Category 2, depending on normal and emergency operations respectively. For that reason, although a collaboration between teams is not required, it is highly encouraged. Applicants can submit to Category 1, Category 2, Category 3, or any combination thereof.

1. CATEGORY 1: FLEXIBLE RENEWABLE GENERATION

Creating flexible renewable generation nodes in the grid is a novel approach that requires control co-design of renewables and storage and involves embedding smart, autonomous decision-making capabilities directly into the system. These intelligent nodes could be placed at strategic points in the grid. Each node would be capable of making local decisions based on real-time data (e.g., power flow, voltage, frequency, and generation availability) and then coordinating with other nodes in a distributed manner to optimize the grid's overall performance.

Real-time automatic control of IBRs with short-term energy storage is crucial to integrating renewable energy sources. Projects under this category shall co-design intelligent nodes consisting of renewables (wind, solar, etc.), energy storage, flexible inverters with both grid-forming and grid-following capabilities, and real-time advanced control/coordination solutions.[24] IBRs shall be flexible, seamlessly transitioning from grid-following to grid-forming and vice-versa, depending on the grid state and the need for grid support in real time.

Projects in this category shall encourage improved power electronics co-design solutions that include some form of storage (battery less short-term energy storage solutions for a few seconds at rated power), in addition to advanced control solutions. Category 1 projects shall include experiments that analyze the performance of the intelligent renewable generators under a set of major potential contingencies and different topology scenarios.

Projects in Category 1 shall address the following critical components in their submission and discuss how these will be designed and experimentally verified during the project lifetime:

1. Flexible grid-forming and grid-following inverters and the ability to seamlessly transition between these two modes following the self-initiated command or a system/grid operator request (n either case justify the decision-making process/algorithm);
2. Design, implementation, and testing of battery-less short-term energy storage (a few seconds at rated power);
3. Propose advanced control solutions to coordinate three or more grid-forming inverters working in parallel while controlling the frequency (load-sharing problem);
4. Analyze the effects of current saturation on system stability and propose solutions to mitigate the instability;
5. Analyze the synchronization challenges under different contingencies and propose solutions to mitigate ill-behaved operation under these conditions;
6. Propose a high-performance control framework that will enhance the grid's capability to quickly respond to real-time data, improve overall system robustness, and prevent instabilities due to communication delays or system failures; and
7. IBR technologies capable of supporting voltage and frequency ride-through for unbalanced 3-phase faults, including line to ground faults.

2. CATEGORY 2: INTELLIGENT AUTOMATIC RELAYS

Projects under this category shall develop new fast-acting relays with smart sensors, automatic contingency prediction, impedance estimation, stability assessment, and under-frequency/under-voltage load-shedding capabilities for emergency operation, as well as other new and improved functionalities.

[24] Rathnayake, Dayan B., Milad Akrami, Chitaranjan Phurailatpam, Si Phu Me, Sajjad Hadavi, Gamini Jayasinghe, Sasan Zabihi, and Behrooz Bahrani. "Grid forming inverter modeling, control, and applications." IEEE Access 9 (2021): 114781-114807.

Specifically, in this program ARPA-E seeks innovative solutions that could improve the conventional power system relays. Submissions could focus on one or more functionalities listed below:

1. Relays, their algorithms, actuation systems, and sensors for *in-situ* frequency-domain system/admittance identification aiding on-line stability monitoring, component characterization for adaptive control, system health monitoring, and system/component model creation with included situational awareness. The power electronics actuators may be needed to be added to perform perturbation injection capability of such relays.
2. Relays, their algorithms, and sensors that can detect incipient fault signatures, the location, and fault type, and isolate the affected areas faster than state-of-the-art. Overcurrent, overvoltage, and combined under-frequency/over-frequency and under-voltage/over-voltage capabilities would all be of interest.
3. Relays, their algorithms, and sensors that can quickly respond to load/source imbalances, frequency fluctuations, intermittency, etc., and feature advanced load-shedding capabilities not currently present in the state-of-the-art relays.
4. Relays, their algorithms, and sensors for automatic contingency prediction.
5. Fast, reliable communication and Supervisory Control and Data Acquisition (SCADA) technologies for faster and more reliable protection coordination.

The experimental verification for Category 2 projects shall include operation/reaction under a set of major potential contingencies and different scenarios or use cases.

3. CATEGORY 3: WIDE-AREA RT-CCD

The grid changes continuously due to the variation of loads, renewable generation, topology, line saturation and contingencies. As a result, algorithms developed by Category 3 projects will select in real time the flexible renewable generators (Category 1) that will provide inertia and damping to the grid, and the intelligent relays (Category 2) that will provide load-shedding capabilities. Note that these inertia, damping, and load-shedding allocation capabilities depend on the state of the grid, including line saturation, renewable resources, and network topology among other factors.

Projects under Category 3 shall develop new optimization control algorithms for energy (inertia) allocation, control authority (damping) allocation, and load-shedding allocation in the grid. Leveraging information from Category 1 and Category 2, grid operators can take a more holistic approach to resolving scenarios for normal and emergency operation while optimizing the grid and its generation assets.

This category seeks submissions that address critical challenges in advancing power grid stability and resilience through innovative tools and testing platforms. The projects shall develop advanced operational tools and their validation.

Projects under Category 3 shall emphasize the computational efficiency, scalability, and adaptability of the tools to address:

1. RT-CCD of the grid, allocating energy and control authority capabilities across the grid for normal operation, and allocating load-shedding capabilities for emergency operation;
2. Grid next-generation optimization and unit commitment algorithms enhancing grid stability by effectively managing contingencies;
3. Proactive operational strategies requiring minimal interventions under all foreseeable contingencies while providing pre-approved, contingency-specific control solutions when necessary;
4. Control solutions for reconfiguration of renewable generators between grid-forming and grid-following inverters, including grid real-time topology changes (line switching);
5. Design of emulation/validation test system representing a complex power grid (replicates grid dynamics, integrates renewable energy sources, and addresses a diverse range of realistic contingency scenarios) that allows real-time validation for stability of operational decisions and the effectiveness of pre-approved control solutions for multiple realistic contingencies; and
6. Scalability and adaptability of solutions to interact with physical emulation/validation systems.

Category 3 seeks to advance grid resilience through technologies that optimize real-time operations, preemptively address contingency risks, and support renewable energy integration. The focus is on solutions that align with federal goals to enhance grid reliability while fostering innovation in both software tools and physical validation systems. Applicants should present their ideas in a way that highlights their relevance to these priorities while safeguarding proprietary information.

Applicants are encouraged to partner with system integrators, utilities, and/or independent system operators (ISOs) to use real system data for their designs. The GRADIENTS program awardees will treat their partner system data as confidential. To the extent such data contains or constitutes Critical Energy/Electric Infrastructure Information (CEII)[25], that data will be maintained according to all applicable requirements and established industry best practices.

[25] See 18 C.F.R. § 388.113(c). *Critical electric infrastructure information* means information related to critical electric infrastructure, or proposed critical electrical infrastructure, generated by or provided to the Federal Energy Regulatory Commission or other Federal agency other than classified national security information, that is designated as critical electric infrastructure information by the Commission or the Secretary of the Department of Energy pursuant to section 215A(d) of the Federal Power Act. Such term includes information that qualifies as critical energy infrastructure information under the Commission's regulations. *Critical energy infrastructure information* means specific engineering, vulnerability, or detailed design information about proposed or existing critical infrastructure that:

F. TECHNICAL PERFORMANCE TARGETS

This section describes the performance metrics and targets for the GRADIENTS program. ARPA-E expects project awardees to achieve these targets. Each Category includes several specific dynamic and techno-economic metrics according to the following definitions.

1. DYNAMIC METRICS

Several key variables are defined below and visualized in Figure 5.

- **RoCoF** is the slope, or gradient, of the frequency after the contingency, in absolute value. [Hz/second]. This is a critical factor in ensuring frequency security, particularly in power systems with low inertia.
- **Reference frequency** is the grid frequency (60 Hz in the US, 50 Hz in Europe), which is represented by f_r in Hz, or $\omega_r = 2\,\pi\,f_r$ in rad/second.
- **Deadband** *(d)* is the interval around the reference frequency where the system operates in steady-state without the need for corrective action. [mHz]
- **Nadir (or zenith)** is the absolute minimum (or maximum) value of the frequency after a contingency. [Hz]
- **Decay ratio (for N)** is the ratio a_N/a_0, where a_N is the magnitude of the N^{th} peak (or trough) in frequency after the nadir (or zenith), and a_0 is the nadir (or zenith). The magnitudes a_N are measured relative to the settled frequency. [nondimensional].
- **Recovery time** (t_r) is the time between the contingency and the instant when the system enters in the deadband *d* around the reference frequency f_r and does not leave it again due to that contingency. [seconds]
- **Settled frequency** is the average value of the frequency after reaching steady-state conditions, which is represented by f_s in Hz, or $\omega_s = 2\,\pi\,f_s$ in rad/second.
- **Settling time** (t_s) is the time between the contingency and the instant when the system enters in the deadband *d* around the settled frequency f_s and does not leave it again due to that contingency. [seconds]
- **Load disturbance** *(Δp)* measures the contingency, typically as a change in the load, in per unit (p.u.).

(i) Relates details about the production, generation, transportation, transmission, or distribution of energy;
(ii) Could be useful to a person in planning an attack on critical infrastructure;
(iii) Is exempt from mandatory disclosure under the Freedom of Information Act, 5 U.S.C. 552; and
(iv) Does not simply give the general location of the critical infrastructure.

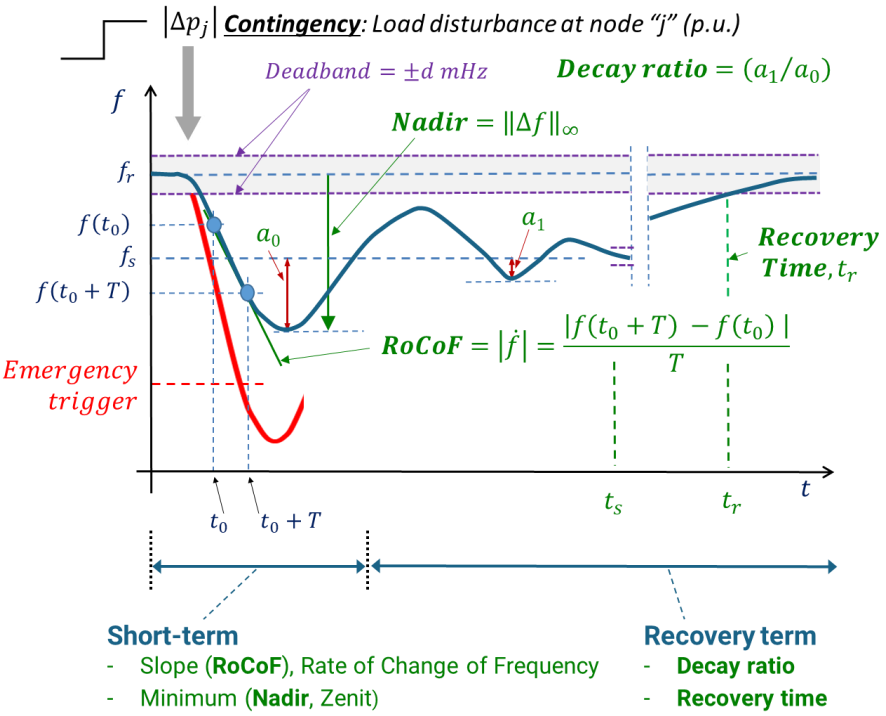


Figure 5. Dynamic metrics.

Table 1 defines the technical performance metrics based on these variables. The subscript "SG" refers to real tests or experiments where all the generators are synchronous generators (SGs). The subscript "test" refers to real tests or experiments where the system combines SGs and IBRs with the new solutions proposed in the project. The left column provides absolute objectives, where L_{RoCoF}, L_{Nadir}, $L_{DecayRatioN}$, $L_{RecTime}$ and $L_{SetTime}$ are the maximum permissible values of the RoCoF, Nadir, Decay ratio, Recovery time and Settling time, respectively. The right column provides relative objectives, where Δ_{RoCoF}, Δ_{Nadir}, $\Delta_{DecayRatioN}$, $\Delta_{RecTime}$, and $\Delta_{SetTime}$ are the ratios of each metric for the cases of 70%, 80% and 90% of IBR penetration versus only synchronous generators. Numerical values $L_{(\cdot)}$and $\Delta_{(\cdot)}$are prescribed later as the absolute and relative design targets for each metric.

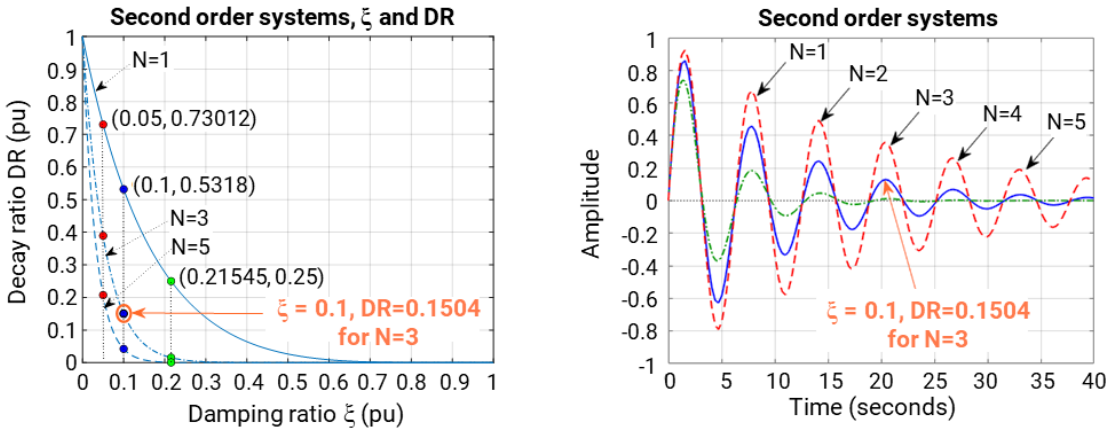
Table 1. Definition of dynamic metrics.[26]

Case (i). Test absolute value		Case (ii). Relative to all-SG case	
1.i	$RoCoF_{test} \leq L_{RoCoF}$	1.ii	$\frac{RoCoF_{test}}{RoCoF_{SG}} \leq \Delta_{RoCoF}$
2.i	$Nadir_{test} \leq L_{Nadir}$	2.ii	$\frac{Nadir_{test}}{Nadir_{SG}} \leq \Delta_{Nadir}$
3.i	$DecayRatioN_{test} \leq L_{DecayRatioN}$	3.ii	$\frac{DecayRatioN_{test}}{DecayRatioN_{SG}} \leq \Delta_{DecayRatioN}$
4.i	$RecTime_{test} \leq L_{RecTime}$	4.ii	$\frac{RecTime_{test}}{RecTime_{SG}} \leq \Delta_{RecTime}$
	$SetTime_{test} \leq L_{SetTime}$		$\frac{SetTime_{test}}{SetTime_{SG}} \leq \Delta_{SetTime}$

The swing equation of a synchronous machine, described in Section I.B.3, can be also expressed as equation 4, where ω_n is the natural frequency, and ξ the damping ratio. The relationship between the damping ratio ξ and the decay ratio *DR* for the amplitude *N* is described in equation 5 and Figure 6.

$$P(s) = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} \quad (4)$$

$$DR(for\ N, in\ p.u.) = \frac{Amplitude_{swing\_N}}{Amplitude_{Nadir\ or\ Zenith}} = e^{-2\pi\xi N / \sqrt{1-\xi^2}} \quad (5)$$



(a) (b)

Figure 6. Simulation of a second order system, like the swing equation of a synchronous machine. (a) Representation of the relationship between damping ratio (ξ) and decay ratio (DR for N), and (b) representation of the frequency oscillation over time with three damping ratios: dashed-line ξ = 0.05, solid-line ξ = 0.1, dashed-dotted-line ξ = 0.21545 [or DR (for N=1) = 25% in Ziegler-Nichols].

[26] ARPA-E expects awardees to achieve a certain level of performance on the grid and make sure the performance is better than just using synchronous generators (SGs). Absolute metrics (Cases i) covers the first objective, and Relative metrics (Cases ii) covers the second objective. Without both metrics, one could be true but not the other.

2. TECHNO-ECONOMIC METRIC

The techno-economic metric is based on the comparison of two designs. Both designs must achieve the same level of grid stability and controllability requested in the GRADIENTS program. The designs are:

- **Design Before** (superscript B): This is the system that achieves the dynamic metrics of the program with pre-existing technologies (synchronous machines, synchronous condensers, batteries, conventional ancillary services market, etc.); and
- **Design After** (superscript A): This is the system that achieves the dynamic metrics of the program after applying the new solutions developed with the GRADIENTS program (new designs in Categories 1, 2 and 3, a market with new defined ancillary services, etc.).

For the original systems (B), the profit margin per year, $Profit^{B}_{Margin}$, is,

$$Profit^{B}_{Margin} = \frac{R^{B}-C^{B}}{R^{B}} = 1 - \frac{C^{B}}{R^{B}} \quad (6)$$

where R^B and C^B are the annual revenue and the annual cost of the entire system with pre-existing technologies. Similarly, for the new systems (A), the profit margin per year, $Profit^{A}_{Margin}$, is,

$$Profit^{A}_{Margin} = \frac{R^{A}-C^{A}}{R^{A}} = 1 - \frac{C^{A}}{R^{A}} \quad (7)$$

where R^A and C^A are the annual revenue and the annual cost of the entire system after applying the new solutions found with the GRADIENTS program respectively. With that, a first approximation of the techno-economic condition is that the new system (A) gives a profit margin greater than the original system (B), or,

$$Profit^{A}_{Margin} > Profit^{B}_{Margin} \quad (8)$$

Combining equations 6 and 8, we have,

$$1 - \frac{C^{\mathrm{A}}}{R^{\mathrm{A}}} > 1 - \frac{C^{B}}{R^{B}} \quad (9)$$

By rearranging the terms σ is defined as the synergy margin[27], and equation 9 written accordingly, so that,

$$\sigma = \frac{\left(\frac{C^A}{C^B}\right)}{\left(\frac{R^A}{R^B}\right)} < 1 \tag{10}$$

Looking for economically attractive solutions, the techno-economic metric for the GRADIENTS program limits the synergy margin to σ_{lim}, or

$$\sigma = \frac{\left(\frac{C^A}{C^B}\right)}{\left(\frac{R^A}{R^B}\right)} \leq \sigma_{lim} \tag{11}$$

As an example, the synergy margin can be applied to different energy systems, proposing a two-dimensional metric space, where the horizontal axis is the LCOE factor, $\sigma_L = \left(\frac{C^A}{C^B}\right)$, and the vertical axis is the revenue or price factor, $\sigma_p = \left(\frac{R^A}{R^B}\right)$. The original design (B) is located at the point (1,1), and the new design (A) should be above the line σ_{lim} = 0.8. See Figure 7.

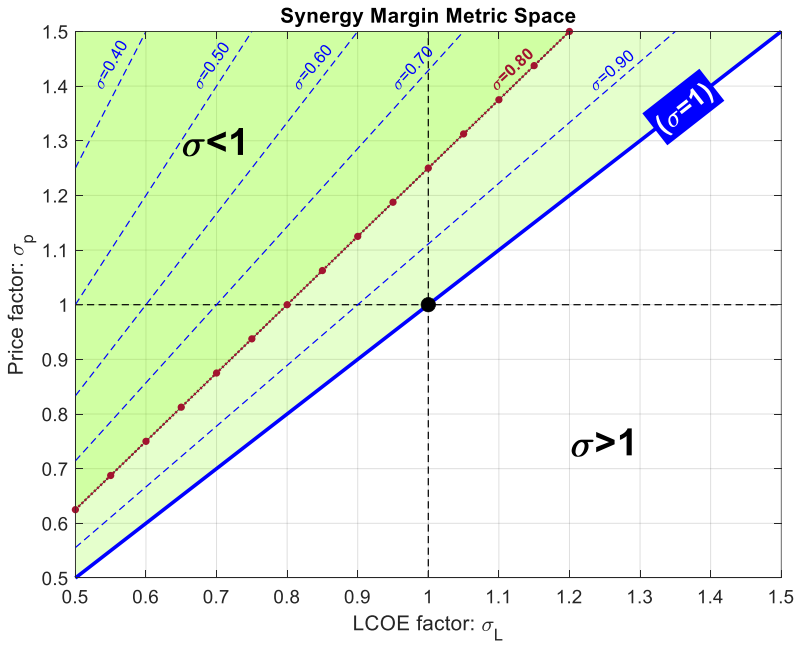


Figure 7. Techno-economic metric space.[24]

[27] Garcia-Sanz, Mario. "Hybrid Energy Systems: Synergy Margin and Control Co-Design." *Advanced Control for Applications: Engineering and Industrial Systems* (2024): e238. https://doi.org/10.1002/adc2.238

This profit margin criterion, $\sigma < 1$, is equivalent to the condition that the profit of Design A exceeds the profit of Design B when the relative revenue, $\frac{R^A - R^B}{R^B}$, increase from the investment is greater than the relative cost increase, $\frac{C^A - C^B}{C^B}$. This techno-economic metric is applied to Categories 1 and 3 below.

3. CATEGORY 1: FLEXIBLE RENEWABLE GENERATION

Projects under Category 1 shall achieve the targets defined in Table 2, for the dynamic and techno-economic metrics previously defined above.

Table 2. Targets for Category 1.

Normal Operation, Dynamic Metrics			
Case (i)		**Case (ii)**	
1.i	$L_{RoCoF} = 0.4\ Hz/sec$	1.ii	$\Delta_{RoCoF} = 0.8$
2.i	$L_{Nadir} = 0.4\ Hz$	2.ii	$\Delta_{Nadir} = 0.8$
3.i	$L_{DecayRatioN} = 0.15$ $for\ N = 3$	3.ii	$\Delta_{DecayRatioN} = 0.8$ $for\ N = 3$
4.i	$L_{RecTime} = 15\ sec$	4.ii	$\Delta_{RecTime} = 0.8$
Techno-economic Metric			
$\sigma_{lim} = 0.8$			

Additionally:

1. Voltage shall meet the specification limits defined by IEEE Std 1547-2018 in all cases.
2. Current distortion shall meet the specification limits defined by IEEE Std 1547-2018, 7.3 in all cases.
3. Tests and experiments under this category shall include at least three IBRs working in parallel, and under different grid conditions with 70%, 80% and 90% of System Non-Synchronous Penetration.
4. Validation of IBR operations under all fault scenarios in an integrated Transmission and Distribution model.
5. Tests and experiments under this category shall include N-1 contingencies in each generator, with values: $0 \leq |\Delta p|_{p.u.} \leq 1$
6. The deadband is $d = \pm 36$ mHz.
7. The under-frequency load-shedding (UFLS) system triggers at 59.0 Hz.

The validation of the new solutions proposed in Category 1 shall be conducted in real experiments on microgrids, cooperatives, or municipal grid segments. The frequency will be measured at a representative point.

4. CATEGORY 2: INTELLIGENT AUTOMATIC RELAYS

Projects under Category 2 shall achieve the targets defined in Table 3, for the dynamic and techno-economic metrics previously defined above.

Table 3. Targets for Category 2

Emergency Operation, Dynamic Metrics			
Case (i)		Case (ii)	
2.i	$L_{Nadir} = 1.5\ Hz$	2.ii	$\Delta_{Nadir} = 0.8$
3.i	$L_{DecayRatioN} = 0.15$ $for\ N = 3$	3.ii	$\Delta_{DecayRatioN} = 0.8$ $for\ N = 3$
4.i	$L_{SetTime} = 60\ sec$	4.ii	$\Delta_{SetTime} = 0.8$

Additionally:

1. Voltage shall meet the specification limits defined by IEEE Std 1547-2018 in all cases.
2. Current distortion shall meet the specification limits defined by IEEE Std 1547-2018, 7.3 in all cases.
3. Interoperability and protection coordination according to IEC-61850.
4. Tests and experiments under this category shall include at least three IBRs working in parallel, and under different grid conditions with 70%, 80% and 90% of system non-synchronous penetration.
5. Tests and experiments under this category shall include N-1 contingencies in each generator, with values: $0 \leq |\Delta p|_{p.u.} \leq 1$
6. The deadband is $d = \pm 36$ mHz.
7. The UFLS system triggers at 59.0 Hz.

The validation of the new solutions proposed in Category 2 shall be conducted in real experiments on microgrids, cooperatives, or municipal grid segments. The frequency shall be measured at a representative point.

5. CATEGORY 3: WIDE-AREA RT-CCD

Projects under Category 3 shall achieve the targets defined in Tables 4 and 5, for the dynamic and techno-economic metrics previously defined above. The performance of Category 3 is

evaluated under normal and emergency conditions in accordance with the metrics of Categories 1 and 2, respectively.

Table 4. Targets for Category 3, normal operation

Normal Operation, Dynamic Metrics			
Case (i)		**Case (ii)**	
1.i	$L_{RoCoF} = 0.4\ Hz/sec$	1.ii	$\Delta_{RoCoF} = 0.8$
2.i	$L_{Nadir} = 0.4\ Hz$	2.ii	$\Delta_{Nadir} = 0.8$
3.i	$L_{DecayRatioN} = 0.15$ $for\ N = 3$	3.ii	$\Delta_{DecayRatioN} = 0.8$ $for\ N = 3$
4.i	$L_{RecTime} = 15\ sec$	4.ii	$\Delta_{RecTime} = 0.8$
Techno-economic Metric			
$\sigma_{lim} = 0.7$			

Table 5. Targets for Category 3, emergency operation

Emergency Operation, Dynamic Metrics			
Case (i)		**Case (ii)**	
2.i	$L_{Nadir} = 1.5\ Hz$	2.ii	$\Delta_{Nadir} = 0.8$
3.i	$L_{DecayRatioN} = 0.15$ $for\ N = 3$	3.ii	$\Delta_{DecayRatioN} = 0.8$ $for\ N = 3$
4.i	$L_{SetTime} = 60\ sec$	4.ii	$\Delta_{SetTime} = 0.8$

Additionally:

1. Voltage shall meet the specification limits defined by IEEE Std 1547-2018 in all cases.
2. Current distortion shall meet the specification limits defined by IEEE Std 1547-2018, 7.3 in all cases.
3. Tests and experiments under this category shall include different grid conditions with 70%, 80% and 90% of system non-synchronous penetration.
4. Tests and experiments under this category shall include N-1 contingencies in each generator, with values: $0 \leq |\Delta p|_{p.u.} \leq 1$
5. The deadband is $d = \pm 36$ mHz.
6. The UFLS system triggers at 59.0 Hz.

If a submission intends to create a new revenue stream such as additional ancillary service, the referenced costs of contingencies are evaluated against value of lost load price.

The validation of the new solutions proposed in Category 3 shall be conducted in emulation. In this category the frequency will be the frequency of the center of inertia, which represents the global frequency dynamic of the power grid.[28]

G. TECHNOLOGY TO MARKET CONSIDERATIONS

As an impact-focused agency, ARPA-E is interested in not only supporting the development of transformative technologies, but also enabling and facilitating their commercialization. With over $70 billion per year in capital investment by U.S. electric transmission and distribution utilities, there is a significant commercial opportunity for grid hardware and software that dramatically improves performance. Grid expansion will become a major segment of the market as the nation progresses towards 'Grid 3.0'.[29] However, development, testing, regulatory approval, and deployment of new power technologies for the grid takes time.

Submissions should provide an assessment of the impact enabled by the proposed technology including discussions on how the proposed technology solution increases safety, reliability, resilience of the grid, and estimated system-level cost benefits if implemented. It is expected that applicants consider that the technology they are proposing is a cost-effective approach to currently available solutions in the market. As part of the technology-to-market (T2M) strategy, selected submissions are expected to continue these types of efforts for the entire period of performance.

To facilitate success in these areas, ARPA-E strongly encourages early and consistent engagement with regional system operators, utilities, system integrators, end users, and relevant stakeholders. ARPA-E also requires the projects of this program to include an advisory board with members that can provide additional guidance and development of these technologies and provide pathways for validation of the developed technologies during the period of performance. Partnering with existing manufacturers and system networks is encouraged to streamline supply chain development and identify future sales and servicing capabilities. Outreach to end users, including grid equipment providers, system integrators, system operators, cooperatives, independent microgrids, and utilities, is also encouraged as Applicants develop their T2M strategy and plans.

H. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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."[30] Accordingly, ARPA-E is substantially involved in the direction of projects from

[28] Milano,F. *Rotor speed-free estimation of the frequency of the center of inertia*. IEEE Trans. Power Syst., vol. 33, no. 1, pp. 1153–1155, Jan. 2018.
[29] https://smartgrid.ieee.org/about-ieee-smart-grid/history/news/a-summary-of-the-grid-3-0-workshop
[30] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- Project Teams must adhere to ARPA-E's agency-specific and programmatic requirements.
- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- 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 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 Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Grants 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. §§ 200.339 – 200.343.
- ARPA-E may provide guidance and/or assistance to the Recipient to accelerate the commercialization of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits[31] to provide mentoring and networking opportunities for Recipients. ARPA-E may also organize and sponsor events to educate Recipients about key barriers to the commercialization 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 commercialization of ARPA-E-funded technologies.

I. FUNDING RESTRICTIONS

1. ALLOWABLE COSTS

All expenditures must be allowable, allocable, and reasonable in accordance with the applicable Federal cost principles. Pursuant to 2 C.F.R. § 910.352, the cost principles in the Federal Acquisition Regulations (48 C.F.R. Part 31.2) apply to for-profit entities. The cost principles contained in 2 C.F.R. Part 200; Subpart E apply to all entities other than for-profits.

[31] "Nonprofits" or "nonprofit organizations" has the meaning set forth at 2 C.F.R. § 200.70.

2. PRE-AWARD COSTS

ARPA-E will not reimburse any pre-award costs incurred by Applicants before they are selected for award negotiations. Please refer to Section VI.A of the NOFO for guidance on award notices.

Upon selection for award negotiations, Applicants may incur pre-award costs at their own risk, consistent with the requirements in 2 C.F.R. Part 200, as modified by 2 C.F.R. Part 910, and other Federal laws and regulations. All submitted budgets are subject to change and are typically reworked during award negotiations. ARPA-E is under no obligation to reimburse pre-award costs if, for any reason, the Applicant does not receive an award or the award is made for a lesser amount than the Applicant expected, or if the costs incurred are not allowable, allocable, or reasonable.

3. PATENT COSTS

For Subject Inventions disclosed to DOE under an award, ARPA-E will reimburse the Recipient – in addition to allowable costs associated with Subject Invention disclosures - up to $30,000 of expenditures for filing and prosecution of United States patent applications, including international applications (PCT application) submitted to the United States Patent and Trademark Office (USPTO).

The Recipient may request a waiver of the $30,000 cap. Note that patent costs are considered to be Technology Transfer & Outreach (TT&O) costs (see Section I.I.8 of the NOFO below) and should be requested as such.

4. CONSTRUCTION

ARPA-E generally does not fund projects that involve major construction. Recipients are required to obtain written authorization from the Grants Officer before incurring any major construction costs.

5. FOREIGN TRAVEL

ARPA-E generally does not fund projects that involve foreign travel. Recipients are required to obtain written authorization from the ARPA-E Program Director before incurring any foreign travel costs and provide trip reports with their reimbursement requests.

6. PERFORMANCE OF WORK IN THE UNITED STATES

ARPA-E requires all work under ARPA-E funding agreements to be performed in the United States. However, Applicants may request a waiver of this requirement where their project would materially benefit from, or otherwise requires, certain work to be performed overseas.

Applicants seeking this waiver must include an explicit request in the Business Assurances & Disclosures Form. Such waivers are granted where ARPA-E determines there is a demonstrated need.

7. PURCHASE OF NEW EQUIPMENT

All equipment purchased under ARPA-E funding agreements must be made or manufactured in the United States, to the maximum extent practicable. This requirement does not apply to used or leased equipment. The Recipients are required to notify the ARPA-E Grants Officer reasonably in advance of purchasing any equipment that is not made or manufactured in the United States with a total acquisition cost of $250,000 or more. Purchases of foreign equipment with a total acquisition cost of $1,000,000 or more require the approval of the Head of Contracting Activity (HCA). The ARPA-E Grants Officer will provide consent to purchase or reject within 30 calendar days of receipt of the Recipient's notification.

8. TECHNOLOGY TRANSFER AND OUTREACH

ARPA-E is required to contribute a percentage of appropriated funds to Technology Transfer and Outreach (TT&O) activities. In order to meet this mandate, every Project Team must spend at least 5% of the Federal funding provided by ARPA-E on TT&O activities to promote and further the development and eventual deployment of ARPA-E-funded technologies. Project Teams must seek a waiver from ARPA-E, located in the Business Assurances & Disclosures Form, to spend less than the minimum 5% TT&O expenditure requirement.

All TT&O expenditures are subject to the applicable Federal cost principles (i.e., 2 C.F.R. 200 Subpart E and 48 C.F.R. Subpart 31). Examples of TT&O expenditures are as follows:

- Documented travel and registration for the ARPA-E Energy Innovation Summit and other energy-related conferences and events;
- Documented travel to meet with potential suppliers, partners, or customers;
- Documented work by salaried or contract personnel to develop technology-to-market models or plans;
- Documented costs of acquiring industry-accepted market research reports; and
- Approved patent costs.

9. LOBBYING

Recipients and Subrecipients may not use any Federal funds, directly or indirectly, to influence or attempt to influence, directly or indirectly, congressional action on any legislative or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. § 1913. This restriction is in addition to those prescribed elsewhere in statute and regulation.

Recipients and Subrecipients are required to complete and submit SF-LLL, "Disclosure of Lobbying Activities" (https://www.gsa.gov/forms-library/disclosure-lobbying-activities) if any non-Federal funds have been paid or will be paid to any person for influencing or attempting to influence any of the following in connection with your application:

- An officer or employee of any Federal agency,
- A Member of Congress,
- An officer or employee of Congress, or
- An employee of a Member of Congress.

10. CONFERENCE SPENDING

Recipients and Subrecipients may not use any Federal funds to:

- Defray the cost to the United States Government of a conference held by any Executive branch department, agency, board, commission, or office which is not directly and programmatically related to the purpose for which their ARPA-E award is made and for which the cost to the United States Government is more than $20,000; or
- To circumvent the required notification by the head of any such Executive Branch department, agency, board, commission, or office to the Inspector General (or senior ethics official for any entity without an Inspector General), of the date, location, and number of employees attending such a conference.

11. INDEPENDENT RESEARCH AND DEVELOPMENT COSTS

ARPA-E does not fund Independent Research and Development (IR&D) as part of an indirect cost rate under its Grants and Cooperative Agreements. IR&D, as defined at FAR 31.205-18(a), includes cost of effort that is not sponsored by an assistance agreement or required in performance of a contract, and that consists of projects falling within the four following areas: (i) basic research, (ii) applied research, (iii) development, and (iv) systems and other concept formulation studies.

ARPA-E's goals are to enhance the economic and energy security of the United States through the development of energy technologies and ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies. ARPA-E accomplishes these goals by providing financial assistance for energy technology projects and has well recognized and established procedures for supporting research through competitive financial assistance awards based on merit review of proposed projects. Reimbursement for independent research and development costs through the indirect cost mechanism could circumvent this competitive process.

To ensure that all projects receive similar and equal consideration, eligible organizations may compete for direct funding of independent research projects they consider worthy of support

by submitting proposals for those projects to ARPA-E. Since proposals for these projects may be submitted for direct funding, costs for independent research and development projects are not allowable as indirect costs under ARPA-E awards. IR&D costs, however, would still be included in the direct cost base that is used to calculate the indirect rate so as to ensure an appropriate allocation of indirect costs to the organization's direct cost centers.

12. BUY AMERICA REQUIREMENT FOR PUBLIC INFRASTRUCTURE PROJECTS

Projects funded through this NOFO that are for, or contain, construction, alteration, maintenance, or repair of public infrastructure in the United States undertaken by applicable recipient types, require that:

- All iron, steel, and manufactured products used in the infrastructure project are produced in the United States; and
- All construction materials used in the infrastructure project are manufactured in the United States.

However, ARPA-E does not anticipate soliciting for or selecting projects that propose project tasks that are for, or contain, construction, alteration, maintenance, or repair of public infrastructure. If a project selected for award negotiations includes project tasks that may be subject to the Buy America Requirement, those project tasks will be removed from the project before any award is issued – i.e., no federal funding will be available for covered project tasks.

This "Buy America" requirement does not apply to an award where the Recipient is a for-profit entity.

13. REQUIREMENT FOR FINANCIAL PERSONNEL

ARPA-E requires Small Business or Nonprofit applicants to identify a finance/budget professional (employee or contracted support) with an understanding of Federal contracting and/or financial assistance and cost accounting (including indirect costs, invoicing, and financial management systems) that will support the team in complying with all applicable requirements.

14. PARTICIPANTS, COLLABORATING ORGANIZATIONS, AND CURRENT AND PENDING SUPPORT

If selected for award negotiations the selected applicant must submit, before the award is issued, an updated list of Covered Individuals[32] who are proposed to work on the project, both at the Recipient and subrecipient level, and a list of all participating[33] organizations. Further, the selectee must submit 1) current and pending support disclosures and resumes for any new

[32] See Section IX, Glossary, for the definition of Covered Individual.
[33] For a definition of "participation" please see footnote 44.

Covered Individuals, and 2) updated disclosures if there have been any changes to the current and pending support submitted with the application.

Throughout the life of the award, recipients have an ongoing responsibility to notify DOE of changes to the Covered Individuals and collaborating organizations, within 30 days of such change, and to submit 1) current and pending support disclosure statements and resumes for any Covered Individuals; and 2) updated disclosures if there are changes to the current and pending support previously submitted to ARPA-E. Recipients must certify on an annual basis that no such changes have occurred since their most recent certification.

Note that foreign participation is treated separately and may require a Foreign Entity Waiver, per Section II.D.

15. PAYMENT OF FEE OR PROFIT

ARPA-E will pay a fee or profit to Recipients in an amount not to exceed 7% of total project cost under any agreement resulting from this NOFO, subject to negotiations. Any fee or profit paid by Recipients to their subrecipients (but not commercial suppliers, vendors, or contractors) must be paid from fee or profit paid to Recipients by ARPA-E. Any fee or profit must be included in the budget submitted with Recipients' Full Applications and will be payable to Recipients upon: (i) completion of all work required by the agreement, (ii) submission and acceptance of all for-profit audit reports and resolution of all findings (if any) identified in the reports, (iii) submission and acceptance by the Government of all closeout documentation required by Attachment 4 to the agreement (refer to ARPA-E's Model Cooperative Agreement found at https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/funding-agreements), and (iv) submission of an acceptable invoice.

II. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. SBIR ELIGIBILITY

SBA rules and guidelines govern eligibility to apply to this NOFO. For information on program eligibility, please refer to the SBIR/STTR website, available at https://www.sbir.gov, and to the "Eligibility" section for SBIR/STTR programs at https://www.sbir.gov/apply.

A Small Business Concern[34] may apply as a Standalone Applicant[35] or as the lead organization for a Project Team.[36] If applying as the lead organization, the Small Business Concern must perform at least 66.7% of the work in Phase I and at least 50% of the work in Phase II and Phase IIS, as measured by the Total Project Cost.[37]

2. STTR ELIGIBILITY

SBA rules and guidelines govern eligibility to apply to this NOFO. For information on STTR program eligibility, please refer to the websites in section II.A.1.

Only a Small Business Concern may apply as the lead organization for a Project Team under STTR. The Small Business Concern must perform at least 40% of the work in Phase I, Phase II, and/or Phase IIS, as measured by the Total Project Cost. A single Research Institution must perform at least 30% of the work in Phase I, Phase II, and/or Phase IIS, as measured by the Total Project Cost. Please refer to Section II.B.1 of the NOFO for guidance on Research Institutions' participation in STTR projects.

3. JOINT SBIR AND STTR ELIGIBILITY

An Applicant that meets both the SBIR and STTR eligibility criteria above may request both SBIR and STTR funding if:

- The Small Business Concern is partnered with a Research Institution;
- The Small Business Concern performs at least 66.7% of the work in Phase I and at least 50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost;

[34] A Small Business Concern is defined by the SBA. Please see SBA.gov for guidelines, including Does Your Small Business Qualify? | U.S. Small Business Administration (sba.gov).
[35] A "Standalone Applicant" is an Applicant that applies for funding on its own, not as part of a Project Team.
[36] A Project Team consists of the Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.
[37] The Total Project Cost is the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.

- The partnering Research Institution performs 30-33.3% of the work in Phase I and 30-50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost; and
- The Principal Investigator (PI) is employed by the Small Business Concern. If the PI is employed by the Research Institution, submissions will be considered only under the STTR program.

B. ELIGIBLE SUBRECIPIENTS

1. RESEARCH INSTITUTIONS

A Research Institution[38] may apply only as a member of a Project Team (i.e., as a Subrecipient to a Small Business Concern). In STTR projects, a single Research Institution must perform at least 30%, but no more than 60%, of the work under the award in Phase I, Phase II, and/or Phase IIS (as applicable), as measured by the Total Project Cost.

2. OTHER PROJECT TEAM MEMBERS

The following entities are eligible to apply for SBIR/STTR funding as a member of a Project Team (i.e., as a Subrecipient to a Small Business Concern):

- For-profit entities (which includes large businesses and small businesses)
- Nonprofits other than Research Institutions[39]
- Government-Owned, Government Operated laboratories (GOGOs)
- State, local, and tribal government entities
- Foreign entities[40]

In SBIR projects, Project Team members other than the lead organization, including but not limited to Research Institutions, may collectively perform no more than 33.3% of the work under the award in Phase I and no more than 50% of the work under the award in Phase II and/or Phase IIS. This includes efforts performed by Research Institutions.

[38] Research Institutions include FFRDCs, nonprofit educational institutions, and other nonprofit research organizations owned and operated exclusively for scientific purposes. Eligible Research Institutions must maintain a place of business in the United States, operate primarily in the United States, or make a significant contribution to the U.S. economy through the payment of taxes or use of American products, materials, or labor.

[39] 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 Subrecipient.

[40] All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (see Section II.B.3 of the NOFO). However, the Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form submitted with the Full Application.

In STTR projects, Project Team members (other than the lead organization and the partnering Research Institution) may collectively perform no more than 30% of work under the award in Phase I, Phase II, and/or Phase IIS.

3. FOREIGN ENTITIES

If a Foreign Country of Concern[41] or individual citizen(s) of a Foreign Country of Concern has any ownership interest in any of the entities included in a proposal, then the Full Application must include a Foreign Entity Waiver request for each such entity in order for ARPA-E to consider the participation of such entities.[42]

C. ELIGIBLE PRINCIPAL INVESTIGATORS

1. SBIR

For the duration of the award, the PI for the proposed project (or, if multiple PIs, at least one PI) must be employed by, and perform more than 50% of his or her work for, the Prime Recipient. The Grants Officer may waive this requirement or approve the substitution of the PI after consultation with the ARPA-E SBIR/STTR Program Director.

For projects with multiple PIs, at least one PI must meet the primary employment requirement. That PI will serve as the contact PI for the Project Team.

2. STTR

For the duration of the award, the PI for the proposed project (or, if multiple PIs, at least one PI) must be employed by, and perform more than 50% his or her work for, the Prime Recipient or the partnering Research Institution. The Grants Officer may waive this requirement or approve the substitution of the PI after consultation with the ARPA-E SBIR/STTR Program Director.

For projects with multiple PIs, at least one PI must meet the primary employment requirement. That PI will serve as the contact PI for the Project Team.

[41] "Foreign Countries of Concern", as defined by the State Department, include (as of December 29, 2023) Burma, People's Republic of China, Cuba, Eritrea, Iran, the Democratic People's Republic of Korea, Nicaragua, Pakistan, Russia, Saudi Arabia, Tajikistan, and Turkmenistan.

[42] The contents of a Foreign Entity Waiver request can be found in the Business Assurances & Disclosures Form.

D. FOREIGN PARTICIPATION

1. FOREIGN NATIONAL PARTICIPATION FROM COUNTRIES OF CONCERN

All applicants selected for an award under this NOFO and project participants (including subrecipients and contractors) who anticipate involving foreign nationals from Foreign Countries of Concern[43] in the performance of an award may be required to provide ARPA-E with specific information about each foreign national to satisfy requirements for foreign national participation. A "foreign national" is defined as any person who is not a United States citizen by birth or naturalization. The volume and type of information collected may depend on various factors associated with the award. ARPA-E approval is required before a foreign national can participate in the performance of any work under an award.

ARPA-E may elect to deny a foreign national's participation in the award. Likewise, ARPA-E may elect to deny a foreign national's access to ARPA-E site, information, technologies, equipment, programs or personnel.

2. FOREIGN PARTICIPATION CONSIDERATIONS

Foreign participation[44] in a project requires a Foreign Entity Waiver (see Waiver Request – Foreign Entity Participation in the Business Assurances & Disclosure Form). Awardees have an ongoing obligation to report new foreign participation in a project and may be required to obtain a waiver before new foreign participation can occur. A Foreign Work Waiver may also be required (see Section I.I.6 and the Business Assurances & Disclosures Form).

E. ELIGIBILITY OF PRIOR SBIR AND STTR AWARDEES: SBA BENCHMARKS ON PROGRESS TOWARDS COMMERCIALIZATION

Applicants awarded multiple prior SBIR or STTR awards must meet DOE's benchmark requirements for progress towards commercialization before ARPA-E may issue a new Phase I award. For purposes of this requirement, Applicants are assessed using their prior Phase I and Phase II SBIR and STTR awards across all SBIR agencies. If an awardee fails to meet either of the benchmarks, that awardee is not eligible for an SBIR or STTR Phase I award and any Phase II award for a period of one year from the time of the determination.

ARPA-E applies two benchmark rates addressing an Applicant's progress towards commercialization: (1) the DOE Phase II Transition Rate Benchmark and (2) the SBA Commercialization Rate Benchmark:

[43] Please see footnote 41 for list of Foreign Countries of Concern.

[44] "Participation" includes any activities performed under an ARPA-E award, including, but not limited to, all work described in the milestone schedule of an award (commonly referred to as "Attachment 3" or the "Statement of Project Objectives (SOPO)") and any services that include testing, including services performed by vendors or consultants. Participation also includes activities that involve the procurement of foreign equipment or supplies.

- The DOE Phase II Transition Rate Benchmark sets the minimum required number of Phase II awards the Applicant must have received for a given number of Phase I awards received during the specified period. **This Transition Rate Benchmark applies only to Phase I Applicants that have received more than 20 Phase I awards during the last five (5) year period, excluding the most recently completed fiscal year**. DOE's Phase II Transition Rate Benchmark requires that 25% of all Phase I awards received over the past five years transition to Phase II awards.

  The SBIR/STTR Phase II transition rates and commercialization rates are calculated using the data in the SBA's TechNet database. For the purpose of these benchmark requirements, awardee firms are assessed once a year, on June 1st, using their prior SBIR and STTR awards across all agencies. SBA makes this tabulation of awardee transition rates and commercialization rates available to all federal agencies. ARPA-E uses this tabulation to determine which companies do not meet the DOE benchmark rates and are, therefore, ineligible to receive new Phase I awards.

- The Commercialization Rate Benchmark sets the minimum Phase III[45] commercialization results that an Applicant must have achieved from work it performed under prior Phase II awards (i.e., this measures an Applicant's progress from Phase II or Phase IIS to Phase III awards). **This benchmark requirement applies only to Applicants that have received more than 15 Phase II awards during the last 10 fiscal years, excluding the two most recently completed fiscal years.**

  The current Commercialization Benchmark requirement, agreed upon and established by all 11 SBIR agencies, is that the Applicants must have received, to date, an average of at least $100,000 of sales and/or investments per Phase II award received, or have received a number of patents resulting from the relevant SBIR/STTR work equal to or greater than 15% of the number of Phase II awards received during the period.

- On June 1 of each year, SBIR/STTR awardees registered on SBIR.gov are assessed to determine if they meet the Phase II Transition Rate Benchmark requirement. (At this time, SBA is not identifying companies that fail to meet the Commercialization Rate Benchmark requirement). Companies that fail to meet the Phase II Transition Rate Benchmark as of June 1 of a given year will not be eligible to apply to an SBIR/STTR NOFO for the following year.

[45] Phase III refers to work that derives from, extends or completes an effort made under prior SBIR/STTR funding agreements, but is funded by sources other than the SBIR/STTR Program. Phase III work is typically oriented towards commercialization of SBIR/STTR research or technology. For more information please refer to the Small Business Administration's "Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program Policy Directive" at https://www.sbir.gov/sites/default/files/2024-07/SBA SBIR_STTR_POLICY_DIRECTIVE_May2023.pdf.

F. COMPLIANCE AND RESPONSIVENESS

Submissions that are noncompliant or nonresponsive to the NOFO as described in Sections IV.D and V.A are not eligible.

G. 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 NOFO, provided that each application is scientifically distinct.

Small business Applicants that qualify as a "Small Business Concern" may apply to only one of the two ARPA-E GRADIENTS NOFOs: DE-FOA-0003555 (GRADIENTS SBIR/STTR), or DE-FOA-0003554 (GRADIENTS). Small businesses that qualify as "Small Business Concerns" are strongly encouraged to apply under the former (SBIR/STTR NOFO). To determine eligibility as a "Small Business Concern" under DE-FOA-0003555 (SBIR/STTR), please review the eligibility requirements in Sections II.A – II.C above.

H. COST SHARING

Cost sharing is not required for this FOA.

III. APPLICATION CONTENTS AND FORMAT

A. GENERAL APPLICATION CONTENT REQUIREMENTS

1. 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 should be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information and may use or disclose such information for any purpose.

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

Notice of Restriction on Disclosure and Use of Data:

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

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

2. EXPORT CONTROL INFORMATION

Do not include information subject to export controls in any submissions, including Concept Papers, Full Applications, and Replies to Reviewer Comments – whether marked as subject to US export control laws/regulations or otherwise. Such information may not be accepted by ARPA-E and may result in a determination that the application is non-compliant, and therefore not eligible for selection. This prohibition includes any submission containing a general, non-determinative statement such as “The information on this page [or pages _ to__] may be

subject to US export control laws/regulations", or similar. Under the terms of their award, awardees shall be responsible for compliance with all export control laws/regulations.

3. CRITICAL ENERGY INFRASTRUCTURE INFORMATION

Do not include Critical Energy/Electric Infrastructure Information (CEII) in application materials. See definition in Section I.E above.

B. CONCEPT PAPERS

1. FIRST COMPONENT: CONCEPT PAPER

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 Federal Funding Requested, and Project Duration.

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 in the template.

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.

Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section II.F of the NOFO).

2. SECOND COMPONENT: SUMMARY SLIDE

Applicants are required to provide a single PowerPoint slide summarizing the proposed project. The slide must be submitted in Microsoft PowerPoint format and must follow the provided template with minimal adjustment. This slide will be used during ARPA-E's evaluation of Concept Papers. A summary slide template is available on ARPA-E eXCHANGE. Summary Slides must conform to the content and format requirements described in the template.

C. FULL APPLICATIONS

Full Applications must conform to the following formatting requirements:

- Each document must be submitted in the file format prescribed below and/or written in the document template at https://arpa-e-foa.energy.gov.
- The Full Application 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.

Fillable Full Application template documents are available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Full Applications found in any component to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section II.F of the NOFO).

ARPA-E provides detailed guidance on the content and form of each component below.

1. FIRST COMPONENT: TECHNICAL VOLUME

The Technical Volume is the centerpiece of the Full Application. The Technical Volume must be submitted in Adobe PDF format. The Technical Volume must conform to the content and form requirements included within the template, including maximum page lengths. If Applicants exceed the maximum page lengths specified for each section, or add any additional sections not requested, ARPA-E may review only the authorized number of pages and disregard any additional pages or sections.

Applicants must provide sufficient citations and references to the primary research literature to justify the claims and approaches made in the Technical Volume. ARPA-E and reviewers may review primary research literature in order to evaluate applications. However, all relevant

technical information should be included in the body of the Technical Volume.

2. SECOND COMPONENT: SF-424

The SF-424 must be submitted in Adobe PDF format using the available template. An instructional document is also available on ARPA-E eXCHANGE. Applicants must complete all required fields in accordance with the instructions. Applicants may identify and include in Block 14 the entities, their addresses, and corresponding census tract numbers for any project activities that will occur within any designated Qualified Opportunity Zone (QOZ). To locate QOZ, go to: https://www.cdfifund.gov/opportunity-zones.

Recipients and Subrecipients are required to complete SF-LLL (Disclosure of Lobbying Activities), also available on ARPA-E eXCHANGE, if any non-Federal funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any Federal agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with your application or funding agreement. The completed SF-LLL must be appended to the SF-424.

ARPA-E provides the following supplemental guidance on completing the SF-424:

- Each Project Team should submit only one SF-424 (i.e., a Subrecipient should not submit a separate SF-424).
- The list of certifications and assurances in Block 21 can be found at https://www.energy.gov/management/articles/certifications-and-assurances-use-sf-424.
- The dates and dollar amounts on the SF-424 are for the entire period of performance, not a portion thereof.
- Applicants are responsible for ensuring that the proposed costs listed in eXCHANGE match those listed on forms SF-424 and the Budget Justification Workbook/SF-424A. Inconsistent submissions may impact ARPA-E's final award determination.

3. THIRD COMPONENT: BUDGET JUSTIFICATION WORKBOOK/SF-424A

Applicants are required to complete the Budget Justification Workbook/SF-424A Excel spreadsheet using the available template. Recipients must complete each tab of the Budget Justification Workbook for the project as a whole, including all work to be performed by the Recipient and its Subrecipients and Contractors. The SF-424A form included with the Budget Justification Workbook will "auto-populate" as the Applicant enters information into the Workbook. Applicants should carefully read the "Instructions and Summary" tab provided within the Budget Justification Workbook, and all instructions at the top of each category tab. For more information, an ARPA-E Budget Justification Guidance document is also available on ARPA-E eXCHANGE.

In accordance with 2 CFR 200.332 Requirements for pass-through entities, the Recipient must ensure the Subrecipients' proposed cost are allowable, allocable, and reasonable.

4. FOURTH COMPONENT: SUMMARY FOR PUBLIC RELEASE

Applicants are required to provide a 250-word maximum Summary for Public Release following the instructions in the available template. The Summary for Public Release must be submitted in Adobe PDF format. For applications selected for award negotiations, the Summary may be used as the basis for a public announcement by ARPA-E; therefore, this summary should not include any confidential, proprietary, or privileged information. This summary may not include any graphics, figures, or tables. The summary should be written for a lay audience (e.g., general public, media, Congress) using plain English.

5. FIFTH COMPONENT: SUMMARY SLIDE

Applicants are required to provide a single PowerPoint slide summarizing the proposed project. The slide must be submitted in Microsoft PowerPoint format and must follow the provided template with minimal adjustment. This slide will be used during ARPA-E's evaluation of Full Applications. A summary slide template is available on ARPA-E eXCHANGE. Summary Slides must conform to the content and format requirements described in the template.

6. SIXTH COMPONENT: BUSINESS ASSURANCES & DISCLOSURES FORM

Applicants are required to provide the information requested in the Business Assurances & Disclosures Form. The information must be submitted in Adobe PDF format and digitally signed by all required parties. The fillable Business Assurances & Disclosures Form template on ARPA-E eXCHANGE includes instructions for items the Applicant is required to disclose, describe, or request a waiver for.

Applicants should submit separate Business Assurances & Disclosures Forms for each member of the Project Team. ARPA-E eXCHANGE will allow multiple PDF documents to be submitted under the Business Assurances & Disclosures Forms file name. Any additional documents other than BADFs submitted under this file name will be disregarded.

7. SEVENTH COMPONENT: SBIR.GOV COMPANY REGISTRATION

Applicants are required to provide a copy of the SBIR.gov Company Registration confirmation document generated from SBIR.gov (see Section IV.A of the NOFO) in Adobe PDF form. Applicants that have previously completed SBIR.gov Company Registration need not register again and may submit a copy their existing Registration.

8. EIGHTH COMPONENT: ADDITIONAL OWNERSHIP CERTIFICATIONS

Only those Applicants that are (a) majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms and/or (b) joint ventures minority-owned by a foreign entity are required to complete the Certification for Applicants Majority-Owned by Multiple Venture Capital Operating Companies, Hedge Funds, and Private Equity Funds and Joint Venture Applicants Minority-Owned by Foreign Business Entities (VCOC/FJV Certification). The certification must be submitted in Adobe PDF format.

In the VCOC/FJV Certification, the Applicant is required to self-identify as an entity that falls into one of those categories, provide certain information, verify its ownership status, and verify that it has completed SBIR.gov Company Registration (see Section IV.A) as such an entity.

Applicants that are neither (a) majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms nor (b) joint ventures minority-owned by a foreign entity are not required to complete the VCOC/FJV Certification.

D. REPLIES TO REVIEWER COMMENTS

Written feedback on Full Applications is made available to Applicants before the submission deadline for Replies to Reviewer Comments. Applicants have a brief opportunity to prepare a short Reply to Reviewer Comments responding to one or more comments or supplementing their Full Application. A fillable Reply to Reviewer Comments template is available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).

Replies to Reviewer Comments must conform to the following requirements:

- The Reply to Reviewer Comments must be submitted in Adobe PDF format.
- The Reply to Reviewer Comments must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11-inch paper with margins not less than one inch on every side. Use Times New Roman typeface, a black font color, and a font size of 12 points or larger (except in figures and tables).
- The Reply to Reviewer Comments must be a maximum of 3 pages – 2 pages maximum for text, and 1 page maximum for images (e.g., graphics, charts, or other data).
- The Control Number must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.

IV. SUBMISSION REQUIREMENTS AND DEADLINES

All documents, templates, and instructions required to apply to this NOFO are either linked in this document or available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE. ARPA-E will not review or consider applications submitted through other means (e.g., fax, hand delivery, email, postal mail).

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.

A. COMPLETION OF SBIR.GOV COMPANY REGISTRATION

The first step in applying to this NOFO is completing the SBIR.gov Company Registration (https://app.www.sbir.gov/company-registration/overview). Upon completing registration, Applicants will receive a unique Small Business Concern (SBC) Control ID and SBC Registration confirmation document in Adobe PDF format. Applicants that have previously completed SBIR.gov Company Registration need not register again.

Applicants must submit their Registration confirmation document with SBC Control ID as part of their Full Application (see Section III.C.7 of the NOFO).

B. UNIQUE ENTITY IDENTIFIER AND SAM REGISTRATION

Applicants must register with the System for Award Management (SAM) at www.sam.gov/SAM prior to submitting an application, at which time the system will assign (if newly registered) a Unique Entity Identifier (UEI). Applicants should commence this process as soon as possible. Registering with SAM and obtaining the UEI could take several weeks.

Recipients must:

- Maintain a current and active registration in SAM.gov at all times during which it has an active Federal award or an application or plan under consideration by a Federal awarding agency, including (if applicable) information on its immediate and highest-level owner and subsidiaries and on all predecessors that have been awarded a Federal contract or financial assistance award within the last three years.;
- Remain registered in SAM.gov after the initial registration;
- Update its information in SAM.gov as soon as it changes;
- Review its information in SAM.gov annually from the date of initial registration or subsequent updates to ensure it is current, accurate and complete;
- Include its UEI in each application it submits; and

- Not make a subaward to any entity unless the entity has provided its UEI.

Subrecipients are not required to complete a full registration in SAM.gov but must obtain a UEI.

ARPA-E may not execute a funding agreement with the Recipient until it has obtained a UEI and completed its SAM registration.

C. USE OF ARPA-E EXCHANGE

To apply to this NOFO, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). 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).

Applicants are encouraged to log in to eXCHANGE using Enhanced Identity Proofing. ARPA-E eXCHANGE offers both Login.gov and ID.me as methods to authenticate identities. Login.gov and ID.me may require some users to go through a validation process that can take up to 10 days. Applicants can still use the legacy Login.gov option.

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 "Submissions" and then "My Submissions" links 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 NOFO, 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.**

D. REQUIRED DOCUMENTS CHECKLIST AND DEADLINES

The following table outlines the required documents and their submission deadlines.

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	NOFO SECTION	DEADLINES

Concept Paper	• Concept Paper (Adobe PDF format)
	  ○ Sections 1-4 (4 pages max.)
	  ○ Bibliographic References (no page limit)
	• Summary Slide (1 page limit, Microsoft PowerPoint format)
		Mandatory	III.B	9:30 AM ET, February 14, 2025

Full Application	• Technical Volume (Adobe PDF format):
	  ○ Cover Page (1 page max.)
	  ○ Executive Summary (1 page max.)
	  ○ Sections 1-5 (20 pages max.)
	  ○ Bibliographic References (no page limit)
	  ○ Personal Qualification Summaries (each summary limited to 5 pages in length, no cumulative page limit)
	• Signed SF-424 (Adobe PDF format);
	• Budget Justification Workbook/SF-424A (Microsoft Excel format);
	• Summary for Public Release (250 words max., Adobe PDF format);
	• Summary Slide (1 slide limit, Microsoft PowerPoint format);
	• Signed Business Assurances & Disclosures Form(s) (no page limit, Adobe PDF format);
	• SBA Company Registration Certificate generated in the SBA Company Registry; (http://sbir.gov/registration) (Adobe PDF format); and
	• If applicable, Certification for Applicants that are (a) Majority-Owned by Multiple Venture Capital Operating Companies, Hedge Funds, or Private Equity Firms; and/or (b) joint ventures minority-owned by a foreign entity (Adobe PDF format).
		Mandatory	III.C	TBD

Reply to Reviewer Comments	• Reply to Reviewer Comments (3 page max., Adobe PDF format)	Optional	III.D	TBD

E. COMPLIANCE

ARPA-E may not review or consider incomplete applications and applications received after the deadline stated in the NOFO. Such applications may be deemed noncompliant (see Section

II.F of the NOFO). 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 III of the NOFO;
- Failing to enter required information in ARPA-E eXCHANGE;
- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the NOFO;
- 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.

F. INTERGOVERNMENTAL REVIEW

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

V. APPLICATION REVIEW INFORMATION

A. RESPONSIVENESS

1. TECHNICAL RESPONSIVENESS REVIEW

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 NOFO.
- Submissions that have been submitted in response to currently issued ARPA-E NOFOs.
- Submissions that are not scientifically distinct from applications submitted in response to currently issued ARPA-E NOFOs.
- 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 NOFO.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the NOFO. Technologies must be scalable such that they could be disruptive with sufficient technical progress.
- 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.B of the NOFO.
- Submissions that propose using funding for construction, alteration, maintenance, or repair of public infrastructure in the United States.

2. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

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

- Category 1:
  - Category 1 submissions that do not include the three components: (1) flexible grid-following/grid-forming inverters, (2) some kind of energy storage, and (3) a control system.
  - Category 1 submissions that do not include some kind of energy storage to inject energy in the grid for at least a few seconds at rated power of the generator.
  - Category 1 submissions that only include electrochemical batteries as the energy storage system.
  - Category 1 submissions that do not include a plan (real experiments on microgrids, cooperatives, or municipal grid segments) for validation.
- Category 2:
  - Category 2 submissions that do not include under-frequency or under-voltage load-shedding algorithms.
  - Category 2 submissions that do not include a stability assessment algorithm.
  - Category 2 submissions that do not include a plan (real experiments on microgrids, cooperatives, or municipal grid segments) for validation.
- Category 3:
  - Category 3 submissions that do not include inertia (energy) and damping (control authority) real-time allocation algorithms.
  - Category 3 submissions that do not include load-shedding real-time allocation algorithms.
  - Category 3 submissions that do not integrate the inertia, damping and load-shedding allocation algorithms with the optimization tools of Tertiary Control.
  - Category 3 submissions that develop control solutions for only some specific subset of operation points.
  - Category 3 submissions that do not include a plan (simulation, emulation, or both) for validation.

B. REVIEW CRITERIA

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 NOFO 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.F of the NOFO for the appropriate technology Category in Section I.E of the NOFO;
- Identification of techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; and
- Demonstration of awareness of competing commercial and emerging technologies and identifies how the proposed concept/technology provides significant improvement over existing solutions.

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

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

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement.

2. CRITERIA FOR FULL APPLICATIONS

Full Applications are evaluated based on the following criteria:

(1) *Impact of the Proposed Technology* (30%) - This criterion involves consideration of the following:

- The potential for a transformational and disruptive (not incremental) advancement in one or more energy-related fields;
- Thorough understanding of the current state-of-the-art and presentation of an

innovative technical approach to significantly improve performance over the current state-of-the-art;
- Awareness of competing commercial and emerging technologies and identification of how the proposed concept/technology provides significant improvement over these other solutions; and
- A reasonable and effective strategy for transitioning the proposed technology from the laboratory to commercial deployment.

(2) *Overall Scientific and Technical Merit* (30%) - This criterion involves consideration of the following:

- Whether the proposed work is unique and innovative;
- Clearly defined project outcomes and final deliverables;
- Substantiation that the proposed project is likely to meet or exceed the technical performance targets identified in this NOFO;
- Feasibility of the proposed work based upon preliminary data or other background information and sound scientific and engineering practices and principles;
- A sound technical approach, including appropriately defined technical tasks, to accomplish the proposed R&D objectives; and
- Management of risk, to include identifying major technical R&D risks and feasible, effective mitigation strategies.

(3) *Qualifications, Experience, and Capabilities of the Proposed Project Team* (30%) - This criterion involves consideration of the following**:**

- The PI and Project Team have the skill and expertise needed to successfully execute the project plan, evidenced by prior experience that demonstrates an ability to perform R&D of similar risk and complexity; and
- Access to the equipment and facilities necessary to accomplish the proposed R&D effort and/or a clear plan to obtain access to necessary equipment and facilities.

(4) *Soundness of Management Plan* (10%) - This criterion involves consideration of the following:

- Plausibility of plan to manage people and resources;
- Allocation of appropriate levels of effort and resources to proposed tasks;
- Reasonableness of the proposed project schedule, including major milestones; and
- Reasonableness of the proposed budget to accomplish the proposed project.

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement.

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

ARPA-E has not established separate criteria to evaluate Replies to Reviewer Comments. Instead, Replies to Reviewer Comments are evaluated as an extension of the Full Application.

C. 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; Scientific~~ and technical disciplines represented in the proposed Project Team;
   b. Technological diversity;
   c. ~~Organizational diversity;~~ Types of organizations (e.g., small business, university) on the proposed Project Team;
   d. ~~Geographic diversity;~~ Area(s) of the country where proposed Project Team members are located and where project work will be performed;
   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 U.S. manufacturing and/or software development
   c. Reduction of energy-related emissions;
   d. Increase in U.S. energy efficiency;
   e. Enhancement of U.S. economic and energy security; or
   f. Promotion of U.S. advanced energy technologies competitiveness.

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

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

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

VI. **Qualified Opportunity Zone (QOZ).** Whether the entity is located in an urban and economically distressed area including a Qualified Opportunity Zone (QOZ) or the proposed project will occur in a QOZ or otherwise advance the goals of QOZ. The goals include spurring economic development and job creation in distressed communities throughout the United States. For a list or map of QOZs go to: https://www.cdfifund.gov/opportunity-zones.

D. REVIEW AND SELECTION PROCESS

1. CONCEPT PAPERS

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria and program policy factors in Sections V.B.1 and V.C of the NOFO. ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to encourage the submission of a Full Application.

2. FULL APPLICATIONS

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive. 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.B.2 and V.C of the NOFO.

3. 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. ARPA-E may also provide more direct feedback at this time. Applicants may submit an optional Reply to Reviewer Comments, which must be submitted by the deadline stated in the NOFO.

ARPA-E performs a preliminary review of Replies to determine whether they are compliant, as described in Section III.D of the NOFO. ARPA-E will review and consider compliant Replies only.

4. 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 Grants 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.

5. 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, risk reviews, and program policy factors in Sections V.B, V.G, and V.C of the NOFO. ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to select an application for award negotiation.

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.

ARPA-E expects to announce selections for negotiations in approximately July 2025 and to execute funding agreements in approximately October 2025.

E. 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 Grants 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.

F. ARPA-E SUPPORT CONTRACTORS

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.

G. RISK REVIEW

If selected for award negotiations, ARPA-E may evaluate the risks posed by the Applicant using the criteria set forth at 2 CFR §200.206(b)(2). ARPA-E may require special award terms and conditions depending upon results of the risk analysis.

Further, as DOE invests in critical infrastructure and funds critical and emerging technology areas, DOE also considers possible vectors of undue foreign influence in evaluating risk. If high risks are identified and cannot be sufficiently mitigated, DOE may elect to not fund the applicant. As part of the research, technology, and economic security risk review, DOE may contact the applicant and/or proposed project team members for additional information to inform the review.

ARPA-E will not make an award if ARPA-E has determined that:

- The entity submitting the proposal or application:
  - has an owner or Covered Individual that is party to a malign foreign talent recruitment program of the People's Republic of China or another foreign country of concern;[27]
  - has a business entity, parent company, or subsidiary located in the People's Republic of China or another foreign country of concern; or
  - has an owner or Covered Individual that has a foreign affiliation with a research institution located in the People's Republic of China or another foreign country of concern; and
- The relationships and commitments described above:
  - interfere with the capacity for activities supported by the Federal agency to be carried out;
  - create duplication with activities supported by the Federal agency;
  - present concerns about conflicts of interest;
  - were not appropriately disclosed to the Federal agency;
  - violate Federal law or terms and conditions of the Federal agency; or
  - pose a risk to national security.

If high risks are identified and cannot be sufficiently mitigated, ARPA-E may elect to not fund the applicant.

VI. AWARD NOTICES AND AWARD TYPES

A. AWARD NOTICES

Recipients should register with FedConnect in order to receive notification that their funding agreement has been executed by the Grants Officer and to obtain a copy of the executed funding agreement. Please refer to https://www.fedconnect.net/FedConnect/ for registration instructions.

1. REJECTED SUBMISSIONS

Noncompliant and nonresponsive Concept Papers and Full Applications are rejected by the Grants Officer and are not merit reviewed or considered for award. The Grants Officer sends a notification email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. The notification 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.

3. FULL APPLICATION NOTIFICATIONS

ARPA-E promptly notifies Applicants of its determination to select, postpone a final decision until a later date, or not select a Full Application for award negotiation. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE.

Written feedback on Full Applications is only made available to Applicants in the Replies to Reviewer Comments process. ARPA-E does not offer or provide debriefings.

ARPA-E may stagger its selection determinations. As a result, some Applicants may receive their notification letter in advance of other Applicants.

a. Successful Applicants

ARPA-E has discretion to select all or part of a proposed project for negotiation of an award. A notification letter selecting a Full Application for award negotiations does not authorize the Applicant to commence performance of the project. **ARPA-E selects Full Applications for award negotiations, not for award.** Applicants do not receive an award until award negotiations are complete and the Grants Officer executes the funding agreement. The notice of Federal award signed by the Grants Officer is the official document that obligates funds. ARPA-E may terminate award negotiations at any time for any reason.

The Grants 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 Grants Officer, either explicit or implied, is invalid.

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

b. Postponed Selection Determinations

A notification letter postponing a final selection determination until a later date does not authorize the Applicant to commence performance of the project. ARPA-E may ultimately determine to select or not select the Full Application for award negotiations.

c. Unsuccessful Applicants

By not selecting 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. ARPA-E hopes that unsuccessful Applicants will submit innovative ideas and concepts for future NOFOs.

B. Pre-Award Costs

ARPA-E will not reimburse any pre-award costs incurred by Applicants before they are selected for award negotiations. Please refer to Section VI.A of the NOFO for guidance on award notices.

Upon selection for award negotiations, Applicants may incur pre-award costs at their own risk, consistent with the requirements in 2 C.F.R. Part 200, as modified by 2 C.F.R. Part 910, and other Federal laws and regulations. All submitted budgets are subject to change and are

typically reworked during award negotiations. ARPA-E is under no obligation to reimburse pre-award costs if, for any reason, the Applicant does not receive an award or the award is made for a lesser amount than the Applicant expected, or if the costs incurred are not allowable, allocable, or reasonable.

C. RENEWAL AWARDS

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

D. 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.

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 Recipient share responsibility for the direction of projects.

Phase I will be made as a fixed-amount award. Phase II and Phase IIS of Combined Phase I/II/IIS awards will be made on a cost-reimbursement basis.

ARPA-E encourages Recipients to review the Model Cooperative Agreement, which is available at https://arpa-e.energy.gov/technologies/project-guidance.

VII. POST-AWARD REQUIREMENTS AND ADMINISTRATION

The Recipient is the responsible authority regarding the settlement and satisfaction of all contractual and administrative issues, including but not limited to disputes and claims arising out of any agreement between the Recipient and a FFRDC contractor. Recipients are required to flow down these requirements to their Subrecipients through subawards or related agreements.

A. NATIONAL POLICY REQUIREMENTS

The following national policy requirements apply to Recipients.

- If an award is made to a DOE/NNSA National Laboratory, all Disputes and Claims will be resolved in accordance with the terms and conditions of the DOE/NNSA National Laboratory's management and operating (M&O) contract, as applicable, in consultation between DOE and the Recipient.
- If an award is made to another Federal agency or its FFRDC contractor, all Disputes and Claims will be resolved in accordance with the terms and conditions of the interagency agreement in consultation between DOE and the Recipient.

1. NATIONAL POLICY ASSURANCES

Project Teams, including Recipients and Subrecipients, are required to comply with the National Policy Assurances in effect on the date of award located at https://www.nsf.gov/awards/managing/rtc.jsp in accordance with 2 C.F.R. § 200.300.

2. ENVIRONMENTAL IMPACT QUESTIONNAIRE

By law, ARPA-E is required to evaluate the potential environmental impact of projects that it is considering for funding. In particular, ARPA-E must determine before funding a project whether the project qualifies for a categorical exclusion under 10 C.F.R. § 1021.410 or whether it requires further environmental review (i.e., an environmental assessment or an environmental impact statement).

To facilitate and expedite ARPA-E's environmental review, Recipients are required to complete an Environmental Impact Questionnaire during award negotiations. This form is available at https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/required-forms-and-templates. Each Recipient must wait to complete the Environmental Impact Questionnaire (EIQ) until after ARPA-E has notified them that Attachment 3 Statement of Program Objectives is in final form. The completed EIQ is then due back to ARPA-E within 14 calendar days.

B. ADMINISTRATIVE REQUIREMENTS

1. INTELLECTUAL PROPERTY AND DATA MANAGEMENT PLANS

ARPA-E requires every Project Team to negotiate and establish an Intellectual Property Management Plan for the management and disposition of intellectual property arising from the project. The Recipient must submit a completed and signed Intellectual Property Management plan to ARPA-E within six weeks of the effective date of the ARPA-E funding agreement. All Intellectual Property Management Plans are subject to the terms and conditions of the ARPA-E funding agreement and its intellectual property provisions, and applicable Federal laws, regulations, and policies, all of which take precedence over the terms of Intellectual Property Management Plans.

ARPA-E has developed a template for Intellectual Property Management Plans (https://arpa-e.energy.gov/technologies/project-guidance/post-award-guidance/project-management-reporting-requirements) to facilitate and expedite negotiations between Project Team members. ARPA-E does not mandate the use of this template. ARPA-E and DOE do not make any warranty (express or implied) or assume any liability or responsibility for the accuracy, completeness, or usefulness of the template. ARPA-E and DOE strongly encourage Project Teams to consult independent legal counsel before using the template.

Awardees are also required, post-award, to submit a Data Management Plan (DMP) that addresses how data generated in the course of the work performed under an ARPA-E award will be preserved and, as appropriate, shared publicly. The Recipient must submit a completed and signed DMP - as part of the Team's Intellectual Property Management Plan - to ARPA-E within six weeks of the effective date of the ARPA-E funding agreement.

2. U.S. COMPETITIVENESS

A primary objective of DOE's multi-billion-dollar research, development and demonstration investments – including ARPA-E awards - is advancement of new energy technologies, manufacturing capabilities, and supply chains for and by U.S. industry and labor. Therefore, in exchange for receiving taxpayer dollars to support an applicant's project, the applicant must agree to the following U.S. Competitiveness Provision as part of an award under this NOFO.

U.S. Competitiveness

> The Contractor (Recipient in ARPA-E awards) agrees that any products embodying any subject invention or produced through the use of any subject invention will be manufactured substantially in the United States unless the Contractor can show to the satisfaction of DOE that it is not commercially feasible. In the event DOE agrees to foreign manufacture, there will be a requirement that the Government's support of the technology be recognized in some appropriate manner, e.g., alternative binding commitments to provide an overall net benefit to the U.S. economy. The Contractor

agrees that it will not license, assign or otherwise transfer any subject invention to any entity, at any tier, unless that entity agrees to these same requirements. Should the Contractor or other such entity receiving rights in the invention(s): (1) undergo a change in ownership amounting to a controlling interest, or (2) sell, assign, or otherwise transfer title or exclusive rights in the invention(s), then the assignment, license, or other transfer of rights in the subject invention(s) is/are suspended until approved in writing by DOE. The Contractor and any successor assignee will convey to DOE, upon written request from DOE, title to any subject invention, upon a breach of this paragraph. The Contractor will include this paragraph in all subawards/contracts, regardless of tier, for experimental, developmental or research work.

A subject invention is any invention of the contractor conceived or first actually reduced to practice in the performance of work under an award. An invention is any invention or discovery which is or may be patentable. The contractor includes any awardee, recipient, sub-awardee, or sub-recipient.

As noted in the U.S. Competitiveness Provision, at any time in which an entity cannot meet the requirements of the U.S. Competitiveness Provision, the entity may request a modification or waiver of the U.S. Competitiveness Provision. For example, the entity may propose modifying the language of the U.S. Competitiveness Provision in order to change the scope of the requirements or to provide more specifics on the application of the requirements for a particular technology. As another example, the entity may request that the U.S. Competitiveness Provision be waived in lieu of a net benefits statement or U.S. manufacturing plan. The statement or plan would contain specific and enforceable commitments that would be beneficial to the U.S. economy and competitiveness. Commitments could include manufacturing specific products in the U.S., making a specific investment in a new or existing U.S. manufacturing facility, keeping certain activities based in the U.S. or supporting a certain number of jobs in the U.S. related to the technology. If DOE, in its sole discretion, determines that the proposed modification or waiver promotes commercialization and provides substantial U.S. economic benefits, DOE may grant the request and, if granted, modify the award terms and conditions for the requesting entity accordingly.

The U.S. Competitiveness Provision is implemented by DOE pursuant to a Determination of Exceptional Circumstances (DEC) under the Bayh-Dole Act and DOE Patent Waivers. See Section VIII.A, “Title to Subject Inventions”, of this NOFO for more information on the DEC and DOE Patent Waiver.

3. NONDISCLOSURE AND CONFIDENTIALITY AGREEMENTS REPRESENTATIONS

In submitting an application in response to this NOFO the Applicant represents that:

(1) **It does not and will not** require its employees or contractors to sign internal nondisclosure or confidentiality agreements or statements prohibiting or otherwise

restricting its employees or contractors from lawfully reporting waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information.

(2) **It does not and will not** use any Federal funds to implement or enforce any nondisclosure and/or confidentiality policy, form, or agreement it uses unless it contains the following provisions:

a. *"These provisions are consistent with and do not supersede, conflict with, or otherwise alter the employee obligations, rights, or liabilities created by existing statute or Executive order relating to (1) classified information, (2) communications to Congress, (3) the reporting to an Inspector General of a violation of any law, rule, or regulation, or mismanagement, a gross waste of funds, an abuse of authority, or a substantial and specific danger to public health or safety, or (4) any other whistleblower protection. The definitions, requirements, obligations, rights, sanctions, and liabilities created by controlling Executive orders and statutory provisions are incorporated into this agreement and are controlling."*

b. The limitation above shall not contravene requirements applicable to Standard Form 312, Form 4414, or any other form issued by a Federal department or agency governing the nondisclosure of classified information.

c. Notwithstanding the provision listed in paragraph (a), a nondisclosure confidentiality policy form or agreement that is to be executed by a person connected with the conduct of an intelligence or intelligence-related activity, other than an employee or officer of the United States Government, may contain provisions appropriate to the particular activity for which such document is to be used. Such form or agreement shall, at a minimum, require that the person will not disclose any classified information received in the course of such activity unless specifically authorized to do so by the United States Government. Such nondisclosure or confidentiality forms shall also make it clear that they do not bar disclosure to congress, or to an authorized official of an executive agency or the Department of Justice, that are essential to reporting a substantial violation of law.

4. INTERIM CONFLICT OF INTEREST POLICY FOR FINANCIAL ASSISTANCE

The DOE interim Conflict of Interest Policy for Financial Assistance (COI Policy) can be found at https://www.energy.gov/management/financial-assistance-letter-no-fal-2022-02. This policy is applicable to all non-Federal entities applying for, or that receive, DOE funding by means of a financial assistance award (e.g., a grant, cooperative agreement, or technology investment agreement or similar other transaction agreement) and, through the implementation of this policy by the entity, to each Investigator who is planning to participate in, or is participating in, the project funded wholly or in part under the DOE financial assistance award. DOE's interim

COI Policy establishes standards that provide a reasonable expectation that the design, conduct, and reporting of projects funded wholly or in part under DOE financial assistance awards will be free from bias resulting from financial conflicts of interest or organizational conflicts of interest. The applicant is subject to the requirements of the interim COI Policy and within each application for financial assistance, the applicant must certify that it is, or will be by the time of receiving any financial assistance award, compliant with all requirements in the interim COI Policy. For applicants to any ARPA-E NOFO, this certification, disclosure of any managed or unmanaged conflicts of interest, and a copy of (or link to) the applicant's own conflict of interest policy must be included with the information provided in the Business Assurances & Disclosures Form. The applicant must also flow down the requirements of the interim COI Policy to any subrecipient non-Federal entities.

5. COMPLIANCE AUDIT REQUIREMENT

A recipient organized as a for-profit entity expending $1,000,000 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 has expended $1,000,000 or more of Federal funds (including funds expended as a Subrecipient) 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.

6. RESEARCH SECURITY TRAINING REQUIREMENT

Covered individuals listed on applications under this NOFO are required to certify that they have taken research security training consistent with Section 10634 of the CHIPS and Science Act of 2022. In addition, applicants who receive an award must maintain sufficient records (records must be retained for the time period noted in 2 CFR 200.334 and made available to DOE upon request) of their compliance with this requirement for covered individuals at the Recipient organization and they must extend this requirement to any and all Subrecipients. To fulfill this requirement, an applicant may utilize the four one-hour training modules developed by the National Science Foundation at https://new.nsf.gov/research-security/training or develop and implement their own research security training program aligned with the requirements in Section 10634(b) of the CHIPS and Science Act of 2022. The submission of an application to this NOFO constitutes the applicant's acceptance of this requirement.

7. TECHNOLOGY PROTECTION PLAN

The Recipient must submit a Technology Protection Plan within 60 days of award setting out the Recipient's policies and procedures for identifying, accessing, handling, controlling, and releasing the following under this Award: (1) Recipient's proprietary information, including non-

public technical information, trade secrets and other confidential business information, including but not limited to information, know-how, methods or processes that give the Recipient a competitive advantage in the marketplace; (2) information that is subject to U.S. export control laws or regulations; (3) information that has been designated as classified or controlled unclassified information (CUI) by DOE/ARPA-E; (4) any other information designated by DOE/ARPA-E as sensitive throughout the period of performance. The Recipient must meet the stated objectives set forth in its Technology Protection Plan. The Recipient must notify ARPA-E of any revisions to the Technology Protection Plan or the proposed security approach. A report on the Recipient's progress toward meeting the objectives and milestones set forth in the Technology Protection Plan must be included in any continuation application. The Technology Protection Plan and any revisions to the plan and all related deliverables must be emailed securely to the point of contact designated by ARPA-E.

Any review comments or feedback provided to the Recipient does not constitute an endorsement or approval of any specific elements within the Technology Protection Plan or the proposed security approach. Therefore, such feedback should not be referenced or used in marketing or promotional materials.

C. REPORTING

Recipients are required to submit periodic, detailed reports on technical, financial, and other aspects of the project, as described in Attachment 4 to ARPA-E's Model Cooperative Agreement (https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/funding-agreements).

1. FRAUD, WASTE, AND ABUSE

An applicant, recipient, or subrecipient must promptly disclose whenever in connection with the federal award (including any activities or subawards thereunder), it has credible evidence of the commission of a violation of Federal criminal law involving fraud, conflict of interest, bribery, or gratuity violations found in Title 18 of the United States Code or a violation of the civil False Claims Act (31 U.S.C. 3729-3733). The disclosure must be made in writing to the Federal agency, the agency's Office of Inspector General, and pass-through entity (if applicable.) Recipients and subrecipients are also required to report matters related to recipient integrity and performance in accordance with Appendix XII of this part. Failure to make required disclosures can result in any of the remedies described in 2 C.F.R. §200.339. (See also 2 C.F.R. part 180, 31 U.S.C. 3321, and 41 U.S.C. 2313.)

For guidance on reporting such violations and information to the DOE Office of Inspector General (OIG), please visit https://www.energy.gov/ig/ig-hotline.

You may report fraud, waste, mismanagement, or misconduct involving SBA programs or employees either online (https://www.sbir.gov/fraud-waste-abuse) or by calling the OIG Hotline toll-free at (800) 767-0385.

2. COMMERCIALIZATION PLAN AND SOFTWARE REPORTING

If your project is selected and it targets the development of software, you may be required to prepare a Commercialization Plan for the targeted software and agree to special provisions that require the reporting of the targeted software and its utilization. This special approach to projects that target software mirrors the requirements for reporting that attach to new inventions made in performance of an award.

VIII. OTHER INFORMATION

A. TITLE TO SUBJECT INVENTIONS

Ownership of subject inventions is governed pursuant to the authorities listed below:

- 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;
- All other parties: The federal Non-Nuclear Energy Act of 1974, 42. U.S.C. 5908, provides that the government obtains title to new subject inventions unless a waiver is granted (see below):
  - Class Patent Waiver for Domestic Large Businesses: DOE has issued a class patent waiver that applies to this NOFO. Under this class patent waiver, domestic large businesses may elect title to their subject inventions similar to the right provided to the domestic small businesses, educational institutions, and nonprofits by law. In order to avail itself of the class patent waiver, a domestic large business must agree to the U.S. Competitiveness Provision in accordance with Section VII.B.2 of this NOFO.
  - Advance and Identified Waivers: For applicants that do not fall under the class patent waiver or the Bayh-Dole Act, those applicants may request a patent waiver that will cover subject inventions that may be made under the award, in advance of or within 30 days after the effective date of the award. Even if an advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver for identified inventions, i.e., individual subject inventions that are disclosed to DOE within the time frames set forth in the award's intellectual property terms and conditions. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784.
- DEC: On June 07, 2021, DOE approved a DETERMINATION OF EXCEPTIONAL CIRCUMSTANCES (DEC) UNDER THE BAYH-DOLE ACT TO FURTHER PROMOTE DOMESTIC MANUFACTURE OF DOE SCIENCE AND ENERGY TECHNOLOGIES. In accordance with this DEC, all awards, including sub-awards, under this NOFO made to a Bayh-Dole entity (domestic small businesses and nonprofit organizations) shall include the U.S. Competitiveness Provision in accordance with Section VII.B.2 of this NOFO. A copy of the DEC may be found on the DoE website. Pursuant to 37 CFR § 401.4, any Bayh-Dole entity affected by this DEC has the right to appeal it by providing written notice to DOE within 30 working days from the time it receives a copy of the determination.

B. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

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

1. GOVERNMENT USE LICENSE

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

2. MARCH-IN RIGHTS

The U.S. Government retains march-in rights with respect to all subject inventions. Through "march-in rights," the Government may require a 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 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: Pursuant to special statutory authority for SBIR/STTR awards, data generated under ARPA-E SBIR/STTR awards may be protected from public disclosure for twenty years from the date of award 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).

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 Preliminary Application, Full Application, Reply to Reviewer Comments, and Small Business Grant Application (if applicable).

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

Covered Individual: an individual who contributes in a substantive, meaningful way to the scientific development or execution of an R&D project proposed to be carried out with an award from ARPA-E. This includes, but is not limited to, the PI, Co-PI, Key Personnel, and technical staff (e.g., postdoctoral fellows/researchers and graduate students). ARPA-E may further designate covered individuals during award negotiations or the award period of performance.

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

Foreign Affiliation: A funded or unfunded academic, professional, or institutional appointment or position with a foreign government or government-owned entity, whether full-time, part-time, or voluntary (including adjunct, visiting, or honorary).

For-Profit Organizations (or For-Profit Entities): Entities organized for-profit that are Large Businesses or Small Businesses as those terms are defined elsewhere in this Glossary.

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

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

Institutions of Higher Education (or *educational institutions*): Has the meaning set forth at 20 U.S.C. 1001.

Large Business: Large businesses are entities organized for-profit other than small businesses as defined elsewhere in this Glossary.

Malign Foreign Talent Recruitment Program: The meaning given such term in section 10638 of the Research and Development, Competition, and Innovation Act (division B of Public Law 117–167) or 42 USC 19237, as of October 20, 2022.

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

PI: Principal Investigator.

SBA: U.S. Small Business Administration.

SBIR: Small Business Innovation Research Program.

Small Business: Small businesses are 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).

STTR: Small Business Technology Transfer Program.

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.

TT&O: Technology Transfer and Outreach. (See Section I.H.8 of the NOFO for more information).