FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

OPTIMIZING NUCLEAR WASTE AND ADVANCED REACTOR DISPOSAL SYSTEMS (ONWARDS)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0002530
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	May 19, 2021
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, Wednesday, June 30, 2021
Submission Deadline for Concept Papers:	9:30 AM ET, Friday, July 9, 2021
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	9:30 AM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	January 2022
Total Amount to Be Awarded	Approximately $40 million, subject to the availability of appropriated funds to be shared between FOAs DE-FOA-0002530 and DE-FOA-0002531.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

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

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

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REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 6 pages in length including graphics, figures, and/or tables, and must include the following: ○ Concept Summary ○ Innovation and Impact ○ Proposed Work ○ Team Organization and Capabilities	Mandatory	IV.C	9:30 AM ET, July 9, 2021
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]	Optional	IV.E	5 PM ET, TBD

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy (DOE), is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358), as further amended by the Energy Act of 2020 (P.L. 116-260) to:

"(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 Funding Opportunity Announcement (FOA) under its authorizing statute codified at 42 U.S.C. § 16538. The FOA and any awards made under this FOA are subject to 2 C.F.R. Part 200 as 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 down the cost/performance metric in a gradual fashion. This continual improvement of a technology is important to its increased commercial deployment and is appropriately the focus of the private sector or the applied technology offices within DOE. By contrast, ARPA-E supports transformative research that has the potential to create fundamentally new learning curves. ARPA-E technology projects typically start with cost/performance estimates well above the level of an incumbent technology. Given the high risk inherent in these projects, many will fail to progress, but some may succeed in generating a new learning curve with a projected cost/performance metric that is significantly lower than that of the incumbent technology.

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

ARPA-E funds applied research and development. The Office of Management and Budget defines "applied research" as an "original investigation undertaken in order to acquire new knowledge…directed primarily towards a specific practical aim or objective" and defines "experimental development" as "creative and systematic work, drawing on knowledge gained from research and practical experience, which is directed at producing new products or processes or improving existing products or processes."[1] Applicants interested in receiving financial assistance for basic research (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")[2] should contact the DOE's Office of Science (http://science.energy.gov/). Office of Science national scientific user facilities (http://science.energy.gov/user-facilities/) are open to all researchers, including ARPA-E Applicants and awardees. These facilities provide advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. Projects focused on early-stage R&D for the improvement of technology along defined roadmaps may be more appropriate for support through the DOE applied energy offices including: the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy (http://fossil.energy.gov/), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

B. PROGRAM OVERVIEW

The program goal of ONWARDS is to support the development of technologies that address significant challenges to closing the back-end (see Figure 1) of advanced reactor (AR) nuclear fuel cycles[3]. Specifically, projects funded under the ONWARDS Program will develop and

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

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

[3] Generation IV (Gen IV) ARs designs include, but are not limited to, very-high temperature reactors (VHTR), molten-salt reactors (MSR), supercritical-water-cooled reactors (SCWR), gas-cooled fast reactors (GFR), sodium-cooled fast reactor (SFR), and lead-cooled fast reactors (LFR). https://www.gen-4.org/gif/jcms/c_59461/generation-iv-systems

demonstrate sustainable technologies that will significantly improve the *disposal impact* (Section I.C below) of used nuclear fuel (UNF)[4] and other waste streams stemming from the implementation of AR fuel cycles by developing innovative and cost-effective approaches in reprocessing[5], material accountancy, and waste forms. ONWARDS metrics include an order-of-magnitude reduction in AR waste volume generation or repository footprint compared to light-water nuclear reactors (LWR)[6], better than 1% fissile-mass accountancy in reprocessing streams, development of high-performance AR waste forms for a variety of potential deep-geological repositories (DGR) and disposal concepts, and costs in the range of $1/megawatt-hour (MWh).

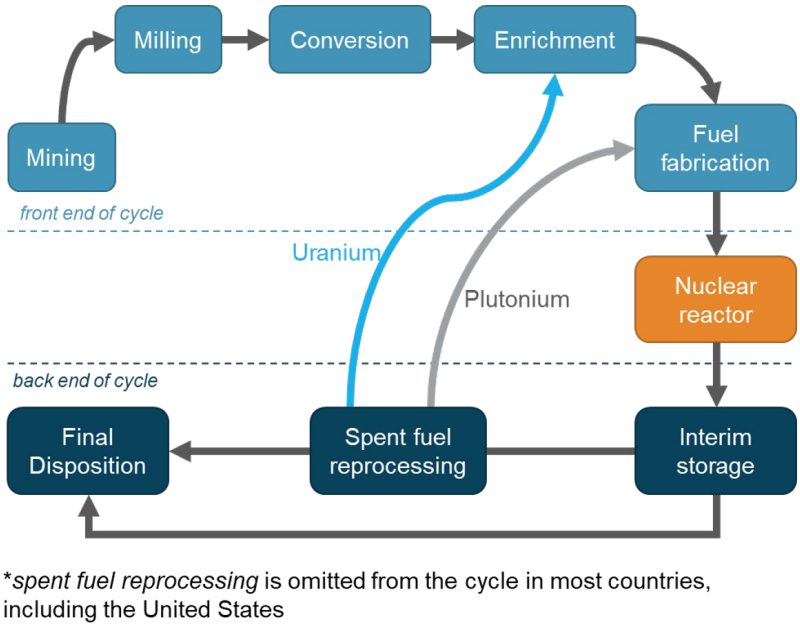

Figure 1: Nuclear Fuel Cycle

This FOA is focused on supporting the development of viable technologies to achieve these metrics. Technical categories of interest are identified in Section I.D of the FOA. Performance targets for the technical categories of interest are provided in Section I.E of the FOA. Section I.F of the FOA provides information on research resources and teaming partnerships that may support Applicants in successfully completing the research and development (R&D) activities necessary to demonstrate the viability of the proposed technology.

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[4] UNF is also known as "spent nuclear fuel" (SNF). https://www.energy.gov/ne/articles/5-fast-facts-about-spent-nuclear-fuel

[5] Reprocessing refers generally to the processes used to separate spent nuclear reactor fuel into nuclear materials that may be recycled for use in new fuel and material that would be discarded as waste. Nuclear Regulatory Commission. 2021. "Reprocessing". https://www.nrc.gov/materials/reprocessing.html

[6] U.S. Nuclear Regulatory Commission (NRC). "Light water reactor". August 25, 2020. https://www.nrc.gov/reading-rm/basic-ref/glossary/light-water-reactor.html

Early consideration of the back-end of the fuel cycle in the AR design process offers a unique opportunity to develop technologies to improve the disposal impact of AR UNF. ONWARDS addresses both open (once-through, no reprocessing) and closed (reprocessing) AR fuel cycles to capture the widest range of likely fuel cycles and to proactively mitigate the disposal impact of waste streams, waste forms, safety and security issues, and final disposition of AR wastes. This Program seeks to enable proliferation-resistant fuel cycles for ARs with an emphasis on minimizing the impact of AR fuel cycle wastes. ONWARDS will be an important complement to ARPA-E's existing nuclear energy research portfolio, such as the MEITNER[7] and GEMINA[8] programs in AR R&D, further ensuring the commercial viability of innovative new ARs. Figure 2 below shows the complementary nature of ARPA-E R&D in this space using a hypothetical AR Closed Fuel Cycle example.

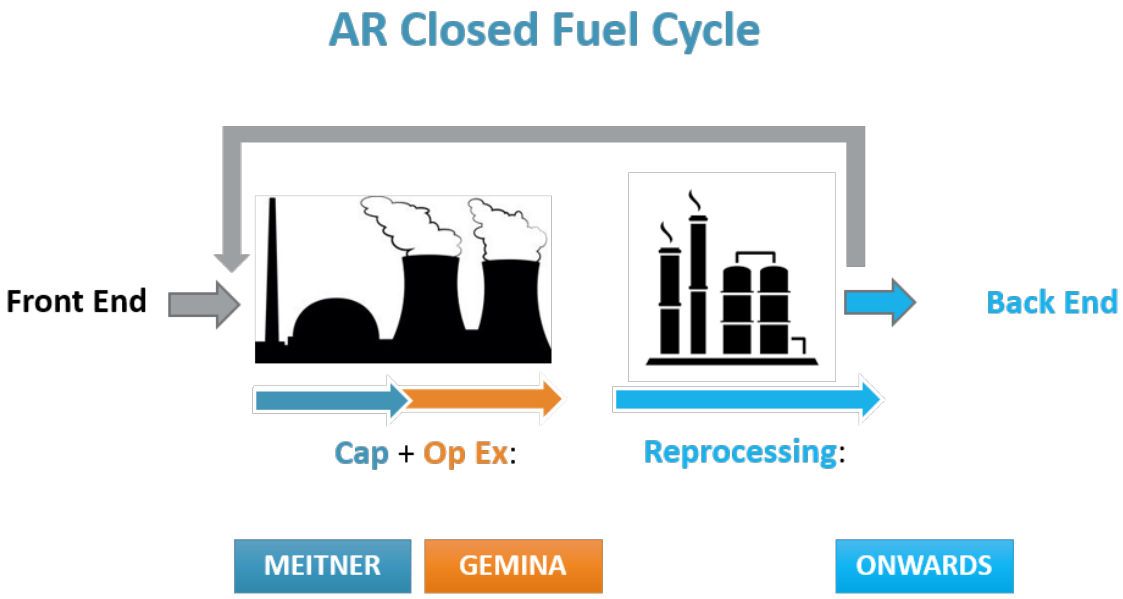

Figure 2 ARPA-E research and development in the advanced reactor technology space

Although the total volume of wastes from the current and likely future fleets of nuclear reactors is small[9] compared to many other energy resources, the special nature of the wastes (e.g., radioactivity, potential for diversion) have posed challenges that, to date, have not been addressed satisfactorily enough to achieve the final disposition of high-level wastes (HLW)[10]

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[7] *Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration* (MEITNER) seeks to identify and develop innovative technologies that can enable designs for lower cost, safer advanced nuclear reactors. https://arpa-e.energy.gov/technologies/programs/meitner

[8] *Generating Electricity Managed by Intelligent Nuclear Assets* (GEMINA) aims to develop digital twin technology for advanced nuclear reactors and transform operations and maintenance (O&M) systems in the next generation of nuclear power plants. https://arpa-e.energy.gov/technologies/programs/gemina

[9] U.S. Department of Energy's (USDOE) Office of Nuclear Energy (NE). "5 Fast Facts about Spent Nuclear Fuel". March 30, 2020. https://www.energy.gov/ne/articles/5-fast-facts-about-spent-nuclear-fuel

[10] NRC. "High-level radioactive waste (HLW)". March 09, 2021. https://www.nrc.gov/reading-rm/basic-ref/glossary/high-level-radioactive-waste-hlw.html

from any commercial nuclear fuel cycle[11]. The lack of a clear final disposition path poses a challenge not only to the sustainability of the current fleet of LWRs, but also to the development and deployment of the next generation of ARs. By identifying and addressing challenges at the back end of the fuel cycle before the deployment of future AR technologies, ONWARDS will support the removal of substantial barriers to the growth of advanced nuclear energy. Additionally, by supporting this R&D during the pre-deployment phase of AR fuel cycles, ONWARDS seeks to leverage the possibility of co-development synergies throughout the AR fuel cycles.

It is recognized that R&D of enabling back-end technologies to support U.S. AR fuel cycles may necessitate access to research resources (e.g., materials, facilities, software, computing resources, subject matter experts) to support the development and testing of sensors in a high radiation environment[12], for the processing of nuclear fuel, for the storage and disposal of radioactive and/or hazardous materials, hot-cells and gloveboxes, and high-performance computing codes and facilities, among other needs. Applicants without existing access to such research resources are encouraged to establish teaming relationships with commercial entities, National Laboratories, universities, etc., with such research resources in order to successfully complete their proposed R&D activities. Applicants without access to required research resources or teaming relationships that enable access to required research resources **will not be disqualified,** nor will they be deemed nonresponsive at the Concept Paper stage for that reason alone; however, applicants at the Full Application stage will need to be able to demonstrate that they have access to the research resources needed to successfully complete R&D activities under the subsequent full-application FOA. Additional information regarding research resources and teaming relationships can be found in Section I.F of the FOA.

C. PROGRAM OBJECTIVES

This Program will support breakthrough R&D that will facilitate the growth of AR fuel cycles and advanced nuclear energy by addressing significant challenges at the back-end of AR nuclear fuel cycles. Specifically, ONWARDS seeks to support development of technologies that enable:

- An order-of-magnitude reduction (compared to a no-reprocessing baseline) in waste volumes or repository footprint with no weakening of existing safeguards standards[13].

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[11] A. David Rossin. "U. S. Policy On Spent Fuel Reprocessing: The Issues". *Frontline*. 2014. https://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/rossin.html

[12] As defined in 10 CFR 20.1003, a "High radiation area means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or 30 centimeters from any surface that the radiation penetrates." https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html

It should be noted that UNF radiation levels may be orders of magnitude higher than the 10 CFR 20.1003 level, and consequently the sensors may need to be operate in these much higher regimes.

[13] NRC. "Nuclear Security and Safeguards". August 24, 2020. https://www.nrc.gov/security.html

- Development of safeguards technologies for AR UNF processing for which there is no existing economically and/or technically viable solution. The goal is to achieve better than 1% accuracy[14] in fissile[15] mass measurement of representative samples in UNF processing in high-radiation backgrounds.
- Proliferation-resistant recycling of uranium (U) and transuranic (TRU) materials[16] for new AR fuel stock. No pure fissile material streams produced during processing, as defined by less than 0.1% actinides by mass in resultant waste stream.
- High durability waste forms for AR UNF (specifically for TRISO fuel, metallic fuel, and/or molten salt reactor (MSR) fuel wastes) across multiple disposal environments.
- Global system disposal costs in the range of $1.00/MWh[17].

The exact nature of the technologies that will determine the needs for the back-end of future AR fuel cycles is both presently undetermined and likely to evolve over time as ARs are deployed and technologies updated. Therefore, **ARPA-E seeks submissions that include technologies that can span multiple AR fuel cycles, disposal concepts, and environments while achieving otherwise high performance.** Further, while this Program requires proposed technologies to be specific to AR fuel cycle concepts, ARPA-E also is interested in submissions that include technologies with backwards compatibility to existing commercial LWR fuel cycle wastes[18], assuming otherwise high performance.

ARPA-E has identified six impact areas as the most important areas that need to be addressed in the development of novel technologies to support the disposal of wastes from AR fuel cycles. Collectively these areas form the disposal impact concept, and submissions to this FOA must describe how the proposed technological innovation, if successful, would affect them. Concept Papers need not necessarily address all of these areas, but collective improvements in one area will be assessed against negative impacts to other areas, and applications that make the greatest positive impacts in as many of these areas as possible while minimizing potential negative impacts in each of the areas are encouraged. The six impact areas are:

i) **Economics**: How will the proposed technology impact the economics of the overall fuel cycle; specifically, what impact will the technology have on the cost of the back-end of the fuel cycle?

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[14] ISO 5725-2:2019, "Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method" https://www.iso.org/standard/69419.html

[15] NRC. "Fissile material". March 9, 2021. https://www.nrc.gov/reading-rm/basic-ref/glossary/fissile-material.html

[16] National Academies. *Proliferation Risk in Nuclear Fuel Cycles: Workshop Summary*; Chapter 3: "Technical Assessment of Proliferation Resistance". (2011). https://www.nap.edu/read/13259/chapter/5

[17] This is consistent with the fee of 1.0 mill per kilowatt-hour ($0.001/kWh, equal to $1.00/MWh) set by the *Nuclear Waste Policy Act of 1982*, as amended, to fund the Nuclear Waste Fund.

[18] World Nuclear Association. "Nuclear Fuel Cycle Overview" (Updated May 2020). https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx

ii) **Existing Infrastructure Utilization**: How will the proposed technology leverage the existing nuclear infrastructure; alternatively, what substantial investments need to be made to successfully implement the proposed technology?

iii) **Regulatory Requirements**: Is the proposed technology compatible with the existing U.S. nuclear regulatory framework? If not, briefly summarize the significant areas of deviation from existing regulations and the reason(s) an acceptable solution may be developed in the future.

iv) **Resource Utilization**: How does the proposed technology promote resource conservation and recovery or otherwise reduce the consumption of raw materials?

v) **Safeguards and Security**: How does the proposed technology impact the safeguarding and security of special nuclear and other sensitive materials? Summarize significant areas of deviation from recognized safeguarding standards (e.g., 10 CFR Part 75) and the reason(s) why you think this might be acceptable in the future.

vi) **Siting Options and Requirements**: Summarize the impact the proposed technology would have on the ability to site a permanent disposal, an interim storage, or other process facility. Describe the impact the proposed technology would have on existing requirements for such a facility.

D. TECHNICAL CATEGORIES OF INTEREST

Three AR fuel cycle concepts, and their variants, are presently considered most promising; however, a fourth fuel cycle concept, "Other FC", has been provided to capture breakthrough fuel cycle technologies:

1) TRi-structural ISOtropic particle (TRISO) fuel cycles[19]
2) Metallic fuel cycles[20]
3) Molten salt fuel cycles[21]
4) Other FC[22]

Three technological categories have been identified as offering the most likely avenues to achieving substantial improvements in disposal impact for the above AR fuel cycles and will thus form the technical categories of this FOA. A fourth category, "Other", has been provided to capture breakthrough technologies that do not fit into the three listed technological areas, but that

[19] USDOE NE. "TRISO Particles: The Most Robust Nuclear Fuel on Earth". July 9, 2019. https://www.energy.gov/ne/articles/triso-particles-most-robust-nuclear-fuel-earth

[20] NRC. "Nuclear Metal Fuel: Characteristics, Design, Manufacturing, Testing, and Operating History". White Paper 18-01, Prepared by the Fast Reactor Working Group. June 2018. https://www.nrc.gov/docs/ML1816/ML18165A249.pdf

[21] World Nuclear Association. "Molten Salt Reactors" (Updated December 2020). https://www.world-nuclear.org/information-library/current-and-future-generation/molten-salt-reactors.aspx

[22] World Nuclear Association. "Nuclear Fuel and its Fabrication" (Updated September 2020). https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/fuel-fabrication.aspx

could nonetheless enable the overall goals of the program as specified in Section I.C. of this FOA These categories are:

i) Category 1 - Process solutions: This technology area includes process improvements that minimize waste volumes, improve intrinsic proliferation resistance of actinide separations, increase resource utilization efficiency, and bolster commercialization.
ii) Category 2 - Safeguards solutions: This technology area includes improved sensor, analysis, and data fusion technologies that will allow for accurate, secure, and timely accounting of nuclear materials (a requirement for proliferation resistance).
iii) Category 3 - Waste form solutions: This technology area includes waste forms solutions for AR fuel cycles with a particular emphasis on waste forms for waste streams from pyroprocessing of UNF or spent fuel from metallic fuel reactors or MSRs.
iv) Category 4 - Other: This category is provided for submissions which do not cleanly fall into the above three categories, but that have the potential of meeting overall programmatic objectives (detailed in Section I.C). Submissions must make a compelling case for inclusion based on improvement the submission would deliver to the fuel cycle disposal impact.

Each applicant is required to indicate their primary technological area(s) of focus, as well as any secondary area(s), if appropriate.

I. Category 1 – Process solutions

Process solutions includes all processes in fuel fabrication and UNF processing that reduce waste (e.g., by recycling uranium and/or plutonium into new nuclear fuel) or otherwise improve the final waste forms or repository performance (e.g., an order of magnitude reduction in waste volumes or repository footprint with no weakening of existing safeguards standards). A further goal is reducing actinide content in process waste streams to less than 0.1% by mass. The focus will be on recycling technologies, which are discussed below in more detail.
There is also interest in processes besides recycling, e.g., process technologies that change the final waste to improve its disposal impact. Examples include:

- Separating >99% of cesium and strontium (either into one or two separate streams) from all other process stream or waste streams.
- Removal of >99% of insoluble fission products from fuel-containing molten salts.

Alternatively, separations that remove the most commercially valuable fission products could provide an alternative revenue-stream to help reduce the cost of the back-end of AR fuel cycles.

Processing Technologies

Many advanced fuel cycles rely on separation of some or all the actinides from the fission products, allowing fissile material to remain in the fuel cycle[23]. The separation of long- and

[23] International Atomic Energy Agency (IAEA). "Spent Fuel Reprocessing Options". IAEA-TECDOC-1587. 2008. https://www-pub.iaea.org/MTCD/publications/PDF/te_1587_web.pdf

short-lived nuclides can reduce the volume of material that requires long-term storage[24]; however, the production of new high-volume waste streams (e.g., added solvents, off-gas, equipment) must be minimal relative to a once-through fuel cycle and have an established path to a robust waste form or final disposition. Further, an economically viable fuel cycle requires that any separation technology must have market appropriate capital and operating costs.

A variety of approaches currently exist that have been, or could be, used for the separations of UNF, including aqueous processing (solvent extraction), pyroprocessing, gaseous fluorination, supercritical CO_2, and chromatography.[25] Of interest to this FOA are technologies that address a linchpin issue that currently limits a technology's deployment for the management of AR UNF. Furthermore, technologies that are compatible with the production of follow-on fuel cycle needs (e.g., refueling, transmutation, isotope production) are sought.

While the Safeguards solutions portion of the FOA, Category 2 below, specifically discusses the development of sensors, monitoring, and other enabling technologies relevant to monitoring and safeguarding a nuclear processing *facility*, the role of safeguards and security-by-design must also be considered in processing technologies developed here (e.g., proposed technologies shall not generate pure plutonium streams) and any processing solution proposed shall not make safeguarding more challenging. Technologies should be proposed that encourage proliferation-resistance and/or intrinsically limit, at the chemical level, production of pure plutonium streams. ARPA-E is interested in process and production designs that would improve economics, security, and provide opportunities for safeguarding.

While breakthroughs in process efficiency that increase proliferation-resistant characteristics are of interest, so are technologies that could chemically prevent the production of pure plutonium streams.

As the two predominant processing approaches currently available, the specific examples of solvent extraction and pyroprocessing are discussed in greater detail below. However, as previously stated, novel technologies that enable other processing approaches are also of interest.

Solvent Extraction

The current standard method for separation of UNF, and the only method presently practiced on an industrial scale, is the PUREX (Plutonium Uranium Reduction EXtraction)[26] process. PUREX can also be modified to separate minor actinides, through processes like CoDCon (co-decontamination) or COEX (co-extraction of actinides). Since this FOA seeks innovative

[24] Baptista, Annibal; Parker, Joshua; Park, Jung-Ho. "Advantages and disadvantages of nuclear fuel reprocessing". *Energia Nucleara*; v. 19(1-2); p. 32-35. https://inis.iaea.org/search/search.aspx?orig_q=RN:39071523

[25] World Nuclear Association. "Processing of Used Nuclear Fuel" (Updated December 2020). https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx

[26] ibid

separations technologies, improvements to PUREX or other technologies considered during the Global Nuclear Energy Partnership (GNEP, now the International Framework for Nuclear Energy Cooperation, IFNEC)[27], such as NPEX (Neptunium / Plutonium EXtraction), TALSPEAK (Trivalent Actinide Lanthanide Separation with Phosphorus-Reagent Extraction from Aqueous Komplexes), TALSqUEAK (Trivalent Actinide–Lanthanide Separation using Quicker Extractants and Aqueous Komplexes, sometimes referred to as Advanced TALSPEAK) and ALSEP (Actinide Lanthanide Separation Process)[28], will only be of interest to ARPA-E under this FOA if they are shown to significantly improve, as delineated in Section I.F of the FOA, the disposal impact for one or more AR fuel cycles relative to their current version.

Many opportunities exist for the development of alternative solvent extraction technologies that would disrupt the processing landscape. Technologies that would enable the co-recovery of the AR fuel cycle relevant actinides (i.e., uranium through americium) in a single separation step could improve both the economics and potentially proliferation resistance. Other technologies that could improve the group separations of the actinides are also of interest.

Pyroprocessing

Pyroprocessing is the high-temperature, non-aqueous, electrochemical separation of UNF into different streams for re-use and/or disposal[29]. Pyroprocessing is potentially attractive for production of fuel for some fast-spectrum AR fuel cycles from used LWR fuel because the TRU elements, including plutonium, are not separated from each other, providing a level of proliferation defense-in-depth.[30] The high radiation field from the other TRU waste helps to mitigate the proliferation risk that would otherwise be associated with a process that enables the separation of pure plutonium.

Technologies that reduce the cost and footprint of future repositories, while maintaining or improving the safety, selectivity, and reliability of pyroprocessing, are of interest. This may include technologies that enable reduction and/or synergistic combinations of unit operations,

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[27] World Nuclear Association. "International Framework for Nuclear Energy Cooperation (Updated November 2016). https://world-nuclear.org/information-library/current-and-future-generation/international-framework-for-nuclear-energy-coopera.aspx

[28] Gelis, Artem & Vandegrift, Georg & Bakel, Allen & Bowers, Delbert & Hebden, Andrew & Pereira, Candido & Regalbuto, Monica. (2009). Extraction behaviour of actinides and lanthanides in TALSPEAK, TRUEX and NPEX processes of UREX+. *Radiochimica Acta*. https://www.researchgate.net/publication/244745650_Extraction_behaviour_of_actinides_and_lanthanides_in_TALSPEAK_TRUEX_and_NPEX_processes_of_UREX

Zarzana, Christopher A., Dean R. Peterman, Gary S. Groenewold, Lonnie G. Olson, Rocklan G. McDowell, William F. Bauer, and Sabrina J. Morgan. "Investigation of the impacts of gamma radiolysis on an advanced TALSPEAK separation." Separation Science and Technology 50, no. 18 (2015): 2836-2843. https://www.osti.gov/pages/servlets/purl/1294594

[29] Michael F. Simpson. "Developments of Spent Nuclear Fuel Pyroprocessing Technology at Idaho National Laboratory" (INL/EXT-12-25124). March 2012. https://inldigitallibrary.inl.gov/sites/sti/sti/5411188.pdf

[30] Argonne National Laboratory. "Recycling Used Nuclear Fuel for a Sustainable Energy Future". 2018. https://www.anl.gov/sites/www/files/2018-10/Pyroprocessing_brochure_2018.pdf

make batch operations continuous, simplify the handling and disposition of waste streams, or completely new processes that improve the cost-effectiveness, safety, and/or security of the pyroprocessing. Any new technologies must not increase the presence of actinides in waste streams, relative to state-of-the-art (SOA) capabilities, and shall not make safeguarding more challenging.

One important area of interest is pyroprocessing techniques with respect to different AR fuel types. Pyroprocessing has been demonstrated on metallic and molten salt fuels. Since many different AR designs and fuel types are being proposed, the ideal advancement in pyroprocessing technology would be applicable to a variety of AR designs and fuel types. It is required that all submissions related to this category discuss which types of fuels they are prepared to handle, and, what, if any, processing needs to be performed to handle different fuel types.

For metallic fuels, previous work includes alloy-forming liquid metal cathode and non-alloying solid metal cathodes. In these areas, research goals would include improved process demonstrations or significant innovations that reduce cost or improve safety, selectivity, and reliability.

For molten salt fuels, possible areas of interest for developing these technologies could include prototype-scale demonstrations/proof-of-principle combined with a conceptual model of a processing plant, and explorations of ideal operational parameters. In addition, due to the non-discrete nature of molten salt fuels, in-situ monitoring of fissile material is highly important for alleviating proliferation concerns. Monitoring must be real-time, rapid and high-precision, even within a high-radiation environment.

II. Category 2 - Safeguards solutions

AR fuel cycles may include UNF process steps not presently employed in the existing LWR commercial fleet. For example, pyroprocessing of metal fast reactor fuel includes dissolution of the fuel in a salt bath. This and other processing steps pose new safeguards challenges for determining and accounting for fissile material. The focus of this Technical Category is fissile material accountancy measurement technologies that will meet regulatory requirements and be accomplished at low time delay periods (latency) within the processing facility.

As discussed in Section I.D.I, processing of UNF often involves steps where the UNF has been transformed into a bulk form that is highly radioactive. The non-discrete form of the UNF during processing combined with a high radiation background poses major challenges for measuring the fissile material in-process or reconciling at end of process. Obtaining unique photon, neutron, or alpha signatures under these conditions are constrained by the difficulty of achieving the requisite signal to noise ratio (SNR) and full or unbiased sampling of the UNF process volume. The required measurement latency time should be commensurate with the

processing time (i.e., the fissile mass accountancy should be obtained before the processed UNF leaves the process Material Balance Areas, MBA)[31].

The U.S. Department of Energy's Office of Nuclear Energy (DOE NE) Materials Protection, Accounting, and Control Technologies (MPACT)[32] program highlights the challenges and possible solutions to safeguarding UNF processing. The MPACT program has studied advanced safeguards- and security-by-design for a generic electrochemical processing facility that illustrates many of the requirements to meet regulatory and non-proliferation requirements. MPACT's approach serves as an example of an overall safeguards-by-design scheme and highlights some fissile mass measurement technologies that pertain to the technical focus of this category.

Passive and active non-destructive analyses (NDA) will be considered under this FOA, as well as systems that sample the processing volume to extract representative unbiased samples. In all cases, the analysis must be performed on-site at the processing facility with the requisite latency discussed above. The goal is to achieve better than 1% accuracy in fissile mass measurement of representative samples in bulk UNF processing in high radiation backgrounds (gamma doses ~1000 R/hr or neutron emission rates ~ 10^4 – 10^5 neutron/sec). Examples of technologies that are in scope of this category include, but are not limited to:

- In-process passive and/or active NDA of fissile material, with an emphasis on unambiguous signatures, low latency, functionality in harsh environments and favorable life-cycle costs
    - Passive radiation signatures: gamma, neutron and alpha spectroscopy and characteristic X-rays[33]

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[31] *IAEA Material Balance Area means an area established for IAEA material accounting purposes, so that:*
(1) The quantity of nuclear material in each transfer into or out of each material balance area can be determined; and
(2) The physical inventory of nuclear material in each material balance area can be determined when necessary in accordance with specified procedures.
NRC. 10 CFR 75.4, "Definitions". June 04, 2018. https://www.nrc.gov/reading-rm/doc-collections/cfr/part075/part075-0004.html

[32] Durkee, et al. (2016) "Material Protection, Accounting, and Control Technologies (MPACT) Advanced Integration Roadmap". Los Alamos National Laboratory. https://doi.org/10.2172/1329653. https://www.osti.gov/servlets/purl/1329653.

Cipiti, et al. (2017) "Material Protection, Accounting and Control Technologies (MPACT) Implementation Plan Lab-Scale Demonstration of Advanced Safeguards and Security Systems", INL/EXT-17-43112. Idaho National Laboratory. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_3239.pdf

[33] Fensin, Michael L., Steven J. Tobin, Howard O. Menlove, and Martyn T. Swinhoe. "Quantifying the passive gamma signal from spent nuclear fuel in support of determining the plutonium content in spent nuclear fuel with nondestructive assay" No. LA-UR-09-03900; LA-UR-09-3900. Los Alamos National Lab. (LANL). 2009. https://www.osti.gov/servlets/purl/990302

  - Active radiation signatures: excitation of characteristic X-rays, k-edge densitometry laser-induced spectroscopy[34], visible and near visible spectroscopy, nuclear resonance fluorescence, neutron interrogation including induced fission, neutron multiplicity[35]
- Process modifications and sampling technologies that significantly improve NDA accuracy and volumetric sampling
- Modeling, to include sensor processing and data fusion, volumetric sampling analysis, and/or machine learning and artificial intelligence (AI/ML) techniques to extract greater "signal"
- Data fusion of multiple signatures and process control variables, AI/ML and other data analysis tools that enable achievement of mass accountancy metrics will also be considered

Passive radiation signatures that have been proposed[36] include gamma, alpha, and neutron spectroscopy and temporal correlation analysis; calorimetry; and microcalorimetry. A particular issue with many passive spectroscopic methodologies is extremely high radiation background (gamma doses ~1000 R/hr or neutron emission rates ~ 10^4 – 10^5 neutron/sec) during in-process monitoring that results in a low SNR, high (or completely overloaded) detector dead time and short detector lifetimes. Neutron measurements are subject to limitations due to non-specificity of neutron flux to fissile content (e.g., Cm background) and neutron multiplication in bulk processes. Active NDA technologies have also been proposed[37] for NDA at various steps and MBAs in the UNF process flow sheets. Active systems often have much greater footprint, complexity, and resource requirements, as well as maintenance and uptime issues. Control and process state monitoring, and other inferential measurements such as voltammetry, off-gas monitoring, and bulk properties measurements (e.g., mass, density), are also of interest. However, a clear quantitative description of how these inferential variables contribute to the unambiguous fissile mass accountancy must be provided. Other categories of interest include improvement in signal processing, increase in SNR from better shielding, pulse shape analysis, data fusion of complimentary isotopic signatures, spatial and temporal correlation of measurements, and advanced AI/ML techniques to enhance anomaly detection and/or improve accuracy.

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[34] Cook, Matthew Tyler. "Hybrid K-edge densitometry as a method for materials accountancy measurements in pyrochemical reprocessing." (2015). https://trace.tennessee.edu/cgi/viewcontent.cgi?article=4694&context=utk_graddiss

[35] Tiitta, Antero. "NDA verification of spent fuel, monitoring of disposal canisters, interaction of safeguards and safety issues in the final disposal." In Safeguards for final disposal of spent nuclear fuel: Methods and technologies for the Olkiluoto site, pp. A1-A16. Radiation and Nuclear Safety Authority STUK, 2003. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.568.2123&rep=rep1&type=pdf

[36] Jamie B. Coble, Steven E. Skutnik, S. Nathan Gilliam & Michael, P. Cooper (2020): Review of Candidate Techniques for Material Accountancy Measurements in Electrochemical Separations Facilities, *Nuclear Technology*, DOI:10.1080/00295450.2020.1724728

[37] Ibid

Simulation and modeling of the design-by-safeguards will be considered only if a reasonable case can be made that it significantly expands upon prior detailed studies or offers a fundamentally different and beneficial operation and measurement protocol from currently accepted practice.

Submissions to this category must propose cost-effective material balancing technologies that satisfy safeguards regulatory requirements to enable commercial-scale processing of UNF. Technologies that significantly advance the SOA with a life cycle cost consistent with the economics of UNF processing are encouraged, as are projects that can demonstrate the technology at a scale that can be reasonably extrapolated to production scale and across multiple processing technologies

III. Category 3 - Waste form solutions

Two essential characteristics govern waste performance in disposal systems. First is the capacity for immobilizing the radioactive or hazardous constituents incorporated in the waste form. Some materials chemically incorporate radioactive constituents at atomic scales, while other encapsulate constituents by physically surrounding and isolating them. The second essential characteristic is the durability of the waste form, which is a measure of the physical and chemical resistance of a waste form material to alteration which allows the associated release of contained radioactive and hazardous materials. The durability of a waste form material depends on its intrinsic properties as well as the physical and chemical conditions in the disposal environment into which it is emplaced.

The goal for research under this category is to achieve viable waste form solutions for AR UNF that support the overall program goal of achieving an order of magnitude reduction in waste form volume and/or repository footprint, and which are high performance from a durability and leaching perspective.

Borosilicate glass was selected for the stabilization of defense-related HLW in the 1980's.[38] Borosilicate glass was selected for the industrial simplicity of the manufacturing process, extensive international manufacturing experience, adequate waste loading, acceptable processing rates, economic factors, and its durability. Studies on the performance of borosilicate glass indicate that it will be able to provide acceptable performance in any of the disposal environments under consideration. However, waste containing components such as halides, sulfates, cesium, technetium, and heavy metals are either chemically incompatible (phase separation) or sparingly soluble leading to undesirable low waste loading which increases waste volume and time and cost of vitrification. [39]

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[38] Plodinec, M. J. "Borosilicate glasses for nuclear waste immobilization." *Glass Technology* 41, no. 6 (2000): 186-192. https://www.researchgate.net/profile/John-Plodinec/publication/233492606_Borosilicate_Glasses_for_Nuclear_Waste_Immobilization/links/55ca2bb808aeca747d69e20e/Borosilicate-Glasses-for-Nuclear-Waste-Immobilization.pdf

[39] National Research Council 2011. Waste Forms Technology and Performance: Final Report. Washington, DC: The National Academies Press. https://dio.org/10.17226/13100

There are other waste forms under development which may circumvent this problem, including alternative glasses, ceramics, metal-based solutions, and other waste form solutions. An alternative waste form, iron phosphate glass, has initially demonstrated a higher tolerance/solubility for halides, sulfates, and heavy metals, and can achieve high waste loading and has a higher density than other waste glass forms[40]. Additionally, zeolite dehalogenation has been demonstrated to allow for the formation of silicate glass waste forms[41]. Ceramic waste forms would include any crystal structure that incorporates waste, but one of the most well-studied examples for chloride waste salt is glass-bonded sodalite ceramic[42]. The formation of this ceramic involves incorporating the salt waste into zeolite, homogenizing with a glass binder, and heating the mixture to form sodalite (an alkali- and halide-containing aluminosilicate) that is encapsulated in glass. Ceramics containing wastes can be encapsulated in other materials besides glass, including metals such as copper[43]. These ceramic-metal (cermet) composites have not yet been demonstrated for salt-containing wastes, but they have increased thermal conductivity and waste form density over glass and have high waste loadings, making them potentially attractive assuming otherwise high performance.

It is a presupposition of this FOA that wastes from the back-end of AR fuel cycles will find ultimate disposition in geological repositories. Waste form development under this FOA should concentrate on wastes from ARs with an emphasis on wastes from molten salt reactors, metallic fuel reactors, or from reprocessing (not exclusively, but especially from pyroprocessing) and should be compatible with the major existing repository concepts:

i) mined repository in salt formations,
ii) mined repository in clay or shale rocks,
iii) mined repository in crystalline rock,
iv) mined repository in unsaturated geology.

Additionally, compatibility of waste forms with disposal in boreholes may be considered. Waste form solutions may include novel highly-durable waste matrices or packaging or any other technological solution that improves the repository performance of the physical waste form.

IV. Category 4 - Other

This category is provided for submissions which do not cleanly fall into the above three categories, but that have the potential of meeting overall programmatic objectives (detailed in

[40] Huang, Wenhai, Delbert E. Day, Chandra S. Ray, Cheol-Woon Kim, and Andrea Mogus-Milankovic. "Vitrification of high chrome oxide nuclear waste in iron phosphate glasses." *Journal of Nuclear Materials* 327, no. 1 (2004): 46-57. https://www.academia.edu/download/39230883/00b7d528dc301144a2000000.pdf

[41] Arm et al. "Status of Fast Spectrum Molten Salt Reactor Waste Management Practice". PNNL (2020). https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-30739.pdf

[42] Riley et al. "Identification of Potential Waste Processing and Waste Form Options for Molten Salt Reactors". U.S. Department of Energy (2018). https://info.ornl.gov/sites/publications/Files/Pub114284.pdf

[43] ibid

Section I.C of this FOA). Submissions must make a compelling case for inclusion based on improvement the submission would deliver to the fuel cycle disposal impact.

E. TECHNICAL PERFORMANCE TARGETS

I. Category 1 – Process solutions

Applicants proposing development of a technology for separating the components of used nuclear fuel should describe how their innovation will accomplish one or more of the following targets of:

- An order of magnitude decrease in HLW repository volume or drift length relative to LWR SNF disposition on an absolute or per gigawatt-year (GWy) basis.
- Reducing actinide content in process waste streams to less than 0.1% by mass
- Providing U and TRU fuel stock suitable for AR refueling consistent with targets for waste streams
- Achieving process simplification by merging/ integrating two or more separate unit processes (e.g., mixing, reactions, separation), or by converting batch unit processes into continuous processes, to achieve significant (e.g., a factor of two or more) cost reductions in the combined processes.
- Providing a dramatically simpler and cost-effective solution for separation of FP and actinides or FP sub-groups.
- Separating >99% of cesium and strontium (into either one or two separate streams) from all other process stream or waste streams.
- Removal of >99% of insoluble fission products from fuel-containing molten salts

All of the following requirements must be met:

- The proposed technology produces an intrinsically proliferation resistant separation and does not at any point create a pure fissile separation.
- The proposed technology will be capable of demonstrating an equivalent throughput processing rate of 1 kg/day for 8 h without any loss of selectivity. While new processes must be demonstrated at this scale, applicants may justify the use of surrogates at larger scale and restricting chemistry with particularly hazardous materials to a smaller scale.
- The proposed technology is either compatible with at least one existing licensed waste form or is codeveloped with a compatible waste form suitable for final geological disposal.

An applicant to this Category shall provide an overview description of their proposed technology that includes:

- The type(s) of UNF that will be processed.
- A short description of how the proposed process meets the impact areas discussed in Section I.C of the FOA.

- A comparison of the proposed technology's performance and cost to SOA technologies applied under proposed conditions.
- The expected maturity (e.g., lab-scale, pilot-demonstration, commercialization) of the proposed technology at the completion of the project as demonstrated by process' equivalent throughput (kg/day).

In addition, each Applicant to this Category must provide the information in Table I.E.I, in summary form.

Table I.E.I: Process Technology Description	
Property	**Description**
Describe proliferation resistance properties	
Provide types and volumes of waste stream per metric ton (MT) of HLW, including the isotopic and chemical composition of each waste stream	
Describe each waste stream and waste form from process, including the NRC-approval state of the waste form, and the need (if any) for the waste form to be co-developed?	
Provide a description of the fuel stock(s) produced	
Estimated commercial scale processing facility capital expenditure (CapEx) and annual Operating and Maintenance (O&M) costs	
Provide scale of facility/modules in units of MT HLW/year.	

II. Category 2 – Safeguards solutions

Unambiguous determination of fissile mass must be the outcome; therefore, proposed technical solutions must provide fissile mass accountancy to better than 99% (< 1% accuracy in mass accountancy) with the following constraints:

- If an inferential signature is proposed, validation data must be provided to demonstrate the accuracy of fissile mass determination.
- If active analysis, full system must meet all system constraints.

- If full volume of UNF is not sampled, an extrapolation methodology must be specified, and validation procedure defined.
- The solution must be operational in high radiation backgrounds that may be encountered during processing.
- Accountancy latency must be at same time scale (or less) as any proposed process.
- Maintenance and service schedules must be consistent with the overall system.

Each applicant to this Category shall provide a schematic with all major system components identified, including required ancillary equipment and provide the information in Table I.EII.1.

Table I.EII.1: System Definition

Property	Description
Process location(s) where sensor is located	
Description of mass accountancy validation (must include realistic sensor data rates, for both signal and backgrounds both from target mass and external sources)	
Latency or throughput of measurement	
Sampling methodology	
Comparison to State-of-the-Art	
Validation Methodology for accuracy determination (including recalibration schedule)	
Scale of technology demonstration to actual operating conditions.	
Estimated Total System Cost	
Schedule for, and cost estimates of, maintenance (include all types of maintenance required, time required for actual servicing, operational or chronological time periods between required maintenance, and any replacement components or consumables needed)	

Table I.EII.1: System Definition	
Property	**Description**
Mean Time Before Failure (include basis)	

For each measurement used to determine the fissile mass accountancy, the applicant shall provide an overview description of the signature and measurement methodology utilized, and, if the methodology utilizes an inferential measurement, an explanation of its relationship to mass accountancy. The following information must be included in the measurement description:

- The units of measurement
- Measurement latency
- An estimate of measurement uncertainty and accuracy, including how these were determined
- A description of the location(s) sampled
- Requirements to accomplish measurement
- The fraction of the volume sampled and method of sampling
- Information requested in of Table I.EII.2

Table I.EII.2: Measurement Description	
Technology Attribute	**Description**
Allowed gamma flux (part/s/cm^2)	
Gamma energy min/max (keV)	
Allowed neutron flux (part/s/cm^2)	
Neutron energy min/max (keV)	
Latency (sec) for result	
Operating atmosphere?	
Maximum allowed temperature (C)	
Estimated unit cost ($)	
Estimated annual O&M ($)	
Estimated lifetime (years)	

III. Category 3 – Waste form solutions

Because of uncertainty of the disposal environment waste form solutions should be applicable to a wide range of geologies and disposal concepts. For each proposed waste form solution, all submissions must address the following:

- Detailed description of the fuel cycle and waste processes (if applicable to this solution)
- Detailed description of technology and comparison to SOA performance

- Detailed description of the scale at which the technology be demonstrated, along with an explanation of how performance at that scale can be extrapolated to commercial scale

Research under this topic must support the program goals of achieving viable waste form solutions for AR UNF (particularly for TRISO, metallic fuel, and molten salt fuel cycles) and an order of magnitude reduction in waste form volumes and/or repository footprint. High performance waste forms from a durability and leaching perspective are of particular interest so long as loading capacity is sufficiently high.

For each proposed waste form, provide the below information[44].

- Summarize the waste loading capacity of the waste matrix, and briefly describe any limiting factors for consideration (% waste loading capacity)
- Describe the degradation rate of the waste matrix (either fractional dissolution rate or g/m2/yr), including the standard used to determine the rate, the alteration product of the waste matrix, and how radionuclides are immobilized
- For the repository (or borehole) types enumerated in Section I.D. above, summarize the significant beneficial or detrimental repository/waste form interactions
- Briefly describe the methodology and results used to determine the waste form's stability at the likely thermal output from radionuclide inventory
- Briefly describe the methodology and results used to determine the waste form's stability at the likely radiation output from the radionuclide inventory
- Briefly describe the methodology and results used to determine the waste form's mechanical stability during pre- and post-emplacement time periods
- Briefly describe the methodology and results used to determine the waste form's inherent resistance to fire
- Summarize the maturity of the large-scale manufacturing technology associated with the potential scale-up of the proposed technology
- Briefly describe the methodology and results used to determine the unit and total cost estimate for the final product that is suitable for repository emplacement
- Briefly describe the methodology and results used to determine the waste form's annual O&M cost estimate

IV. Category 4 – Other

The target values for this category must be directly tied to the global program goals and specific targets from categories 1-3. Comparison must be made to SOA related to a proposed solution.

[44] The NRC, in 10 CFR Part 60, "Disposal of high-level radioactive wastes in geologic repositories" (https://www.nrc.gov/reading-rm/doc-collections/cfr/part060/index.html), has put into place applicable requirements related to waste forms. In addition, guidance documents, found in NRC Regulatory Guides (https://www.nrc.gov/reading-rm/doc-collections/reg-guides/index.html), provide clarifying information to support implementing specific regulations, including Part 60.

It is important to provide a clear description of why the proposed solution does not fit cleanly into categories 1-3 and how the selected targets from the other categories satisfy the global requirements of the program. All relevant information requested in Tables must be completed.

F. RESEARCH RESOURCES AND TEAMING PARTNERSHIPS

ARPA-E is in the process of developing a listing of DOE National Labs and other resources that may be available at the Full Application stage of this FOA to applicants that have not identified sufficient capabilities to complete activities proposed in their Concept Paper submission to this FOA.

It is anticipated that each applicant will either be in possession of the research resources or establish the requisite teaming partnerships needed to complete R&D activities under this FOA. Applicants without access to required research resources or teaming relationships that enable access to required research resources **will not be disqualified,** nor will they be deemed nonresponsive at the Concept Paper stage for that reason alone; however, applicants at the full application stage will need to be able to demonstrate that they have access to the research resources needed to successfully complete R&D activities under this FOA.

To facilitate the teaming arrangements described above, ARPA-E urges applicants and other interested parties to review the ONWARDS Team Partner List and to provide pertinent information described therein. The ONWARDS Team Partner List can be found at: https://arpa-e-foa.energy.gov/Default.aspx#FoaId7bbcf978-a550-4593-9574-4ae36cc14553

A list of DOE National Laboratories is available at:
https://science.osti.gov/sbir/ApplicantResources/National-Labs-Profiles-and-Contacts.

For help in contacting personnel at other Federal agency laboratories, go to www.federallabs.org, or contact DOE's Federal Laboratory Consortium for Technology Transfer (FLC, https://federallabs.org/) Management Support Office by phone at (856) 667-7727 or by email at flcmso@utrs.com.

Awardees could also leverage DOE Office of Nuclear Energy (DOE-NE) programs, such as the GAIN (Gateway for Accelerated Innovation in Nuclear) initiative (https://www.inl.gov/research-program/gain) and the Nuclear Science User Facilities (NSUF) Network (https://nsuf.inl.gov/), to perform strategic experiments–either during or after completion of the Program.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $40 million available for new awards under this FOA, to be shared between FOAs DE-FOA-0002530 and DE-FOA-0002531, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 10-15 awards under FOAs DE-FOA-0002530 and DE-FOA-0002531. ARPA-E may, at its discretion, issue one, multiple, or no awards.

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

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be April 2022, or as negotiated.

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

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

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

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

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

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

B. RENEWAL AWARDS

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

C. ARPA-E FUNDING AGREEMENTS

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[45] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.D below.

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[46]

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

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

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

Any Federally Funded Research and Development Centers (FFRDC) involved as a member of a

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

Project Team must provide the information requested in the "FFRDC Lab Authorization" and "Field Work Proposal" section of the Business Assurances & Disclosures Form, which is submitted with the Applicant's Full Application.

When a FFRDC/DOE Lab (including the National Energy Technology Laboratory or NETL) is the *lead organization* for a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the lead entity for the rest of the Project Team. Notwithstanding the use of multiple agreements, the FFRDC/DOE Lab is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

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

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

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

3. OTHER TRANSACTIONS AUTHORITY

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

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

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

D. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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

- Project Teams must adhere to ARPA-E's agency-specific and programmatic requirements.
- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- ARPA-E may, at its sole discretion, modify or terminate projects that fail to achieve predetermined Go/No Go decision points or technical milestones and deliverables.
- During award negotiations, ARPA-E Program Directors and Prime Recipients mutually establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. In addition, ARPA-E will negotiate and establish "Go/No-Go" milestones for each project. If the Prime Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Contracting Officer, ARPA-E may – at its discretion - renegotiate the statement of project objectives or schedule of technical milestones and deliverables for the project. In the alternative, ARPA-E may suspend or terminate the award in accordance with 2 C.F.R. §§ 200.339 and 200.340.
- ARPA-E may provide guidance and/or assistance to the Prime Recipient to accelerate the commercial deployment of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits[47] to provide mentoring and networking opportunities for Prime Recipients. ARPA-E may also organize and sponsor events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E may establish collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

[47] The term "nonprofit organization" or "nonprofit" is defined in Section IX.

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

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

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[48] as the lead for a Project Team,[49] or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

2. DOMESTIC ENTITIES

For-profit entities[50], educational institutions[51], and nonprofits[52] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

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

State, local, and tribal government entities are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

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

3. FOREIGN ENTITIES

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

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

[49] A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

[50] For-Profit Organizations (Other than Small Businesses) (or *large businesses*): Means entities organized for-profit other than small businesses as defined elsewhere in this Glossary.

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

[52] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

Foreign entities must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed or to be formed) under the laws of a State or territory of the United States to receive funding. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate. All work under the ARPA-E award must be performed in the United States. The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/ (see "View Template Application Documents"). Refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

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

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

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

B. COST SHARING[53]

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

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

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.C.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime Recipient must provide at least 20% of the Total Project Cost[54] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[55]

2. INCREASED COST SHARE REQUIREMENT

Large businesses[56] are strongly encouraged to provide more than 20% of the Total Project Cost as cost share. ARPA-E may consider the amount of cost share proposed when selecting applications for award negotiations (see Section V.B.1 of the FOA).

Under an "other transaction" agreement, the Prime Recipient is normally expected to provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this cost share requirement, as appropriate.

3. REDUCED COST SHARE REQUIREMENT

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

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is required to provide at least 5% of the Total Project Cost as cost share.
- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs/DOE Labs/Federal agencies and instrumentalities (other than DOE) are required to provide at least 5% of the Total Project Cost as cost share.Small businesses – or consortia of small businesses – may provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the "Cost Share Grace Period").[57] If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.
- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.

[54] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.
[55] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988(c)
[56] The term "For-Profit Organizations (Other than Small Businesses)" or "large business" is defined in Section IX.
[57] The term "small business" is defined in Section IX.

- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.
- Projects that do not meet any of the above criteria are subject to the base cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

4. LEGAL RESPONSIBILITY

Although the cost share requirement applies to the Project Team as a whole, the funding agreement makes the Prime Recipient legally responsible for paying, or ensuring payment of the entire cost share. The Prime Recipient's cost share obligation is expressed in the funding agreement as a static amount in U.S. dollars (cost share amount) and as a percentage of the Total Project Cost (cost share percentage). If the funding agreement is terminated prior to the end of the period of performance, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

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

5. COST SHARE ALLOCATION

Each Project Team is free to determine how much each Project Team member will contribute towards the cost share requirement. The amount contributed by individual Project Team members may vary, as long as the cost share requirement for the project as a whole is met.

6. COST SHARE TYPES AND ALLOWABILITY

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G of the FOA.

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

funding or property was not provided to the state or local government by the Federal Government.

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

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

In addition, Project Teams may not use independent research and development (IR&D) funds[58] to meet their cost share obligations under Cooperative Agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under "other transaction" agreements.

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

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

Applicants may wish to refer to 2 C.F.R. Parts 200 and 910, and 10 C.F.R Part 603 for additional guidance on cost sharing, specifically 2 C.F.R. §§ 200.306 and 910.130, and 10 C.F.R. §§ 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

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

[58] As defined in Federal Acquisition Regulation SubSection 31.205-18.

8. COST SHARE VERIFICATION

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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

Full Applications are deemed compliant if:

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

Full Applications found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Full Applications, including Full Applications submitted through other means, Full Applications submitted after the applicable deadline, and incomplete Full Applications. A Full Application is incomplete if it does not include required information and documents, such as Forms SF-424 and SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

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

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

2. RESPONSIVENESS CRITERIA

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

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that do not address the required technical information (i.e. information that "must" be included), as specified in Sections I.D and I.E of the FOA.
- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Submissions for proposed technologies that are not transformational, as described in Section I.A of the FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress.
- Submissions that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy. Submissions that describe a technology but do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

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

- Submissions that target fuel cycles other than those specified in Section I.D (i.e. fuel cycles other than TRISO fuel cycles, metallic fuel cycles, molten salt fuel cycles, and Other FC).
- Submissions dealing exclusively with back-end solutions for Generation III reactors or legacy CSNF accumulated to date,
- Submissions that exclusively seek to develop repository-specific technology.

4. LIMITATION ON NUMBER OF SUBMISSIONS

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

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

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

2. CONCEPT PAPERS

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

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

ARPA-E will encourage a subset of Applicants to submit Full Applications. Other Applicants will be discouraged from submitting a Full Application in order to save them the time and expense of preparing an application submission that is unlikely to be selected for award negotiations. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. Unsuccessful Applicants should continue to submit innovative ideas and concepts to future FOAs.

3. FULL APPLICATIONS

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

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

4. REPLY TO REVIEWER COMMENTS

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

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

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

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

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

6. SELECTION FOR AWARD NEGOTIATIONS

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

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

B. APPLICATION FORMS

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

C. CONTENT AND FORM OF CONCEPT PAPERS

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

- The Concept Paper must not exceed 6 pages in length including graphics, figures, and/or tables.
- The Concept Paper must be submitted in Adobe PDF format.
- The Concept Paper must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11 inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator's Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.
- The first paragraph must include the Lead Organization's Name and Location, Principal Investigator's Name, Technical Category, Proposed Funding Requested (Federal and Cost Share), and Project Duration.

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

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

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

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

1. CONCEPT PAPER

a. CONCEPT SUMMARY

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

b. INNOVATION AND IMPACT

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

  Indicate and briefly justify the primary and any secondary technology areas that best describe the proposed concept as described in Section I.D. of the FOA. Additionally, describe how the proposed technological innovation, if successful, would affect the impact areas described in Section I.C. of the FOA.

Impact Area	Effect relative to SOA (positive/negative/neutral)	Description or justification
Economics		
Existing Infrastructure Utilization		
Regulatory Requirements		
Resource Utilization		
Safeguards and Security		
Siting Options and Requirements		

- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Explain the concept's potential to be disruptive compared to existing or emerging technologies.
- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the Technical Performance Targets in Section I.E of the FOA for the appropriate Technology Category in Section I.D of the FOA. Provide any additional information requested for each category as defined in Section I.E.

  Provide the additional information below for each primary and secondary category.

For technology category 1, provide the information requested in Section I.E.I of the FOA and table I.EI.1.

Table I.EI.1: Process Technology Description	
Property	**Description**
Describe proliferation resistance properties	
Provide types and volumes of waste stream per metric ton (MT) of HLW, including the isotopic and chemical composition of each waste stream	
Describe each waste stream and waste form from process, including the NRC-approval state of the waste form, and the need (if any) for the waste form to be co-developed?	
Provide a description of the fuel stock(s) produced	
Estimated commercial scale processing facility capital expenditure (CapEx) and annual Operating and Maintenance (O&M) costs	
Provide scale of facility/modules in units of MT HLW/year.	

For technology category 2, provide the information requested in Section I.E.II of the FOA, table I.EII.1, and table I.EII.2 for each measurement used to determine the fissile mass accountancy.

Table I.EII.1: System Definition	
Property	**Description**
Process location(s) where sensor is located	
Description of mass accountancy validation (must include realistic sensor data rates, for both signal and backgrounds both from target mass and external sources)	

Table I.EII.1: System Definition	
Property	**Description**
Latency or throughput of measurement	
Sampling methodology	
Comparison to State-of-the-Art	
Validation Methodology for accuracy determination (including recalibration schedule)	
Scale of technology demonstration to actual operating conditions.	
Estimated Total System Cost	
Schedule for, and cost estimates of, maintenance (include all types of maintenance required, time required for actual servicing, operational or chronological time periods between required maintenance, and any replacement components or consumables needed)	
Mean Time Before Failure (include basis)	

Table I.EII.2: Measurement Description	
Technology Attribute	**Description**
Allowed gamma flux (part/s/cm^2)	
Gamma energy min/max (keV)	
Allowed neutron flux (part/s/cm^2)	
Neutron energy min/max (keV)	
Latency (sec) for result	
Operating atmosphere?	
Maximum allowed temperature (C)	
Estimated unit cost ($)	
Estimated annual O&M ($)	
Estimated lifetime (years)	

For technology category 3, proved the information requested in Section I.E.III of the FOA and address each of the bullets below.

- Summarize the waste loading capacity of the waste matrix, and briefly describe any limiting factors for consideration (% waste loading capacity)

- Describe the degradation rate of the waste matrix (either fractional dissolution rate or g/m2/yr), including the standard used to determine the rate, the alteration product of the waste matrix, and how radionuclides are immobilized
- For the above enumerated repository (or borehole) types, summarize the significant beneficial or detrimental repository/waste form interactions
- Briefly describe the methodology and results used to determine the waste form's stability at the likely thermal output from radionuclide inventory
- Briefly describe the methodology and results used to determine the waste form's stability at the likely radiation output from the radionuclide inventory
- Briefly describe the methodology and results used to determine the waste form's mechanical stability during pre- and post-emplacement time periods
- Briefly describe the methodology and results used to determine the waste form's inherent resistance to fire
- Summarize the maturity of the large-scale manufacturing technology associated with the potential scale-up of the proposed technology
- Briefly describe the methodology and results used to determine the unit and total cost estimate for the final product that is suitable for repository emplacement
- Briefly describe the methodology and results used to determine the waste form's annual O&M cost estimate

For technology category 4 – Other, provide the information listed above that is applicable to the proposed technology, and justify why the other information is not required.

c. PROPOSED WORK

- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives, including a proposed budget and justification for level of proposed funding.
- Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.
- Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach. Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.
- Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?
- Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant.

d. TEAM ORGANIZATION AND CAPABILITIES

- Indicate the roles and responsibilities of the organizations and key personnel that comprise the Project Team.
- Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.
- Identify key capabilities provided by the organizations comprising the Project Team and how those key capabilities will be used in the proposed effort.
- Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

F. INTERGOVERNMENTAL REVIEW

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

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

H. OTHER SUBMISSION REQUIREMENTS

1. USE OF ARPA-E eXCHANGE

To apply to this FOA, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx). ARPA-E will not review or consider applications submitted through other means (e.g., fax, hand delivery, email, postal mail). For detailed guidance on using ARPA-E eXCHANGE, please refer to the "ARPA-E eXCHANGE Applicant Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

Upon creating an application submission in ARPA-E eXCHANGE, Applicants will be assigned a Control Number. If the Applicant creates more than one application submission, a different Control Number will be assigned for each application.

Once logged in to ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx), Applicants may access their submissions by clicking the "My Submissions" link in the navigation on the left side of the page. Every application that the Applicant has submitted to ARPA-E and the corresponding Control Number is displayed on that page. If the Applicant submits more than one application to a particular FOA, a different Control Number is shown for each application.

Applicants are responsible for meeting each submission deadline in ARPA-E eXCHANGE. **Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.** Under normal conditions (i.e., at least 48 hours in advance of the submission deadline), Applicants should allow at least 1 hour to submit a Concept Paper, or Full Application. In addition, Applicants should allow at least 15 minutes to submit a Reply to Reviewer Comments. Once the application is submitted in ARPA-E eXCHANGE, Applicants may revise or update their application until the expiration of the applicable deadline.

Applicants should not wait until the last minute to begin the submission process. During the final hours before the submission deadline, Applicants may experience server/connection congestion that prevents them from completing the necessary steps in ARPA-E eXCHANGE to submit their applications. **ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.**

ARPA-E may not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications may be deemed noncompliant (see Section III.C.1 of the FOA). The following errors could cause an application to be deemed "incomplete" and thus noncompliant:

- Failing to comply with the form and content requirements in Section IV of the FOA;
- Failing to enter required information in ARPA-E eXCHANGE;
- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA;
- Uploading the wrong document(s) or application(s) to ARPA-E eXCHANGE; and
- Uploading the same document twice, but labeling it as different documents. (In the latter scenario, the Applicant failed to submit a required document.)

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

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

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

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

1. CRITERIA FOR CONCEPT PAPERS

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

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

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

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

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

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

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

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

II. **Relevance to ARPA-E Mission Advancement.** Project contributes to one or more of ARPA-E's key statutory goals:
   a. Reduction of U.S. dependence on foreign energy sources;
   b. Stimulation of 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-Leveraging of Federal Funds**. Project leverages Federal funds to optimize advancement of programmatic goals by proposing cost share above the required minimum or otherwise accessing scarce or unique resources.

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

VII. **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.

2. ARPA-E REVIEWERS

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

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

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

3. ARPA-E SUPPORT CONTRACTOR

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

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

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

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

2. CONCEPT PAPER NOTIFICATIONS

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

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

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

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2021]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

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

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

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

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

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

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

B. DEBRIEFINGS

ARPA-E does not offer or provide debriefings. ARPA-E provides Applicants with a notification encouraging or discouraging the submission of a Full Application based on ARPA-E's assessment of the Concept Paper. In addition, ARPA-E provides Applicants with reviewer comments on Full Applications before the submission deadline for Replies to Reviewer Comments.

VIII. OTHER INFORMATION

A. TITLE TO SUBJECT INVENTIONS

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

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions. If Prime Recipients/Subrecipients elect to retain title, they must file a patent application in a timely fashion, generally one year from election of title, though: a) extensions can be granted, and b) earlier filing is required for certain situations ("statutory bars," governed by 35 U.S.C. § 102) involving publication, sale, or public use of the subject invention.
- All other parties: The Federal Non-Nuclear Energy Research and Development Act of 1974, 42. U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below)*.
- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues "class patent waivers" under which large businesses and foreign entities that meet certain stated requirements, such as cost sharing of at least 20%, may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.
- GOGOs are subject to the requirements of 37 C.F.R. Part 501.
- Determination of Exceptional Circumstances (DEC): DOE has determined that exceptional circumstances exist that warrant the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to maximize the manufacture of technologies supported by ARPA-E awards in the United States. The DEC, including a right of appeal, is dated September 9, 2013 and is available at the following link: http://energy.gov/gc/downloads/determination-exceptional-circumstances-under-bayh-dole-act-energy-efficiency-renewable. Please see Section IV.D and VI.B for more information on U.S. Manufacturing Requirements.

B. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

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

1. GOVERNMENT USE LICENSE

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

2. MARCH-IN RIGHTS

The U.S. Government retains march-in rights with respect to all subject inventions. Through "march-in rights," the Government may require a Prime Recipient or Subrecipient who has elected to retain title to a subject invention (or their assignees or exclusive licensees), to grant a license for use of the invention. In addition, the Government may grant licenses for use of the subject invention when Prime Recipients, Subrecipients, or their assignees and exclusive licensees refuse to do so.

The U.S. Government may exercise its march-in rights if it determines that such action is necessary under any of the four following conditions:

- The owner or licensee has not taken or is not expected to take effective steps to achieve practical application of the invention within a reasonable time;
- The owner or licensee has not taken action to alleviate health or safety needs in a reasonably satisfactory manner;
- The owner has not met public use requirements specified by Federal statutes in a reasonably satisfactory manner; or
- The U.S. Manufacturing requirement has not been met.

C. RIGHTS IN TECHNICAL DATA

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

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

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

D. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

Applicants may not include any Protected Personally Identifiable Information (Protected PII) in their submissions to ARPA-E. Protected PII is defined as data that, if compromised, could cause harm to an individual such as identity theft. Listed below are examples of Protected PII that Applicants must not include in their submissions.

- Social Security Numbers in any form;
- Place of Birth associated with an individual;
- Date of Birth associated with an individual;
- Mother's maiden name associated with an individual;
- Biometric record associated with an individual;
- Fingerprint;
- Iris scan;
- DNA;
- Medical history information associated with an individual;
- Medical conditions, including history of disease;
- Metric information, e.g. weight, height, blood pressure;
- Criminal history associated with an individual;
- Ratings;
- Disciplinary actions;
- Performance elements and standards (or work expectations) are PII when they are so intertwined with performance appraisals that their disclosure would reveal an individual's performance appraisal;
- Financial information associated with an individual;
- Credit card numbers;
- Bank account numbers; and
- Security clearance history or related information (not including actual clearances held).

E. FOAS AND FOA MODIFICATIONS

FOAs are posted on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/), Grants.gov (http://www.grants.gov/), and FedConnect (https://www.fedconnect.net/FedConnect/). Any modifications to the FOA are also posted to these websites. You can receive an e-mail when a modification is posted by registering with FedConnect as an interested party for this FOA. It is recommended that you register as soon as possible after release of the FOA to ensure that you receive timely notice of any modifications or other announcements. More information is available at https://www.fedconnect.net.

F. OBLIGATION OF PUBLIC FUNDS

The Contracting Officer is the only individual who can make awards on behalf of ARPA-E or obligate ARPA-E to the expenditure of public funds. A commitment or obligation by any individual other than the Contracting Officer, either explicit or implied, is invalid.

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

G. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

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

- The rejection of a Concept Paper, Full Application, and/or Reply to Reviewer Comments;
- The termination of award negotiations;
- The modification, suspension, and/or termination of a funding agreement;
- The initiation of debarment proceedings, debarment, and/or a declaration of ineligibility for receipt of Federal contracts, subcontracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

H. RETENTION OF SUBMISSIONS

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

I. MARKING OF CONFIDENTIAL INFORMATION

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

Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information 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.

J. COMPLIANCE AUDIT REQUIREMENT

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

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

IX. GLOSSARY

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

Application: The entire submission received by ARPA-E, including the Preliminary Application, Full Application, Reply to Reviewer Comments, and Small Business Grant Application (if applicable).

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

Cost Sharing: Is the portion of project costs from non-Federal sources that are borne by the Prime Recipient (or non-Federal third parties on behalf of the Prime Recipient), rather than by the Federal Government.

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

DOE: U.S. Department of Energy

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

FFRDCs: Federally Funded Research and Development Centers

FOA: Funding Opportunity Announcement

For-Profit Organizations (Other than Small Businesses) (or *large businesses*): Means entities organized for-profit other than small businesses as 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.

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

Nonprofit Organizations (or *nonprofits*): Has the meaning set forth at 2 C.F.R. § 200.70.

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

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

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).

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

Subject Invention: Any invention conceived or first actually reduced to practice under an ARPA-E funding agreement.

Task: A task is an operation or segment of the work plan that requires both effort and resources. Each task (or sub-task) is connected to the overall objective of the project, via the achievement of a milestone or a deliverable.

Total Project Cost: The sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.

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