FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

HARNESSING EMISSIONS INTO STRUCTURES TAKING INPUTS FROM THE ATMOSPHERE (HESTIA)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0002625
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	November 8, 2021
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, December 10, 2021
Submission Deadline for Concept Papers:	9:30 AM ET, December 20, 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:	June 2022
Total Amount to Be Awarded	Approximately $41 million, subject to the availability of appropriated funds to be shared between FOAs DE-FOA-0002625 and DE-FOA-0002626.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $500,000 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 4 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, December 20, 2021
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2022]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2022]	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. FOA SPECIFIC DEFINITIONS

- **Atmospheric Carbon:** Greenhouse gases (GHGs), measured in CO_2 equivalents, originally absorbed from the atmosphere through means including biomass growth and/or direct capture (from air or the ocean).
- **Best-in-class incumbent**: Commercially available building material and/or element that meets highest required performance specification for use in building construction.
- **Biogenic carbon:** Carbon accumulated originally during biomass growth.

[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.

- **Building**: One of the following building types, as referenced by the U.S. Department of Energy:[3] residential single-family homes (preferentially 2,500 square feet), mid-rise apartments, small/medium office, stand-alone retail, large office, or warehouse (non-refrigerated) commercial buildings.
- **Building element**: Any component that supports, encloses, or protects the building structure (e.g., foundation, flooring, walls, insulation, beams, columns).
- **Carbon negative building**: Total embodied and operational emissions of the building, including routine maintenance and replacement of common building elements, are less than the atmospheric carbon stored in the materials of the building itself.
- **Carbon negative material**: Embodied emissions are less than the atmospheric GHGs captured and stored (in any form) in the material itself over a specified time period.
- **Carbon storage**: Net CO_2 or CO_2 equivalents contained in a material from biogenic, atmospheric CO_2/CH_4 or recycled carbon sources. Carbon in the material can be converted to CO_2 equivalents to calculate carbon negativity as defined below.
- **Carbon storage wt.%**: Total percentage of atmospheric carbon contained in the finished product of a material by mass.
- **Embodied emissions**: GHG emissions attributed to raw material extraction, transport, manufacture, assembly, and installation of a building, along with replacement/refurbishment and disassembly/disposal at the end-of-life. Note: carbon emissions, embodied carbon and embodied emissions are herein used synonymously.
- **Geographic region**: Climate zones for this Program should be selected from one of the 16 referenced by the U.S. Department of Energy.[4]
- **[LCA] Cradle-to-gate**: LCA (Life Cycle Analysis) of production stages / modules or A1-A3 (i.e. raw material supply, transport to factory, and manufacturing).
- **[LCA] Cradle-to-grave**: LCA beginning with production stages A1-A3, and including construction stages A4-A5 and operation stages B1-B7, through to end-of-life stages C1-C4.
- **[LCA] Functional unit**: Both the purpose and performance of a building material for comparison with competitors. The mass of the material is acceptable as a functional unit only if all competing materials have the same density *and* performance specifications as the proposed material. Otherwise, more appropriate functional units must be derived that reflect performance/purpose of the proposed material and its competitors.
- **[LCA] Net upfront embodied emissions:** Upfront (A1-A3 or “cradle-to-gate") embodied emissions minus atmospheric carbon stored in the final material.
- **[LCA] Upfront embodied emissions**: Non-atmospheric GHGs released to atmosphere during A1-A3 (i.e. cradle-to-gate) of the life cycle.
- **Life cycle stages:** Stage of the product/process life cycle where material and energy inputs and outputs are tallied (i.e. raw material, extraction, transportation, manufacturing, use, end-of-life/disposal, etc.).

[3] https://www.energycodes.gov/prototype-building-models#:~:text=Commercial%20Prototype%20Building%20Models%20The%20U.S.%20Department%20of,support%20both%20published%20model%20codes%20and%20potential%20changes

[4] https://www.energy.gov/eere/buildings/commercial-reference-buildings

- **Long-term carbon storage**: Centuries time scale, including "permanent" storage options, (e.g., minerals).
- **Material**: Used for building applications and fully developed for use or into a finished product (e.g., gypsum board, decking plank, mass timber beam).
- **Medium-term carbon storage**: "Temporary" storage on time scales of the order of years to decades.
- **Operational emissions**: GHGs emitted directly or indirectly to operate the building (e.g., heating, cooling, lighting).
- **Repeatability**: Ability to achieve test results within a statistically relevant boundary for multiple samples, using the same analysis / test method and instrumentation.
- **Reproducibility**: Ability to produce more than one set of samples at different points in time, and generate test data on each set that falls within a statistically relevant boundary
- **Service life of the building**: 100 years. The replacement frequency factor of individual elements is dependent on the element and its use.
- **Standard**: Published methods of specimen preparation and testing, namely ASTM and ISO.

C. PROGRAM OVERVIEW

The goal of the HESTIA program is to support the development of technologies that nullify embodied greenhouse gas (GHG) emissions[5] (see Section I.B above), while simultaneously transforming buildings into net carbon storage structures. Specifically, projects funded under the HESTIA Program will develop and demonstrate building materials and whole-building designs that are net carbon negative (see Section I.B above) on a life cycle basis[6] by utilizing atmospheric CO_2 or CH_4 (see Section I.B above) from a wide range of potential feedstocks (e.g., forestry and purpose-grown products, agricultural residues, marine derived, direct carbon utilization) in the production process. HESTIA metrics are:

- storage of more carbon in the chemical structure of the finished product than emitted during manufacture, construction, and use,
- relevant performance testing (e.g., flammability, strength) as required per applicable building code and incumbent specifications,
- market advantage (e.g., improved material performance in at least one area, lower cost, easier installation) over the best-in-class incumbent building element(s) (i.e. structural and/or enclosure) selected for replacement, and
- sufficient retention of carbon storage over service lifetime and minimized end-of-life emissions where possible by designing for reuse, repurposing, and/or recycling.

This FOA supports the development of viable technologies to achieve these metrics in a cost-effective manner to meet building construction industry demand for low-cost. Technical

[5] Embodied emissions are also referred to as embodied carbon due to the bulk consisting of carbon dioxide and methane.

[6] LCA stages A1-A3 or cradle-to-gate for building materials in the Program and cradle-to-grave at the building level for the Program

categories of interest are identified in Section I.E of the FOA. Performance targets for the technical categories of interest are provided in Section I.F of the FOA. Section I.G of the FOA provides information on Life Cycle Assessment (LCA) requirements. To ensure that the technologies developed through this Program are evaluated consistently and transparently, a separate solicitation[7] will be used to develop and perform Life Cycle Assessments (LCAs) in conjunction with and to support Applicants of this FOA.

The HESTIA Program offers a unique opportunity to address the growing need for market-ready negative emission technologies to implement carbon removal strategies by changing the paradigm for building construction through the use of carbon negativity as a design parameter. Projects will create novel designs that maximize the energy benefits of carbon storage in addition to manufacturing methods and performance of the materials themselves.

In doing so, HESTIA is also important to reducing embodied emissions, which while a smaller overall percentage (i.e. roughly 10% of total annual US GHG emissions, with similar trends globally[8,9]) compared to operational emissions[10] (i.e. 30% of total annual US GHG emissions[11]), are particularly urgent to address from a life cycle perspective. The majority of embodied emissions are concentrated at the start of a building's lifetime and locked in before the building is operational. This upfront emissions spike[12] can be equivalent to 10 years of operational emissions in a building constructed to meet standard code, increase to 35 years for more advanced, higher operating efficiency buildings and to more than 50 years for high-efficiency buildings operating with lower carbon intensity energy (see Figure 1). Embodied emissions, historically approximately 20% of a building's total life cycle emissions, increase in percentage to 50-90% of the total, with operational efficiency improvements arising from the implementation of more stringent building energy codes, coupled with further decarbonization of the electric grid from increased adoption of renewable power generation.[13] Unfortunately,

[7] Special Program Announcement for Solicitation on Topics Informing New Program Areas (DE-FOA-0001953) Topic V. "Life Cycle Assessment for Carbon Negative Buildings.

[8] EIA Annual Energy Outlook 2021 with Projections to 2050, EIA. https://www.eia.gov/outlooks/aeo/

[9] Global Alliance for Buildings and Construction 2018 Global Status Report: Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector. IEA (International Energy Agency) and UNEP (United Nation Environment Programme).
https://www.worldgbc.org/sites/default/files/2018%20GlobalABC%20Global%20Status%20Report.pdf .

[10] GHGs emitted directly or indirectly from energy consumed to operate the building (e.g., heating, cooling, lighting)

[11] U.S. Environmental Protection Agency, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#commercial-and-residential.

[12] Non-biogenic GHGs released into atmosphere during A1-A3 or "cradle-to-gate." Net upfront embodied emissions = upfront (A1-A3 or "cradle-to-gate") embodied emissions minus material carbon captured from atmosphere and stored.

[13] Rock, M.; Ruschi Mendes Saade, M.; Balouktsi, M; Nygaard Rasmussen, F.; Birgisdottir, H.; Frischknecht; Habert, G.; Lutzkendorf, T.; Passer, A., "Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation," *Applied Energy* V. 258, 114107 (2020).

these time horizons exceed the window between now and fulfilling 2050 climate targets,[14,15] necessitating the urgent prioritization of embodied emission reduction strategies.

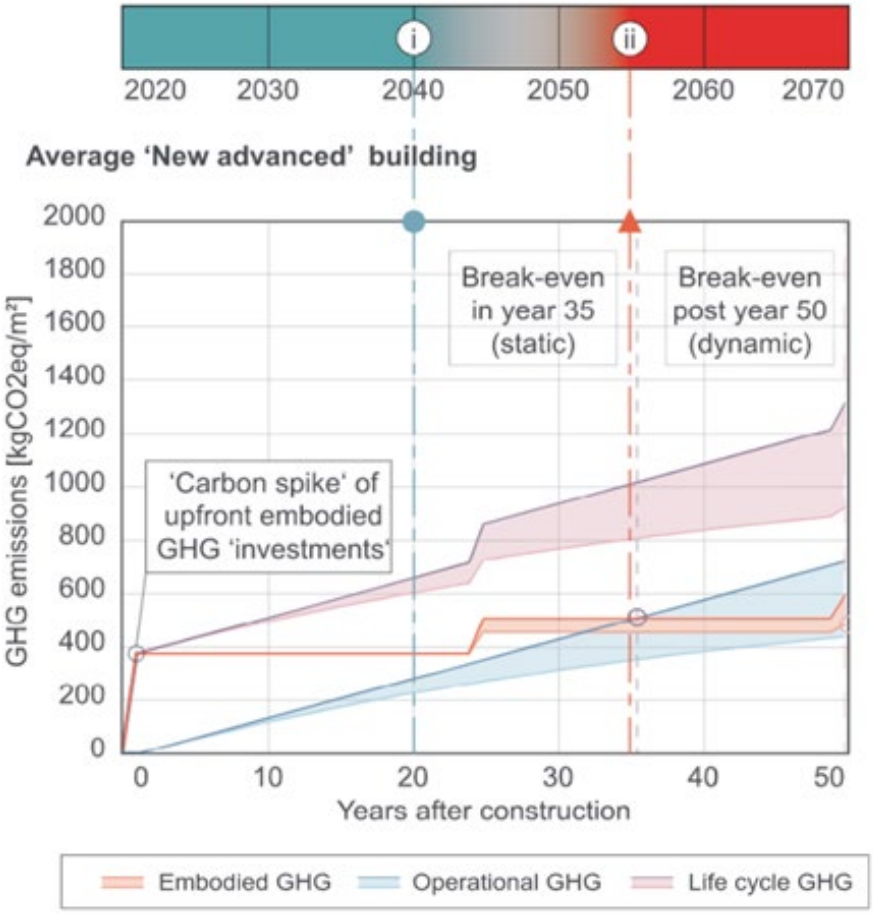

Figure 1. Annual GHG emissions (i.e. embodied, operational, and total life cycle) over the building's lifetime, including break-even points between operational and embodied contributions.[13]

Strategies for lowering the embodied carbon footprint of buildings include emerging methods of fabrication, offsite manufacturing, and robotics.[16] More efficient construction methods and building designs can enable the use of more efficient structural solutions to maximize structural efficiency and reduce the amount of material used (e.g., advanced framing), as well as designing material size modules in standard sizes to minimize waste (e.g., 4x8 plywood, gypsum

[14] U.S. Mid-Century Strategy for Deep Decarbonization, November 2016, https;//unfcc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf.

[15] IPCC, Summary for Policymakers. Global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emissions pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, 2018, ISBN 978-92-9169-151-7.

[16] Hasz, A.; Ryan, N.; Glickman, J., "Advanced Building Construction (ABC) – A Not Quite "Easy as 1-2-3" Initiative to Scale Deep Energy Retrofits and Transform U.S. Buildings," ACEEE Summer Study on Energy Efficiency in Buildings 5, 219-234, 2020. https://www.aceee.org/files/proceedings/2020/event-data/pdf/catalyst_activity_107449/catalyst_activity_paper_20200812132347405_15177b9e_4179_4fc7_83b4_14be6801bd33

board). Using less material can also mean less available volume for carbon storage on an absolute basis across the building stock, but the combination of the contribution of this strategy in nullifying embodied emissions, coupled with efforts to maximize carbon sequestration capacity on a per unit level, can enable a pathway to net negative carbon emissions.

Effective approaches to further reducing embodied emissions can include avoiding demolition by renovating, repurposing, and/or recycling to extend the service life of the material and/or structure or decreasing the use of carbon-emitting materials,[17] however, both buildings and the materials used in their construction are not typically designed for reuse. Furthermore, current construction practices tend to be material destructive. As such, incorporating methods that can extend the service life of building materials and designs (i.e., ease of retrofitting, modularity) developed under the HESTIA Program are especially encouraged for reducing cradle-to-grave building stock life cycle emissions. Moreover, GHG benefits of carbon-negative (A1-A3) materials can be bolstered after their primary use phase by displacing carbon-emitting materials, while GHG impacts of carbon-emitting (A1-A3) materials can be reduced by recycling methods.

Recognizing that new construction cannot be completely avoided,[18] both retrofit and new construction applications are within the scope of the HESTIA program to achieve maximum impact across the building stock. Additionally, ARPA-E will support solutions for a wide variety of different building types and materials, due in part, to the variability of embodied carbon contributions (see Figure 2). The development of both new materials and designs can also enable multi-functional components that can be leveraged to reduce emissions even further.

[17] Malmqvist, T., et al., "Design and Construction Strategies for Reducing Embodied Impacts from Buildings 0 Case Study Analysis," *Energy & Buildings*, V. 166, 35-47, May 2018.

[18] EIA AEO 2021. Between 2020 and 2050, residential housing units in the US are projected to increase by 22% and total square footage in the US commercial sector is projected to increase by almost 33%

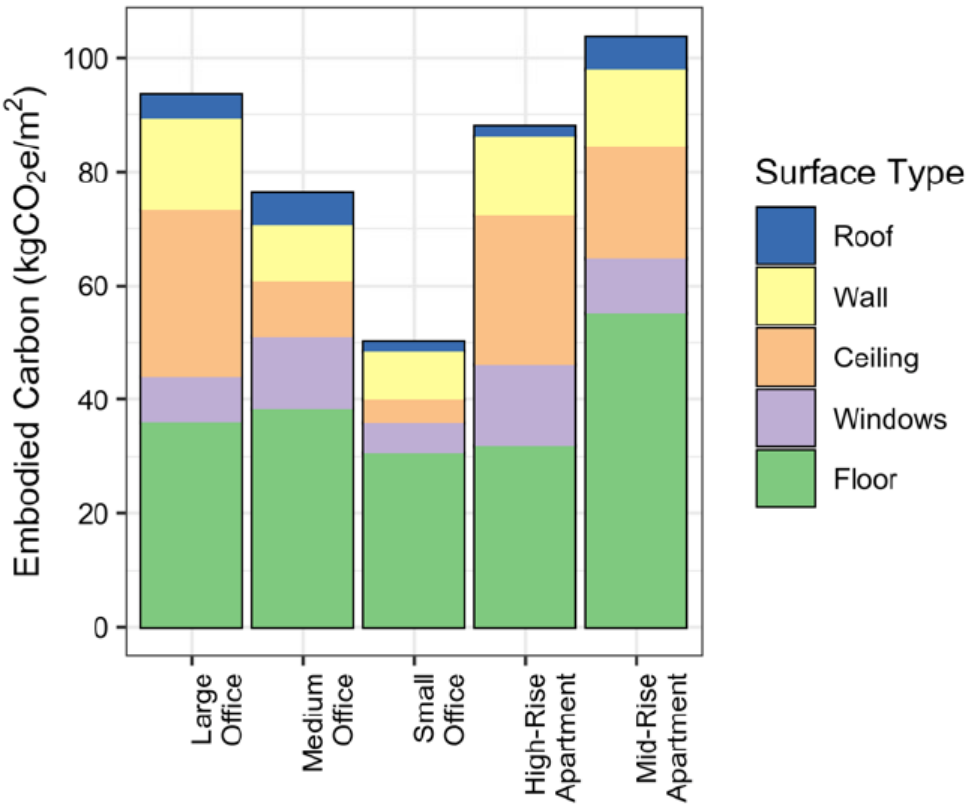

Figure 2. **Representative embodied carbon contributions as a function of building type and element.** (Note: Significant data on embodied carbon is still difficult to obtain. In this model, for example, insulation has a minor contribution because only its thermal impacts are included.[19])

Most materials used to assemble buildings not only have a high embodied carbon footprint, but also store no or minimal amounts of carbon (e.g., steel, concrete, and drywall).[20] Carbon storing materials that are readily available for consideration in building designs consist of natural materials, such as different types of lumber and particle board, and for which net benefits to GHG emissions can be diminished due to supply chain considerations (e.g., forestry practices).[21] While materials that can potentially achieve carbon negativity (e.g., mass timber, straw bale, hemp) are emerging in use (see Figure 3), they still have limited code-compliant options,[22] which form the basis for materials selection in building design and construction, as well as drive adoption of new technologies. With the HESTIA Program, ARPA-E seeks to accelerate the development and commercialization of such promising materials that contain atmospheric carbon in their finished product via the optimization of chemistries, recipes, manufacturing, and designs to achieve broad adoption in the building construction market at a pace sufficient to

[19] Arehart, J. H.; Srubar, W. V.; Pomponi, F.; D'Amico, B. "Embodied Energy and Carbon Emissions of DOE Prototype Buildings from a Life Cycle Perspective" *ASHRAE Trans*. 2020, 126, VC-20-C002.
[20] King, B., "The New Carbon Architecture" 2017.
[21] Diaz, D.D.; Loreno, S.; Ettl, G.J.; Davies, B., "Tradeoffs in Timber, Carbon, and Cash Flow under Alternative Management Systems for Douglas-Fir in the Pacific Northwest," *Forests*, V. 9(8), 2018.
[22] The International Building Code Council (IBCC) recently introduced three new construction types of mass timber. https://www.constructionexec.com/article/tall-mass-timber-buildings-now-possible-under-2021-ibc-code-changes

contribute to carbon drawdown targets. It is also envisioned that the outputs of this Program will inform future building code updates that better capture embodied carbon.

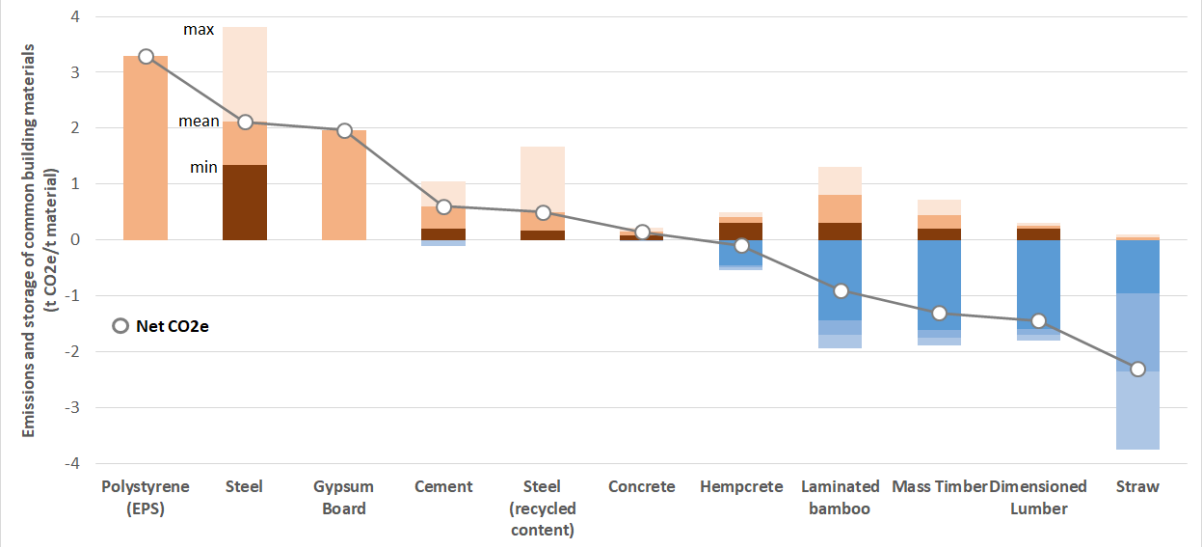

Figure 3. Upfront embodied emissions (blue) and carbon storage amount (orange) for common building materials where the net CO_2 equivalents is the difference between the mean emissions estimate and the mean storage estimate. Data from ref[23] and [24] evaluated on a life cycle assessment system boundary of A1-A3.

Given the urgency and scale required for implementing negative emissions technologies,[25] both medium- (e.g., biogenic) and long-term (e.g., mineral, direct capture, etc.) storage (see Section I.B)[26] approaches are of interest in this Program and both carbon retention and service life will be assessed. For materials/processes that absorb CO_2 (e.g. direct air capture, direct ocean capture, biomass, etc.) "cradle" begins at atmospheric CO_2 which is absorbed and serves as a negative sink. Emissions from land use change, cultivation, harvesting, etc. must all be captured in raw material extraction. For materials/processes that do not absorb CO_2 from the atmosphere, including fossil-derived sources, "cradle" begins at raw material extraction. Biogenic CO_2 emitted is considered a positive source of emissions in this Program. Recycled materials (that would otherwise go to a landfill) entering the system boundary are assumed to have a carbon footprint of zero. Any recycling processes (i.e. collection, transportation, processing, upgrading, etc.) proposed must be included within the system boundary. If the proposed process uses a waste product or co-product from another process, the LCA –

[23] Pomponi, F. and Moncaster, A. "Scrutinising Emboded Carbon in Buildings: The Next Performance Gap Made Mainfest, "*Renewable and Sustainable Energy Reviews,* V. 81(P2), 2431-2442, 2018, DOI: 10.1016/j.rser.2017.06.049.

[24] Ruuska., "Carbon Footprint for building products," 2013, https://cris.vtt.fi/en/publications/carbon-footprint-for-building-products-eco2-data-for-materials-an.

[25] National Academy of Sciences, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, 2019.

[26] Short term storage refers to immediate use applications, such as fuels, and out-of-scope for this Program.

discussed in detail below -- will account for the GHG footprint and system changes in GHGs of using that waste material/by-product instead of for its original purpose

Through a separate solicitation, ARPA-E also seeks to overcome the limitations in existing LCA tools and frameworks critical to evaluating carbon negativity in buildings in terms of cradle-to-grave modeling for rapid screening and quantification of GHG impacts (including comparative LCAs between proposed building materials and incumbent materials, as well as hot spot analyses for nascent materials). These frameworks and tools will incorporate both dynamic LCA to track cumulative and temporal life cycle impacts over a building's lifetime as well as spatial-temporal modeling tools to estimate site-specific parameters important for LCA of different feedstocks. Applicants to this HESTIA FOA will be expected to provide relevant information during both the Concept Paper and Full Application Stages, as well as the duration of the Project (if selected for an Award), to enable consistent and transparent analyses of proposed building materials and designs against the HESTIA targets. Additional information regarding requirements, as well as the anticipated relationship with the LCA team(s) awarded through the separate solicitation (see DE-FOA-1953, Appendix V "Life Cycle Assessment for Carbon Negative Buildings") can be found in Section I.G.

D. PROGRAM OBJECTIVES

This Program will support breakthrough research and development that will facilitate the utilization of carbon negative materials in building construction by concurrently addressing significant challenges in optimizing materials chemistries and matrices, manufacturing, and building designs in a cost-effective manner. Specifically, ARPA-E seeks to support development of technologies that enable:

- Carbon negativity on both cradle-to-gate and cradle-to-grave life cycle bases for developed building materials,
- Carbon negativity on a cradle-to-grave life cycle basis at the whole-building level (i.e. both embodied and operational emissions) for designed structures,
- Performance enhancement of at least one building construction or operational energy usage requirement, or other market advantage, and
- Preliminary demonstration of recycle, repurpose, and/or reuse potential of proposed material, as well as building design for disassembly to enable longer service lifetimes and/or minimize end-of-life embodied carbon footprint contributions.

In order to broadly penetrate the buildings industry, **ARPA-E seeks submissions that span a range of possible feedstocks, materials, building elements, building types, and geographic regions.** The exact nature of these variables will inform the assessment of the scalability of proposed solutions and their technoeconomic feasibility relative to incumbent technologies.

Technologies supported through HESTIA will need to assess their economic viability through technoeconomic analysis of the proposed material or building through to production. Potential levelized cost of carbon abatement will also be assessed during the course of the Program and relative to complementary carbon removal strategies. Scenarios will be developed, in

coordination with the LCA Partner Team(s) who will provide LCA calculations including carbon impacts, to evaluate the cost versus benefit of developed technologies by separately determining breakeven carbon price (to be provided as US dollars per ton CO_2 equivalents[27]) necessary to yield a comparable overall production cost to the incumbent to be replaced.[28]

At the same time, the element(s) and type(s) of building along with climate zone(s) targeted will determine the appropriate testing standards and code specifications to benchmark against over the course of a Project. While technologies proposed through this FOA will need to select a targeted building element(s) (i.e. frame and/or enclosure), building type(s), and climate zone(s) (see section I.C) for the purposes of performance validation to evaluate building construction market readiness and the overall carbon footprint from an LCA perspective, the vision is for technologies developed under this Program to ultimately be adopted broadly across the building stock. Materials beyond a single use case (e.g., combined structural and insulative properties), for example, are encouraged, as they provide additional opportunities for reducing the overall embodied carbon footprint, as well as a competitive market advantage over incumbent technologies. Material and design technologies are expected to generate samples of sufficient size for preliminary testing per applicable standards and in sufficient quantity and repetition for demonstrating repeatability and reproducibility over the course of the Program.

ARPA-E has identified the following five impact areas that need to be addressed in the development of carbon negative buildings and to support their role in nullifying embodied emissions. Collectively these areas, along with achieving the carbon storage and emission reduction targets, form the carbon negative building concept. In addition to completion of the tables provided in Section I.F, submissions to this FOA must describe the role of these areas in the proposed technological innovation, which if successful, will enable proposed new technologies to become competitive in the relatively mature building construction market. The impact areas are:

i. **Feedstock balance:** How will the proposed technology effectively utilize sources of atmospheric carbon? Submissions must provide preliminary information regarding raw material and feedstock availability (i.e. sources and amount), land use considerations, manufacturing and delivery methods, as well as other supply chain considerations in the Full Application phase to assist with this evaluation (see Sections I.F).

ii. **Construction methods:** How will the proposed technology be constructed and/or installed? Describe how existing and emerging construction practices (e.g., automation) will be utilized and include any corresponding carbon benefits and/or penalties.

[27] Note that carbon calculations should take into account elemental carbon in the material / building vs CO_2, since carbon tax / credit is based on tons of CO_2.

[28] The carbon credit or tax calculated for a given material should consider the lifecycle carbon storage and emissions. Thus, the carbon numbers derived during LCA analysis should be used to calculate the carbon credit / tax, and not only the carbon stored in the material.

iii. **Carbon retention:** How will the proposed technology sufficiently retain carbon stored in its finished product over the typical service life of the targeted building element(s)/ building type(s)? Describe how carbon loss will be evaluated and estimated annually.

iv. **Code compliance and testing requirements:** How will the proposed technology be used in the building construction process? Describe the impact the proposed technology will have on the applicable structural and energy performance requirements, including either exceeding performance in at least one key area over current state of the art or demonstrating another market advantage (e.g., lower cost, easier installation).

v. **End-of-life:** How does the proposed technology's end-of-life strategy impact its overall carbon footprint? Describe how potential material recycle, repurposing, and/or reuse, as well as building design for disassembly could extend existing service lifetimes. How do the associated challenges for the proposed strategy need to be evaluated?

E. TECHNICAL CATEGORIES OF INTEREST

Two technological categories have been identified to achieve substantial progress towards buildings that are net carbon negative over their life cycle. These categories are the technical categories of this FOA and are:

i) Category A - Building Materials: This technology area includes new materials and process improvements (e.g., optimization of chemistries, recipes, and manufacturing) that minimize embodied emissions, increase the atmospheric carbon contained in the finished product, and bolster commercialization.

ii) Category B – Building Designs: This technology area includes design improvements at the whole-building level that incorporate carbon storing materials to increase carbon storage in the structure, improve operational efficiency, increase material repurposing, and lend themselves to more efficient construction methods. Designs for deconstruction/disassembly are also beneficial in achieving the emissions reduction goal of this Category. To the extent such designs are to be made commercially available as Architectural drawings, ARPA-E is prepared to consider modifications to the standard provisions in an award related to copyright to facilitate the wide spread dissemination of such drawings.

Each applicant must indicate which one of the two technological areas they are applying to.

I. CATEGORY A – BUILDING MATERIALS

Building material solutions include all possible carbon-storing materials derived from readily available atmospheric CO_2 feedstocks that can be used to manufacture at least one structural and/or enclosure element that is net carbon negative. A commercial and/or residential building type (refer to Section I.B for applicable building types), as well as climate zone, should be chosen for initial testing to meet the performance requirements of the Program as a first market target. Technologies funded under this FOA will also need to ensure that stored carbon is sufficiently retained to achieve the cradle-to-grave life cycle targets of the Program. A number of materials (see examples listed in Table 1), already exhibit high carbon storage values in their finished product form, but are not necessarily net carbon negative on a cradle-to-grave basis when fully accounting for all inputs. Furthermore, some technologies can also exhibit the ability to sequester additional carbon after the point of manufacture and while in use (e.g., continued carbonation of exposed cement[29]).

Table 1. Total Carbon Content in Select Incumbent Building Materials[30]
(Note: carbon shown can include non-atmospheric carbon sources)

Material	Wt% Carbon
Glued laminated timber – Sweden	47.1
Oriented strand board (raw) – Germany	46.1
Wood fiber insulation – Finland	33.8
Massive parquet flooring – Germany	46.2
Laminate flooring – Europe	40.2

The focus will be on materials that by the end of the Program will satisfy at a minimum current state of the art building construction and operational energy performance requirements for the targeted application. There is also an interest in material products that have more than one function or combine multiple functions in a manufactured part to further reduce total embodied emissions. Technologies proposed in this Category should be sufficiently mature in their development that by the end of the first year of the Program, they can demonstrate a preliminary assessment of at least one key performance test (e.g., strength, thermal resistance) for the targeted building element(s) to assess viability for further exploration (See Table 2 for examples). Depending on the level of development, these initial tests could be on a smaller scale of the material and use alternative methods (e.g., non-ASTM and non-ISO standards). By the end of the second year of the Program, materials development is expected to progress to the point of initial testing per applicable ASTM and ISO standards, with sufficient repeatability and reproducibility for testing (see Section I.B).

[29] Cao, Z., Myers, R.J., Lupton, R.C. et al. The sponge effect and carbon emission mitigation potentials of the global cement cycle. *Nat Commun* **11**, 3777 (2020)
[30] Adapted using data from: Ruuska, A. "Carbon Footprint for Building Products" VTT Technology 115, 2013; http://eralberta.ca/wp-content/uploads/2017/05/K130111-Blue-Planet-Final-Report-PUBLIC.pdf

Table 2. Limited List of Example Tests for Building Elements

Building Element Type Replacement	Test Type
Foundation, cementitious slab	• Compressive strength
Drywall	• Water resistance • Flexural strength
Flooring (finished)	• Indentation load deflection • Tensile strength • Compressive strength • Impact insulation • Flame spread
Insulation	• R-value • Mold resistance • Moisture vapor permeance • Coefficient of thermal expansion • Fire rating / fire resistance

Methods for designing proposed carbon storing materials for repurposing and/or reuse are also encouraged as a means to extend the service life of the chosen building element(s) and minimize the end-of-life embodied carbon footprint. In addition to durability and carbon retention testing, the challenges associated with the proposed end-of-life strategy should be included at the Full Application stage, along with a simplified demonstration of reuse capability, if applicable, that is reflective of current and/or expected construction practices (e.g., nail pull tests for drywall as defined in ASTM C473). Preliminary reuse may also consider other construction practices that may alter the material during deconstruction (e.g., caulks and sealants, tapes, adhesives, mortar and grouts). Proposed methods of initial construction assembly that minimize material damage during deconstruction are also encouraged.

Carbon Storing Materials

A variety of promising carbon storing materials are being explored and commercialized for building construction.[31] Availability, however, is generally still at small scales, bear higher cost per unit and/or face performance challenges (e.g., lower flame resistance for biogenic carbon containing materials). Of interest in this FOA are technologies that collectively overcome these barriers while also nullifying associated emissions and increasing the total amount of carbon stored in the selected material (see Figure 4). Bio-based materials, as noted above, generally already achieve high carbon storage values (i.e. ranges typically 40 wt.% or higher stored in their structure during raw material growth). As such, for proposed materials that utilize biogenic feedstocks, ARPA-E is particularly interested in technologies that can nullify emissions associated with raw material sourcing, transportation, logistics and that can overcome existing

[31] Kriegh, J.; Magwood, C.; Srubar, W., "Carbon-Storing Materials Summary Report," *Carbon Leadership Forum*, February 2021, https://carbonleadershipforum.org/download/15508/.

performance barriers (e.g., flammability). Compatibility with corresponding construction techniques is also essential. ARPA-E is also interested in repurposing carbon-negative materials with high atmospheric carbon content after their primary service life ends to replace high-emitting materials, furthering their GHG reduction potential.

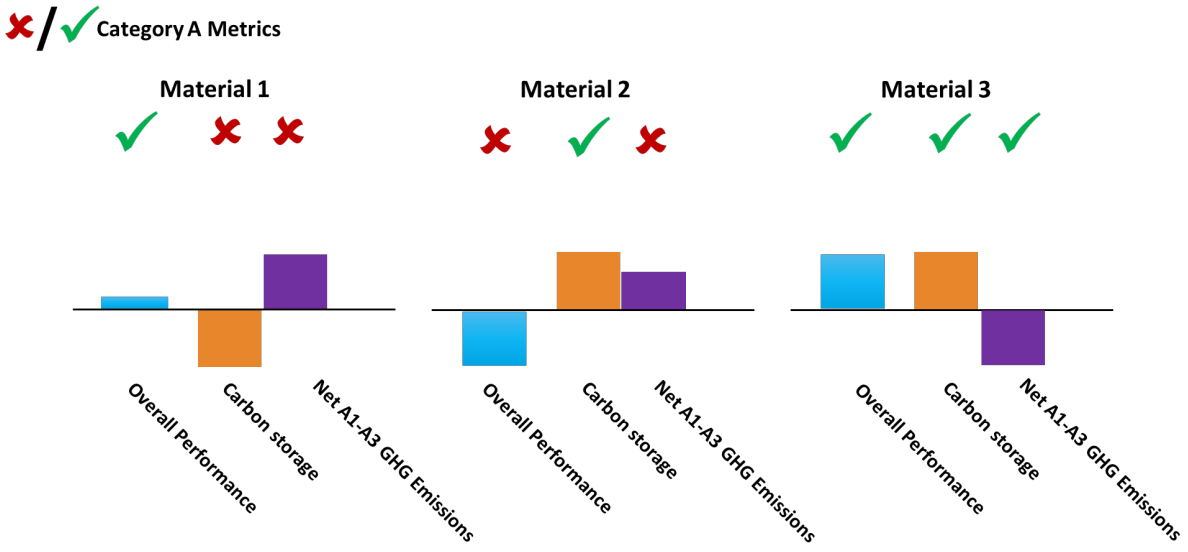

Figure 4. Examples illustrating materials that: (1) already meet building performance specifications, but are not carbon negative, and (2) store carbon, but are not carbon negative due to embodied emissions footprint and also do not yet meet building performance specifications relative to the incumbent. The HESTIA Program aims to achieve materials as illustrated for Material 3.

Specific examples of the types of materials that could be considered are discussed in greater detail below. However, as previously stated, technologies that enable new materials, as well as nascent approaches to existing materials not included here are also of great interest (e.g., synthetic biological, bio-mimetic approaches) for this Program. If part of the value proposition for the proposed material is in enabling a more efficient construction method than current practices, associated risks and carbon impacts should also be discussed.

Cementitious Materials

Methods for producing low carbon cements and concretes have included curing with CO_2, inclusion of synthetic aggregates derived from CO_2, and biologically induced cementation.[32] These routes have been shown to achieve up to approximately 5 wt.% carbon stored in the

[32] Siegel, R.P., "Cutting the Carbon from Concrete," *Mechanical Engineering*, V. 142(02), 38-43, 2020.

finished product. [33] Since this FOA seeks net carbon negative materials, it is anticipated that this amount will need to be increased dramatically to fully offset all associated emissions, as delineated in Section I.E of the FOA. In addition, recycling these materials can lower their GHG footprint enough such that the amount of carbon stored to achieve carbon negativity could be reduced.

Bio-derived Insulation Materials

Building insulation materials derived from bio-based feedstocks (e.g., straw bale, cellulose) are already available at various levels.[34] These polymers are potentially attractive for use because of their readily attainable high carbon storage values and low embodied carbon footprint, however, R-values are still lower than traditionally used petroleum-derived materials (see Figure 5).[35,36] The hydrophilic properties of these materials further increase heat transfer in humid conditions.[37,38] As such, technologies such as hydrophobic natural fibers, close cell-like materials, and structural insulated panels, that are designed with both embodied carbon and insulation performance in mind, are also of interest in this FOA.

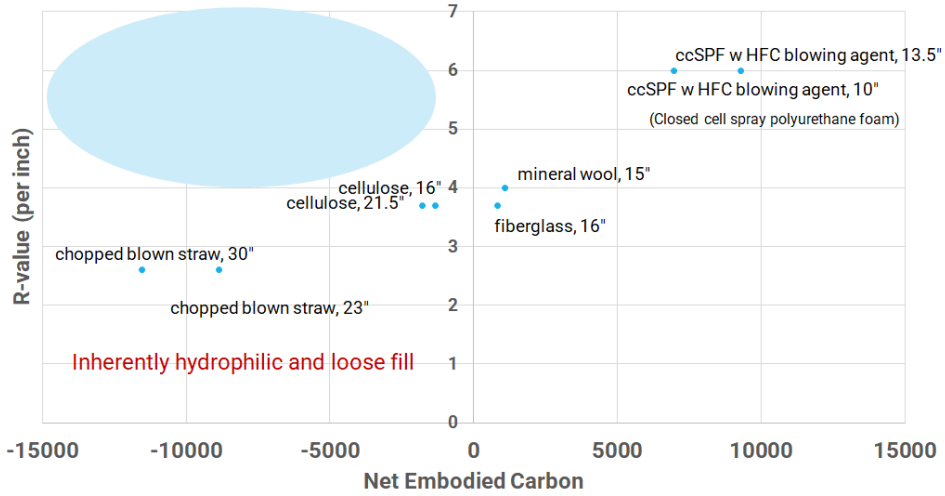

Figure 5. Thermal resistance for select building insulation materials as a function of their net embodied carbon.[39]

[33] Calculations based on data from Constantz, B., "Carbon Capture and Mineralogic Sequestration - Addressing the World Wide Epidemic on a World Wide Scale," *CCEMC Grand Challenge Round One*, 2016, http://eralberta.ca/wp-content/uploads/2017/05/K130111-Blue-Planet-Final-Report-PUBLIC.pdf.

[34] Kriegh, J.; Magwood, C.; Srubar, W., "Carbon-Storing Materials Summary Report," *Carbon Leadership Forum*, February 2021, https://carbonleadershipforum.org/download/15508/.

[35] Asdrubali, F.; D'Alessandro, F.; Schiavoni, S., "A Review of Unconventional Sustainable Building Insulation Materials," *Sustainable Materials and Technologies,* V. 4, 1-17, 2015.

[36] Abu-Jdayil, B., et. al., "Traditional, State-of-the-Art and Renewable Thermal Building Insulation Materials: An Overview," *Construction and Building Materials,* V. 214, 709-735, 2019.

[37] Babu, K., et. al., "A Review on the Flammability Properties of Carbon-Based Polymeric Composites: State-of-the-Art and Future Trends," *Polymers (Basel),* V. 12(7), 1518, 2020.

[38] Bahrami, M.; Abenojar, J.; Martinez, M. A., "Recent Progress in Hybrid Biocomposites: Mechanical Properties, Water Absorption, and Flame Retardancy," *Materials (Basel)*, V. 13(22), 5145, 2020.

[39] Magwood, C., "Opportunities for Carbon Capture and Storage in Building Materials." *Master's Thesis, Trent University*, 2019. http://digitalcollections.trentu.ca/objects/etd-784.

Bio-based polymers are also being explored in the production of structural building materials, including cellulose nanofibers in oriented straw board.[40] Adoption of bio-based polymers will also be contingent upon the ability to source large quantities of feedstocks, and technologies that can demonstrate these capabilities are encouraged.

Mycelium-based Materials

Derived from agricultural residues, mycelium-based materials are attractive replacements for both insulation (e.g., foams, plastics) and structural (e.g., timber) replacements due to the low raw material cost ($0.07-0.17/kg raw materials) and emissions associated with fabrication.[41] Temporary structures have been constructed from mycelium bricks,[42] and commercialization of mycelium acoustic panels is also being explored.[43] As a bio-based material, mycelium also exhibits high carbon contents (i.e. 40-70 wt.%) compared to, for example, the ~4.5 wt.% stored in the paper facing of traditional gypsum-based drywall used for interior/exterior walls and ceilings. Increasing the silica content can increase flame resistance and improve the fire rating performance. Technologies that can improve these properties while also overcoming mechanical performance challenges, including water adsorption and consistency, are all of interest in this FOA.

Mass Timber and Engineered Woods

In addition to the common use of wood in building construction, mass timber and engineered woods (i.e. cross-laminated timber), are emerging as viable replacements to steel and concrete, as well as vinyl siding.[44] For example, mass timber, particularly glulam, has shown potential for replacing steel beams of equivalent or lower strength and stiffness while reducing embodied emissions. Chemical treatment of or composites formed with mass timber are useful in improving adoption, as well as increasing their carbon storage potential.[45,46] Technologies that can advance these routes while also offsetting GHG emissions from forestry practices and associated production are of interest. Improvements to flame resistance are also encouraged.

Direct GHG Utilization

Solid carbon produced from atmospheric CO_2 has the potential to lock carbon away as part of a composite (e.g., carbon fiber) while not impinging on arable land. Approaches demonstrated to-date include carbon dioxide mineralization and electro-reduction to convert CO_2 into products.[47] Technologies that would enable more efficient conversion to products could reduce

[40] See, e.g., US 10695947, 2020, UMaine; https://www.zureli.com/product/oriented-structural-straw-board
[41] M. Jones et al. Materials and Design 187 (2020) 108397
[42] https://www.arup.com/news-and-events/hyfi-reinvents-the-brick
[43] https://mogu.bio/
[44] Churkina, G.; Organschi, A.; et al., "Buildings as a global carbon sink," *Nature Sustainability,* V. 3, 269-276, 2020.
[45] Ramage, M.H, et al., "The wood from the trees: The use of timber in construction," *Renewable and Sustainable Energy Reviews,* V. 68, 333-359, 2017.
[46] Chen, C. et al., "Structure-property-function relationships of natural and engineered wood," *Nature Materials Reviews,* V. 5, 642-666, 2020.
[47] See, e.g., "https:///www.xprize.org/prizes/carbon.

overall costs for these and other less explored routes. Other novel processes for or uses of mineralized or reduced carbon dioxide are also of interest.

Methane pyrolysis, if widely adopted, for example, would produce vast quantities of solid carbon, but would also need to demonstrate a nullification of associated upstream production emissions (e.g., biogas, bioenergy with carbon capture and storage), along with sufficient carbon storage.

II. CATEGORY B – BUILDING DESIGNS

Achieving carbon negative buildings may include new design methods not presently employed in the building construction process. Constraints to existing design methods and materials selection pose added challenges to demonstrating carbon negativity at the whole-building level. For example, cross-laminated timber relies on adhesives, with their own embodied carbon footprint, for meeting structural requirements. The focus of this technical category is new building design technologies that will nullify cradle-to-grave emissions under a given set of assumptions by optimizing design decisions around carbon storing materials to create carbon negative buildings (see Figure 6).

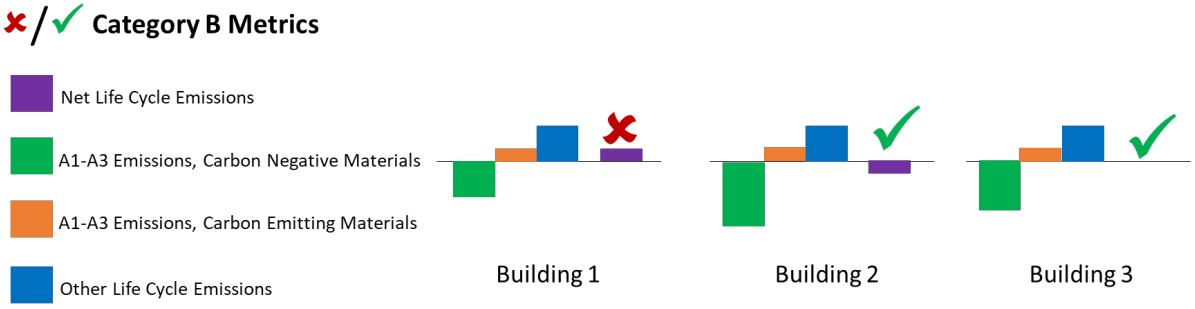

Figure 6. Illustration of pathways for achieving carbon negativity at the whole-building level while using a mixture of both carbon storing and carbon emitting materials.

Strategies to reduce embodied emissions include whole-building re-design, material choice, and selection of materials best suited to address specific performance needs in each part of the building. These efforts are not widely adopted, however, due to the risk-averse nature of the industry, and focus on conventional readily-available materials, without consideration for carbon negativity - the focus of HESTIA. As such, the enhanced performance and carbon negativity of materials described in Section I.E.1, may not be fully exploited at the whole-building level, minimizing or even negating those benefits.

Architectural designs proposed in this Category for the chosen commercial and/or residential building, as well as climate zone (as specified in Section I.B), will need to incorporate at least one carbon negative building material that has been sufficiently developed to have been previously used in a full-scale prototype. For example, a carbon negative concrete already

commercially available for road pavement applications, but demonstrated in the Program for building structures or enclosures (e.g., building foundation) is considered in scope. Furthermore, carbon negative material(s) chosen for this Category must be able to undergo necessary performance testing. Preliminary information should be included on the carbon storage capacity and feedstock sources being considered, as outlined in Section I.F, which will be validated through direct measurement. Submissions will also need to describe how the innovations proposed will achieve cradle-to-grave net carbon negativity at the whole-building level, which may be confirmed by LCA over the course of the Program.

Improvements to building designs and specifications have been shown to result in significant reductions in embodied emissions, lowering the barrier to achieving a carbon negative building. For example, a 21-46% reduction in upfront emissions was recently demonstrated for three different commercial building types through readily available material choices (e.g., procuring low carbon cement specified at 56-day strength).[48] These efficiency improvements resulted in only a < 1% increase in project costs. Rammed earth approaches, consisting of soil mixtures, have enabled similar embodied emission reductions and have also experienced cost decreases by simplifying wall designs and use of panel forms.[49] In addition to material performance issues (e.g., thermal property limitations require added insulation, whose added thickness affects overall structural properties and cost), there are construction challenges that need to be overcome through innovations in building design methods. Technologies that address the loadbearing limitations of these types of carbon storing materials through framing design and selection, as well as reinforcement strategies are of interest. Also of interest in this FOA is the incorporation of lighter weight structural materials for flooring and framing on higher levels of multi-story buildings to reduce the need for higher strength materials at lower levels, multi-functional materials (e.g., insulation) that can reduce the total material installation requirements and improve building operational efficiency, and modular materials to further reduce emissions during building construction.

These examples are intended to be illustrative, and use of other carbon negative materials not listed here and/or design strategies are also of interest. For assessment and testing purposes, applicants must select a building type and geographic region for reference (see Section I.B).

Construction methods can also result in significant embodied emissions from material loss, active material formation (e.g., applying foam insulation), and associated energy usage. Proposed design technologies in this Program will also need to consider innovations to reduce labor and/or mechanical intensity, while also ensuring high levels of control over material sourcing and batching. Efforts are actively underway to disrupt the building construction process itself, through off-site manufacturing and automated assembly approaches, including

[48] Jungclaus, M.; Esau, R.; Olgyay, V.; Rempher A., "Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities, *Rocky Mountain Institute,* 2021, https://rmi.org/insight/reducing-embodied-carbon-in-buildings/ Kriegh, J.; Magwood, C.; Srubar, W., "Carbon-Storing Materials Summary Report," *Carbon Leadership Forum*, February 2021, https://carbonleadershipforum.org/download/15508/.

[49] See, e.g., https://www.yourhome.gov.au/materials/rammed-earth.

the Advanced Building Construction Initiative.[50] Technologies proposed in this Category should describe how they will be incorporated into these new emerging construction methods that are moving away from the traditional model of off-site material manufacturing by separate entities and manual assembly. Design solutions are encouraged that facilitate the transition from on-site material cutting-to-scale (e.g., framing and walls), mixing and fabrication (e.g., foundations), and assembly of various parts using nails, screws and adhesives. More widespread use of these methods will further decrease costs with increasing builder experience.

Building disassembly, driven by economics, tends to default to tear-down for both whole-building removal and retrofits. Material repurposing is seldom considered and the nature of current assemblies is such that if repurpose is a goal, disassembly is more time-consuming. In order to achieve the HESTIA goals of carbon negativity on a cradle-to-grave basis, extending the primary service life is critical. As such, proposed methods for disassembly are encouraged for proposed design submissions to this Category. Tests of reuse capability (e.g., nail pull) over the course of the Program to address the challenges with repurposing carbon-negative materials used in the building design are also of interest.

F. TECHNICAL PERFORMANCE TARGETS

I. CATEGORY A – MATERIALS DEVELOPMENT

Applicants proposing the development of a carbon negative building material to be used in one or more building elements should describe how their innovation will accomplish the following targets of:

- Achieving carbon negativity on a cradle-to-gate basis in the finished material product.
- Overcoming potential construction and/or operational energy performance barriers for the proposed material.
- Achieving a market advantage in at least one dimension (e.g., higher R-value, lower cost) for the building construction and/or enclosure element(s) selected for replacement.
- Demonstrating recycling, repurposing, and /or reusability potential at the end of the original service life.

The applicant must also describe how the proposed project will meet all of the following requirements during the Program:

- The proposed developed materials, confirmed by a materials-level LCA (to be conducted in coordination with the LCA Partner Team(s) as noted in Section I.G), achieves cradle-to-gate carbon negativity, and at a minimum, does not increase gate-to-grave emissions, (to be analyzed in coordination with the LCA Partner Team(s) as noted in Section I.G).

[50] The DOE Building Technologies Office (BTO)'s Advanced Building Construction (ABC) Initiative. https://www.energy.gov/eere/buildings/advanced-building-construction-initiative

- The proposed developed materials achieve appropriate building construction specifications against the best-in-class incumbent element(s), through standardized testing (i.e. ASTM / ISO) performed either by Awardee or third party test labs and with consideration of the building type(s)/geographic region(s) selected. Both repeatable and reproducible results will be required.

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

- The type(s) of feedstock(s) that will be processed, along with the availability and scalability of the proposed material.
- A short description of how the proposed process meets the impact areas discussed in Section I.D of the FOA.
- The challenges for the proposed technology that need to be overcome and a comparison of the proposed technology's cost and performance to state-of-the-art for the targeted material.
- A short description of how the proposed material will be installed in new building construction and/or retrofit, as well as how it will be removed and repurposed at the end of its original service life.

In addition, each applicant to this category must specify the building element(s) targeted, as well as the selected building type(s) and climate zone(s) selected for initial testing (as defined in Section I.B). The information in Table I.F.I.1, must also be provided in summary form.

Table I.F.I.1: Carbon Negative Material Technology Description

Property	Description
Chemical composition of proposed material and estimate of wt.% atmospheric carbon that will be stored in the finished material product. Specify method of carbon measurement.	
How carbon negativity will be achieved on a cradle-to-gate basis (i.e. A1-A3) for the finished product.	
Market (e.g., performance or cost) improvement relative to best-in-class incumbent building element(s).	
Initial key performance tests (e.g., strength, flammability, thermal resistance) and relevant tests based on applicable standards (i.e. ASTM/ISO) for selected building element(s) being replaced and building type(s) / climate zone(s) selected and as defined in Section I.C.	

II. CATEGORY B – BUILDING DESIGNS

Applicants proposing the design of a building that is carbon negative over its lifetime should describe how their innovation will accomplish the following targets of:

- Achieving carbon negativity on a cradle-to-grave basis.
- Maintaining operational efficiency for the selected building type. I.e., the new building design cannot reduce operation efficiency relative to the state-of-the-art for the selected building type.
- Incorporating at least one carbon negative building material that also can meet the necessary testing specifications for the incumbent building element(s) in which it is used.
- Achieving a market advantage in at least one area for the carbon negative building element(s) for the selected building type(s) and geographic region(s) (as defined in Section I.B).
- Demonstrating potential for reusability, repurposing and/or recyclability for building structural and/or enclosure element(s) at the end of their service life. Building designs, construction, deconstruction and reconstruction methods, or material designs that lower the barriers to reuse, repurpose or recycle the materials in a building are encouraged. Material reuse, repurpose or recycling can be specific to the chosen carbon negative material(s), other materials, a portion of the building, or the entire building. These strategies, however, should focus on the building materials / elements of interest to this Program. Components such as electrical wiring, plumbing, and cosmetic inclusions (furniture, etc.) are out of scope. Whether a material is recycled, reused, or repurposed should be guided by the impact of that decision on the LCA results.
- Achieving a market advantage for the constructed building, demonstrated or translated to a dollar amount. For example, technoeconomic analysis of the building may show a lower overall cost versus an incumbent design; or the building may demonstrate an inherent performance advantage, such as reduced operational cost, that can be translated into financial savings over the building's operating life.

The applicant must also describe how the proposed project will meet all of the following requirements during the Program:

- Carbon negative material(s) chosen for proposed design, confirmed by a materials-level LCA (to be conducted in coordination with the LCA awardee(s) as noted in Section I.G), must achieve cradle-to-gate carbon negativity, and at a minimum, must not increase gate to grave emissions, (to be analyzed in coordination with the LCA Partner Team(s) as noted in Section I.G).
- The proposed design, confirmed by a building-level LCA (to be conducted in coordination with an LCA awardee as noted in Section I.G), achieves cradle-to-grave carbon negativity. Assumptions, to be analyzed in partnership with the LCA Partner Team as noted in Section I.G, including a 100-year lifetime for the building.
- Architectural plans achieve required building construction and operational specifications as validated with applicable methods (i.e., architectural drawings, building energy

simulation tools such as EnergyPlus,[51] building information modeling, construction schedules and plans) with consideration of the building type/geographic region selected. Both repeatable and reproducible results will be required. If the market advantage is a materials performance enhancement, that must also be demonstrated.

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

- The carbon negative material(s) that will be incorporated and the current stage of development for the material(s) in terms of full-scale prototype production, including its availability and scalability. Include information to substantiate commercial readiness of selected material supply chain analyses of production requirements.
- A short description of how the proposed design method meets the impact areas discussed in Section I.D of the FOA for the selected building type(s) (as specified in Section I.B).
- The challenges for the proposed technology that need to be overcome and a comparison of the proposed technology's cost and performance to state-of-the-art for the targeted design.
- A short description of how the targeted design will be used in new building construction and/or retrofit, including possible material reuse for the proposed building design and disassembly processes.

In addition, each applicant to this category must specify the building element(s) targeted, as well as the selected building type(s) and climate zone(s) selected for initial testing, as defined in Section I.B. The information in Table I.F.II.1, must also be provided in summary form.

Table I.F.II.1: Carbon Negative Building Technology Description	
Property	**Description**
Chemical composition of proposed material and estimate of wt.% atmospheric carbon that will be stored in the finished building product. Specify method of carbon measurement.	
How carbon negativity will be achieved on a cradle-to-grave basis over the lifetime of the building.	
Market advantage and expected benefits relative to best-in-class incumbent building type(s).	
Initial key performance tests (e.g., strength, flammability, thermal resistance) and relevant tests based on applicable standards where feasible (i.e. ASTM/ISO) for selected building	

[51] https://www.energy.gov/eere/buildings/building-energy-modeling

element(s) being replaced and building type(s) / climate zone(s) selected (as defined in Section I.B). (Note: materials proposed for Category B that are near commercialization may already be tested and demonstrated to meet specifications. However, appropriate tests must still be identified and performance data provided in the course of the Program.)	

G. LCA REQUIREMENTS AND TEAMING

In addition to a preliminary completion of the tables provided in Section I.F, include a high level, semi-quantitative description of how and why proposed building materials for Category A and building designs for Category B can be defined as carbon negative at their cradle-to-gate (i.e. A1-A3) and cradle-to-grave stages, respectively, as well as why the technology proposed has a lower GHG footprint than the incumbent. This information will form the basis of a more rigorous LCA to be conducted over the course of the Program with an LCA awardee.

Projects funded under the HESTIA Program will be required to cooperate with one of the LCA awardee(s) selected through a separate solicitation (see DE-FOA-0001953, Appendix V "Life Cycle Assessment for Carbon Negative Buildings"). LCA awardee(s) will be funded separately by ARPA-E and HESTIA Projects will not need to budget for LCA development tasks. The LCA awardee(s) will establish both material and whole building LCA frameworks and tools to evaluate projects against HESTIA Program targets over the course of the Program. The LCA awardee(s) will meet and provide regular feedback to HESTIA Projects in the form of "hotspot analyses," or analyses that show areas for potentially reducing the GHG footprint of technologies developed through the Program. Projects funded through this FOA are expected to collaborate with the LCA awardee(s) and use these outputs to further improve on and/or modify the proposed technologies. Furthermore, HESTIA Projects will be expected to provide any and all data, estimates, and/or assumptions necessary and as requested by LCA awardee(s) for completion of the LCA, including, but not limited to the following:

- Bill of raw materials (only Category A)
- Bill of materials (only Category B)
- Sourcing location(s) and manufacturing location(s) for all raw materials, manufacturing sites, and construction sites (both Categories A and B)
- Energy and material consumption, as well as emissions of materials manufacturing process(es) (only Category A and B)
- Rate of refurbishment/replacement of material(s), maintenance process(es) (both Categories A and B)
- Disposal or end-of-life options for each material developed and/or used (both Categories A and B)

Projects funded under the HESTIA Program will be expected to regularly update both ARPA-E and the LCA awardee(s) with data including but not limited to those listed above. For optimal results, regular communication between the two parties is encouraged as a means to identify ways to better achieve the goals of the Program. HESTIA Project Teams are also encouraged to include in-house LCA expertise wherever necessary in the development of the proposed technology.

While entities are open to apply to both solicitations, ARPA-E will review the proposed members of the LCA awardee(s) once awarded. Modifications to team compositions may then be necessary to ensure there are no potential conflicts of interest (i.e. personal and/or organizational).

Since the LCA awardee(s)will need to utilize sensitive, potentially proprietary, and "protected" data from HESTIA awardees, the LCA awardee(s) must commit to, and their award will require, maintaining strict confidentiality regarding data provided to them by a HESTIA awardee and the results that are generated using such data. ARPA-E will prepare and provide at the Full Application Phase, a Non-Disclosure Agreement (NDA) that the LCA awardee(s) will be required to sign with each applicable HESTIA awardee. Data generated about individual HESTIA awardee data will only be provided to the specific HESTIA awardee whose data has been utilized and to ARPA-E. The LCA awardee(s) will not obtain data rights or other intellectual property rights in any results.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $41 million available for new awards under this FOA, to be shared between FOAs DE-FOA-0002625 and DE-FOA-0002626, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 10-15 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

Individual awards may vary between $500,000 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 September 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 quantitative 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."[52] 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.[53]

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

[52] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[53] 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[54] 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.

[54] 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,[55] as the lead for a Project Team,[56] 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[57], educational institutions[58], and nonprofits[59] 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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[55] A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.

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

[57] 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.

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

[59] 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.

5. ELIGIBILITY WITH RESPECT TO SOLICITATION ON TOPICS INFORMATION NEW PROGRAM APREAS TOPIC V

An entity may submit separate applications to this FOA: Harnessing Emissions into Structures Taking Inputs from the Atmosphere (HESTIA) DE-FOA-0002625 or Harnessing Emissions into Structures Taking Inputs from the Atmosphere SBIR/STTR (HESTIA SBIR/STTR) DE-FOA-0002626 (collectively, the "HESTIA Program") and the Solicitation on Topics Informing New Program Areas: Topic V, DE-FOA-0001953. However, any individual participating on a Financial Assistance Award from ARPA-E under Solicitation on Topics Informing New Program Areas: Topic V, DE-FOA-0001953, will be prohibited from participating on any HESTIA Project Team.

B. COST SHARING[60]

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

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.C.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime Recipient must provide at least 20% of the Total Project Cost[61] as cost share, except as provided in Sections III.B2 or III.B.3 below.[62]

2. INCREASED COST SHARE REQUIREMENT

Large businesses[63] 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").[64] 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.

[60] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[61] 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.
[62] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988(c)
[63] The term "For-Profit Organizations (Other than Small Businesses)" or "large business" is defined in Section IX.
[64]The term "small business" is defined in Section IX.

- 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.
- 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[65] 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

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

costs would be included in Total Project Costs for purposes of calculating the cost-sharing requirements of the applicant.

8. COST SHARE VERIFICATION

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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

Full Applications are deemed compliant if:

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

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

not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

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

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

2. RESPONSIVENESS CRITERIA

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

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to 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 distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by any other office within Department of Energy.
- Submissions that are not distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by other government agencies or the private sector.

- Submissions that do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

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

- Development of specific chemistries, polymers, minerals, or other individual components of a material, only; raw materials only; any material not in a finished product form for use in building construction
- Development of materials not comprising the framing and enclosure of a building structure. For example, electrical, plumbing, cosmetic inclusions (e.g., furniture), or landscaping.
- Materials that already exist on the market in any capacity or reflect incremental change to existing materials (only applies to Category A)
- Isolated materials development without full consideration of compatible manufacturing methods
- Building designs that do not include carbon negative materials as defined in the FOA
- Building designs that do not consider material reuse at the end of the service life of the material or building
- LCAs of proposed building materials, building design, incumbent building materials, and/or incumbent, conventional building design(s)

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

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

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

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

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

1. CONCEPT PAPER

a. CONCEPT SUMMARY

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

b. INNOVATION AND IMPACT

- Clearly identify the problem to be solved with the proposed technology concept. Additionally, describe the role of the impact areas described in Section I.D. of the FOA on the proposed technological innovation.
- 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.F of the FOA for the appropriate Technology Category in Section I.E of the FOA. Provide any additional information requested for each category as defined in Section I.F.

  Provide the additional information below for the applicable category.

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

Table I.F.I.1: Carbon Negative Material Technology Description

Property	Description
Chemical composition of proposed material and estimate of wt.% atmospheric carbon that will be stored in the finished material product. Specify method of carbon measurement.	

How carbon negativity will be achieved on a cradle-to-gate basis (i.e. A1-A3) for the finished product.	
Market (e.g., performance or cost) improvement relative to best-in-class incumbent building element(s).	
Initial key performance tests (e.g., strength, flammability, thermal resistance) and relevant tests based on applicable standards (i.e. ASTM/ISO) for selected building element(s) being replaced and building type(s) / climate zone(s) selected and as defined in Section I.C.	

For technology category B, provide the information requested in Section I.F.II of the FOA, table I.F.II.1.

Table I.F.II.1: Carbon Negative Building Technology Description	
Property	**Description**
Chemical composition of proposed material and estimate of wt.% atmospheric carbon that will be stored in the finished building product. Specify method of carbon measurement.	
How carbon negativity will be achieved on a cradle-to-grave basis over the lifetime of the building.	
Market advantage and expected benefits relative to best-in-class incumbent building type(s).	
Initial key performance tests (e.g., strength, flammability, thermal resistance) and relevant tests based on applicable standards where feasible (i.e. ASTM/ISO) for selected building element(s) being replaced and building type(s) / climate zone(s) selected (as defined in Section I.B). (Note: materials proposed for Category B that are near commercialization may already be tested and demonstrated to meet specifications. However,	

appropriate tests must still be identified and performance data provided in the course of the Program.)	

c. PROPOSED WORK

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

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 FEBRUARY 2022]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2022]

F. INTERGOVERNMENTAL REVIEW

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

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2022]

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.F of the FOA for the appropriate technology Category in Section I.E 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 FEBRUARY 2022]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2022]

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 FEBRUARY 2022]

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 FEBRUARY 2022]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2022]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2022]

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 no later than three business days 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:

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions;
- All other parties: The federal Non-Nuclear Energy Act of 1974, 42. U.S.C. 5908, provides that the government obtains title to new subject inventions unless a waiver is granted (see below):
  - Class Patent Waiver for Domestic Large Businesses: DOE has issued a class patent waiver that applies to this FOA. Under this class patent waiver, domestic large businesses may elect title to their subject inventions similar to the right provided to the domestic small businesses, educational institutions, and nonprofits by law. In order to avail itself of the class patent waiver, a domestic large business must agree to the U.S. Competitiveness Provision in accordance with Section VI.B.8. of this FOA.
  - Advance and Identified Waivers: For applicants that do not fall under the class patent waiver or the Bayh-Dole Act, those applicants may request a patent waiver that will cover subject inventions that may be made under the award, in advance of or within 30 days after the effective date of the award. Even if an advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver for identified inventions, i.e., individual subject inventions that are disclosed to DOE within the time frames set forth in the award's intellectual property terms and conditions. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784.
- DEC: On June 07, 2021, DOE approved a DETERMINATION OF EXCEPTIONAL CIRCUMSTANCES (DEC) UNDER THE BAYH-DOLE ACT TO FURTHER PROMOTE DOMESTIC MANUFACTURE OF DOE SCIENCE AND ENERGY TECHNOLOGIES. In accordance with this DEC, all awards, including sub-awards, under this FOA made to a Bayh-Dole entity (domestic small businesses and nonprofit organizations) shall include the U.S. Competitiveness Provision in accordance with Section VI.B.8 of this FOA. A copy of the DEC may be found on the DoE website. Pursuant to 37 CFR § 401.4, any Bayh-Dole entity affected by this DEC has the right to appeal it by providing written notice to DOE within 30 working days from the time it receives a copy of the determination.

B. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

Where 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.

- To the extent that architectural drawings resulting from performance of the project are to be widely disseminated, ARPA-E is willing to consider modifications to the copyright provisions of the award.

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).