FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

ELECTRIC VEHICLES FOR AMERICAN LOW-CARBON LIVING SBIR/STTR (EVs4ALL SBIR/STTR)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0002761
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	May 3, 2022
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, June 6, 2022
Submission Deadline for Concept Papers:	9:30 AM ET, June 16, 2022
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:	December 2022
Total Amount to Be Awarded	Approximately $45 million, subject to the availability of appropriated funds to be shared between FOAs DE-FOA-0002760 and DE-FOA-0002761.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $275,766 and $3,952,638.

- For eligibility criteria, see Section III.A – III.D of the FOA.
- For cost share requirements under this FOA, see Section III.E 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.F.1 through III.F.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).

TABLE OF CONTENTS

REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: ○ Concept Summary ○ Innovation and Impact ○ Proposed Work ○ Team Organization and Capabilities	Mandatory	IV.C	9:30 AM ET, June 16, 2022
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2022]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 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 improvements to the cost/performance metric in a gradual fashion. This continual improvement of a technology is important to its increased commercial deployment and is appropriately the focus of the private sector or the applied technology offices within DOE. 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 better 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 and Carbon Management (https://www.energy.gov/fecm/office-fossil-energy-and-carbon-management), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity (https://www.energy.gov/oe/office-electricity).

B. SBIR/STTR PROGRAM OVERVIEW

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are Government-wide programs authorized under Section 9 of the Small Business Act (15 U.S.C. § 638). The objectives of the SBIR program are to (1) stimulate technological innovation in the private sector, (2) strengthen the role of Small Business Concerns in meeting Federal R&D needs, (3) increase private sector commercialization of innovations derived from Federal R&D activities, (4) foster and encourage participation by socially and economically

[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.

disadvantaged and women-owned Small Business Concerns, and (5) improve the return on investment from Federally funded research and economic benefits to the Nation. The objective of the STTR program is to stimulate cooperative partnerships of ideas and technologies between Small Business Concerns and partnering Research Institutions through Federally funded R&D activities.[3]

ARPA-E administers a joint SBIR/STTR program in accordance with the Small Business Act and the SBIR and STTR Policy Directive issued by the U.S. Small Business Administration (SBA).[4] ARPA-E provides SBIR/STTR funding in three phases (Phase I, Phase II, and Phase IIS).

C. PROGRAM OVERVIEW

According to the Intergovernmental Panel on Climate Change (IPCC), global warming of 1.5 to 2 degrees Celsius (^{o}C) will be exceeded during the twenty-first century unless deep reductions in carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions occur in the coming decades.[5] The United States (U.S.) alone is responsible for generating approximately 15% of global CO_2 emissions[6] despite being inhabited by only 5% of the Earth's population. At present, the transportation sector is responsible for 28% of total domestic emissions,[7] with road-based passenger vehicles accounting for 57% of that segment.[8] Domestically, passenger vehicles [i.e., cars, sport utility vehicles (SUVs), minivans and pick-up trucks] collectively emit more than one billion tons of CO_2 per year.

As the U.S. works to decarbonize the transportation sector and produce an increasing amount of "clean" (zero emission) electricity, electric vehicles (EVs) become logical alternatives to internal combustion engines (ICEs). However, to accelerate and/or broaden EV adoption, consumer-centric considerations need to be more thoroughly addressed, including cost, convenience, reliability, and safety. While early adopters contributed to record EV sales in 2021, comprising 3.6% of total cars sold in the U.S.,[9] 42% of these EVs were sold in California, followed by other states with comparable climates and/or wealth.[10] Furthermore, EV ownership is dominated by a minority demographic of the U.S. population based on age,

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

[4] See 84 Fed. Reg. 12794 (Apr. 2, 2019).

[5] "Climate Change 2022: Impacts, Adaptation and Vulnerability", Intergovernmental Panel on Climate Change, 2022 [IPCC_AR6_WGII_FinalDraft_FullReport.pdf]

[6] Global Greenhouse Gas Emissions Data | US EPA

[7] U.S. Emissions | Center for Climate and Energy Solutions (c2es.org)

[8] Fast Facts: U.S. Transportation Sector GHG Emissions (pdf) (December 2021, EPA-420-F-21-076)

[9] "EV Consumer Behavior", Electric Vehicle Council of the Fuels Institute, June 2021 [EV-Consumer-Behavior-Report.pdf (fuelsinstitute.org)]

[10] "Electric Vehicle Ownership Costs: Today's Electric Vehicles Offer Big Savings for Consumers", *Consumer Reports*, October 2020 [EV Ownership Cost Final Report (consumerreports.org)]

gender, annual salary, level of education, and other factors.[9] Although it is expected that EVs will continue to gain market share domestically, significantly more effort is required to address and remove key technology barriers to EV adoption among a greater percentage of the population. In response to these challenges, ARPA-E's **E**lectric **V**ehicles **for A**merican **L**ow-carbon **L**iving (**EVs4ALL**) program will focus on advancing next-generation battery technologies that have the potential to significantly improve affordability, convenience, reliability, and safety of EVs compared to those available today, to directly address the following key market needs:

- Approximately 37% of Americans live in residences without garages or carports and therefore do not have access to the convenience of charging at home. Thus, EV batteries capable of safe, rapid charging are necessary to appeal to this market.[11]
- Many Americans live in northern states[12] where EV battery performance can be experienced as unsatisfactory at low temperatures, due to reductions in capacity and power. Consequently, EV batteries that are more resilient at low temperatures are critical to motivate greater adoption in colder climates.
- The median U.S. household income is approximately $70,000[13] and although a subset of used EV models may be available to purchase for less than $20,000,[14] their maximum range (miles) may be perceived as unacceptably low. Since two thirds of Americans purchase used vehicles rather than new,[15] more durable ("longer-lasting") EV batteries are required to stimulate and assure the used EV market.

If the EVs4ALL program can successfully achieve its primary objective, which is to increase domestic EV adoption through elimination of these key detractors, it will directly impact three ARPA-E mission areas as follows:

i) 80% adoption of electrically powered passenger cars in the U.S. could reduce annual energy consumption by 4 quadrillion British Thermal Units (Quads), thereby improving the energy efficiency of the sector.
ii) 80% adoption of electrically powered cars could reduce overall CO_2 emissions by 800 million tons/year, thereby reducing energy-related emissions.
iii) Solutions to i) and ii) may also target the utilization of "noncritical" battery materials in order to address supply chain risk and drive down cost, thereby reducing imports of critical metals and supporting ARPA-E's energy independence mission.

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[11] "Fact #958: January 2, 2017, Sixty-Three Percent of all Housing Units have a Garage or Carport", Vehicle Technologies Office [https://www.energy.gov/eere/vehicles/fact-958-january-2-2017-sixty-three-percent-all-housing-units-have-garage-or-carport]
[12] https://www.census.gov/data/tables/time-series/demo/popest/2020s-state-total.html
Masias, J. Marcicki, and W. A. Paxton, *ACS Energy Lett.*, 2021, 6, 2, 621-630.
[13] https://www.census.gov/library/publications/2021/demo/p60-273.html
[14] https://www.recurrentauto.com/research/used-electric-vehicle-buying-report#:~:text=Although%20used%20EVs%20are%20on,EV%20price%20is%20%2439.6
[15] U. S. Department of Transportation Bureau of Transportation Statistics Website [https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases-thousands-vehicles]

Note that the benefits postulated in i) and ii) are predicated on additional electricity supply comprised of 25% natural gas and 75% clean (zero emissions) energy.

Background

Since the launch of commercial lithium-ion batteries (LiB) in 1991,[16] the field has witnessed steady improvements in gravimetric and volumetric energy density at both the cell and pack levels. The history of commercial LiB starts with the pioneering Sony cell, which was introduced with a modest gravimetric energy density ~100 Watt-hour per kilogram (Wh/kg). Improvements to energy density since this introduction have been documented and reported.[17] A summary of the progress is depicted in Figure 1 which shows that while improvements of 6% per year were realized on average between 1991 and 2005, recent progress has been a more modest 3% per year. Discussion with industry experts indicated that 350 Wh/kg may be achieved by 2030, but that next generation ("beyond LiB") chemistries are needed to achieve 400 Wh/kg and greater.

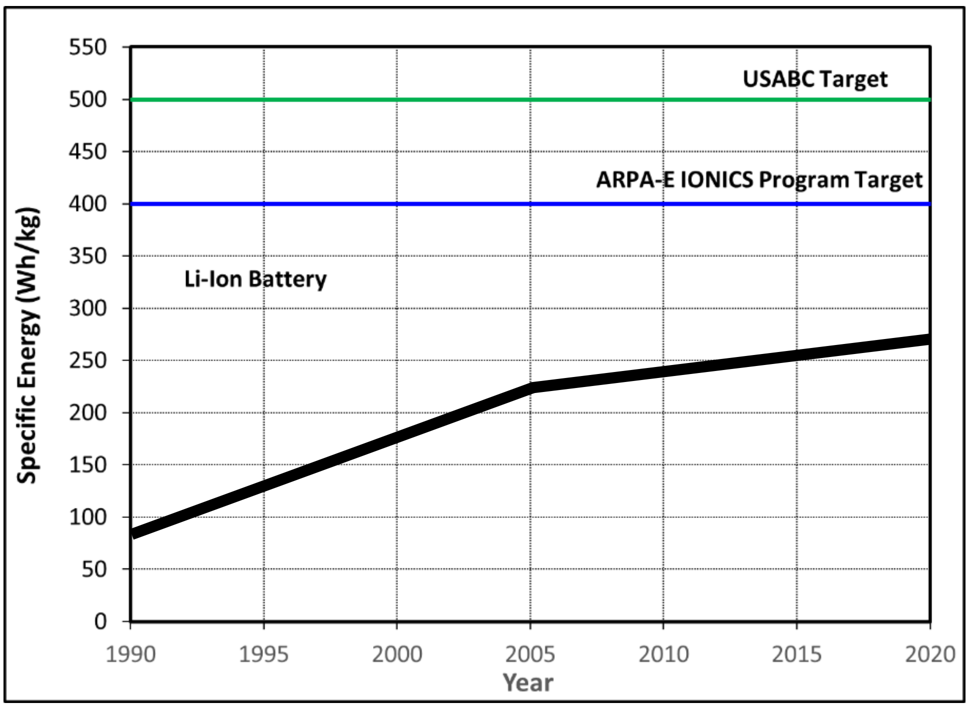

Figure 1. Trend for increasing energy densities for commercial LiB from 1990 to 2019, based on published data;[17] the exclusive intent of the figure is to communicate the higher rate of progress (i.e., energy density) during the period from 1991-2005 compared to 2005-2019.

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[16] Sony commercialized LiB in 1991.

[17] A. Masias, J. Marcicki, and W. A. Paxton, *ACS Energy Lett.*, 2021, 6, 2, 621-630.
G. Pistoia and B.Liaw, "Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost", Green Energy and Technology, 2018
Zeigler and Trancik, *Energy Environ. Sci.*, 2021, **14**, 1635-1651, DOI: 10.1039/D0EE02681F

The ARPA-E IONICS program, United States Advanced Battery Consortium (USABC), and U.S. Department of Energy (DOE) roadmaps identify specific energy targets at (or exceeding) 400 Wh/kg as essential; however, charge time is often viewed as a secondary priority. Perspectives shared during discussions with battery experts[18] support the conclusion that, although battery innovation programs focused primarily on achieving high energy density have merit for specific vehicles and use cases (pick-up trucks, for example), such targets are less relevant in many other scenarios. Stated alternatively, achieving higher energy density by itself may be an ineffective strategy for enabling a large proportion of prospective car buyers to purchase affordable new or used EVs. This hypothesis is at least partially supported by the transition to using lower energy density lithium iron phosphate (LFP) cathodes for lower end models that was embraced by a U.S.-based EV manufacturer and EV manufacturers in China.[19] Additionally, an analysis of car ownership in the U.S. reveals that two-thirds of households have two or more cars, and that the second, third, fourth, etc., cars in any household travel over forty percent fewer miles on average per week compared to the primary vehicle.[20] Therefore, the combination of (1) recent EV industry decisions in favor of lower energy density batteries and (2) behavioral trends for households with more than one vehicle may be perceived as support for the coexistence of discrete markets for both higher and lower range EVs.

Fast-Charging and Charging Infrastructure

Fast charging, i.e., 80% charge input in 5 to 15 minutes, is undoubtedly more desirable than the 30-to 40-minutes required for most commercially available EVs today. Admittedly, fast charging may be less important to the segment of the population that reside in homes with personal garages or car ports who can enjoy the convenience of charging at home without time pressure. However, fast charging is expected to become a key factor for other groups contemplating the purchase of an EV.

- People who live in densely populated urban areas typically park cars on the street or in large garages shared by other residents of the same apartment building or community. Therefore, this segment of the EV owner population would most often rely on charging at a public charging station. The major challenges associated with this EV "refueling" process may include (1) unacceptable levels of inconvenience to the EV owner, including a significant alteration of daily lifestyle/routine, and/or (2) a logistical nightmare considering the congestion expected at these service centers due to extended charging required for EVs compared to refueling an ICE vehicle.
- While apartment complexes may accommodate EV owners by installing charging stations on-site, these facilities are likely to be limited in number such that the actual accessibility of "at-home" charging is expected to be modest at best.

[18] https://arpa-e.energy.gov/events/high-energy-fast-charging-batteries-for-ev-applications-workshop
[19] "Tesla Plans Shift to Lithium Iron-Phosphate Batteries Globally", BNEF report, October 20, 2021.
[20] FOTW #1047, September 17, 2018: Daily Vehicle Miles Traveled Varies with the Number of Household Vehicles | Department of Energy

- The cost of installing a home charger can be significant and may be hampered by location and availability, including in rural areas. Sharing high capacity, fast charging stations much as a gas station is shared eliminates this barrier.
- Taxis, ride share drivers, and small delivery vehicles typically rely on a fast turn-around when refueling to minimize interruptions to daily business operations.

Although the benefits of fast charging during extended journeys have some relevance to all drivers and such a need will also be addressed by this program, they are not the primary motivation for this initiative.

Charging Infrastructure

350 kW chargers for EVs exist today in the U.S. while 500 kW chargers for commercial vehicles are being tested by at least one major automotive manufacturer.[21] If EV batteries are capable of safely accepting fast charging, these chargers could provide 200 miles of range in 9.5 minutes and 6.7 minutes, respectively, which assumes 4 miles = 1 kWh and 90% charger efficiency.

As the domestic charging infrastructure receives increasing levels of investment – both government and private – charging stations are expected to become ubiquitous. In city environments, the power grid may be able to support the load surges required for rapid charge and the development of charging stations with battery load peak shifting could be part of a total solution. While the prevalence of fast direct current (DC) charging in the near term remains unclear, at least one industry observer has forecast that up to 24% of vehicle charging could be fast charge by 2040.[22] It remains to be seen how charger infrastructure will evolve in the U.S. and how both government and the private sector will drive overall charger penetration and capability. This program seeks to develop and advance batteries capable of safely accepting high power charge from both available and future attainable charger technologies. At the same time, such batteries will need to demonstrate compatibility with the existing charger infrastructure irrespective of the kilowatt (kW) rating.

In addition to charger innovations, the battery itself will likely evolve to use higher system voltages to better accommodate faster charging. For example, two production model EVs,[23] both launched in 2021, employ 800 volt (V) electrical systems. Assuming that safety can be managed cost effectively, the development of higher voltage battery systems is anticipated.[24] Voltage and pack configuration aside, the charging capability of a battery is related to charge acceptance and to the transfer and flux of both ions and electrons at electrode interfaces and active material surfaces. Thus, next generation battery cell chemistry and design solutions are required to safely enable these fundamental battery processes at extremely high rates. Based on current electrode design strategies, ARPA-E anticipates that current densities of > 20

[21] https://insideevs.com/news/457796/daimler-first-public-megawatt-truck-charging-station/
[22] "Charging Infrastructure Forecast Model (CIFM 2.0)", BNEF Insight, Ryan Fisher, June 2021
[23] Porsche Taycan and the Hyundai Ioniq 5
[24] https://evcentral.com.au/ev-voltage-bmw-says-numbers-game-is-not-a-competition

milliamps per square centimeter (mA/cm^2) would be required to achieve the target charge rates in this program. Accordingly**, a primary focus of the EVs4ALL program includes development of next generation battery technologies to overcome the fundamental limitations of fast charge**. While the program acknowledges the importance of advancing charger technology in parallel to battery cell-centric initiatives, approaches limited to charger and/or charger infrastructure development are outside the scope of this program.

Low Temperature Performance

Many northern states experience winter temperatures below freezing and the performance of a vehicle when the outside temperature is -10°C or -20°C is an important operational factor which is exacerbated when a home garage is not available. Multiple studies have quantified the loss of EV battery performance in such cold temperatures. One study concluded that a reduction in range of up to 40% can occur in cold temperature scenarios compared with moderate temperature conditions.[25] This loss is attributable, at least in part, to the need to divert a percentage of available battery energy to actively heat the interior vehicle cabin – a requirement that ICEs easily handle by utilizing their copious waste heat. According to another source, LiB cell performance losses can be as high as 25% at -10 °C,[26] which is due to a combination of reduced delivered capacity and lower running voltage. **The cold temperature focus of the EVs4ALL program is strictly limited to this loss of battery performance at lower temperatures** and will not address the topic of interior cabin heating.

ARPA-E anticipates that significant, simultaneous improvements to (1) electron conducting components, (2) reaction kinetics, and (3) species diffusion will likely be required to realistically achieve rapid charging and better low temperature discharge. It is reasonable to believe that some of the solutions targeted to improve charge power will directly translate into better low temperature battery performance.

Used EV Value

The price of new EVs, as well as their rate of depreciation, will be key factors that determine their affordability for the two-thirds of the population that do not purchase or lease new vehicles.[15] As discussed above, the median U.S. household income is $70,000 and for many of these households a reasonable used vehicle purchase price may be $15,000 or less. While used EVs are available for less than $15,000, the limited models are typically more compact in size with a modest range, putting it at a significant disadvantage relative to similarly priced ICEs – and households with a lower income may be less likely to have garages or home chargers. Beyond basic cost considerations, it is critical that future EVs maintain as much range as possible within a reasonable total life mileage. Decades ago, the battery industry adopted an 80% battery capacity retention target for end-of-life after cycling. However, it is increasingly likely that a higher capacity retention percentage will be required to make used EVs more

[25] How Temperature Affects EV Range with Hot & Cold Climate (recurrentauto.com)
[26] BU-502: Discharging at High and Low Temperatures - Battery University

attractive to consumers. This need is reflected in the targets for Categories 1 and 2 of the EVs4ALL program.

Affordability and Materials Dependence

Currently, the cost of a battery that can provide a reasonable EV range is three times that of a comparable ICE – $9,000 for a 75 kilowatt-hour (kWh) battery[27] *versus* $3000 for a 4-cylinder ICE – which is reflected in the higher price tag for new EVs. While a continued trend toward lower LiB prices was anticipated, the latest forecasts suggest a pause to the price decline, which may or may not be temporary. Specifically, an industry observer predicts that battery prices will increase in 2022 relative to their 2021 benchmarks,[28] and while this is partially a consequence of the present inflationary pressures facing many products, nickel and cobalt prices are a disproportionate factor.

At their peak (prior to February 2022), the cost of the nickel and cobalt required for the battery cathode would have comprised greater than 20% of today's total battery cost. According to the U.S Geological Survey (USGS), the U.S. mined less than 1% of global nickel and cobalt in 2020, while cobalt was primarily sourced from the Democratic Republic of the Congo (DRC, ~69%), Russia (~6%) and Australia (~4%).[29] Likewise in 2020, ~31% of nickel originated from Indonesia, ~13% from the Philippines, and ~11% from Russia.[30] A lack of domestic cobalt and nickel resources creates both commercial supply-chain and national security concerns, with the former motivating EV manufacturers to transition to low-cost, abundant LFP cathodes for a subset of EV models, despite reduced performance.[19] In summary, the high cost of nickel and cobalt make achieving cost parity between state-of-the-art EV batteries and ICEs extremely unlikely. Low-cost, high-performance cathodes that contain low (preferably no) nickel and cobalt are needed if the vision of EVs for all Americans is to be achieved.

Ultimately, it will be difficult for EVs to become affordable to the mass market if battery costs remain around $120/kWh. A more commercially viable cost target at the battery pack-level is generally acknowledged to be $75-$80/kWh.[31] An obvious strategy to reduce cost is to pursue alternative battery chemistries that are inherently low-cost, produced from domestically abundant materials, and have minimal-to-no dependence on cobalt and nickel. Additionally:

i) Designs must maximize the active material energy by employing proportionately a minimum of inactive cell elements and/or battery hardware.

[27] https://insideevs.com/news/444542/evs-45-percent-more-expensive-make-ice
[28] "EV Battery Prices Risk Reversing Downward Trend as Metals Surge", James Frith, BNEF News, Sept. 14, 2021
[29] Mineral Commodity Summaries 2022 - Cobalt (usgs.gov)
[30] Mineral Commodity Summaries 2022 - Nickel (usgs.gov)
[31] "Battery Price Declines of Past Decade Could Soon Face Reversal", BNEF News, James Frith, November 2021

ii) Lower energy batteries could become a larger proportion of the EV battery portfolio, which would then depend on wider availability of more convenient charging to alleviate range anxiety and relax the consumer requirement for higher range EVs.

There is no doubt that LiB, the incumbent, has a phenomenal head-start on alternative, next-generation chemistries, especially when considering key advantages such as scale, engineering maturity, and established manufacturing processes. Nevertheless, new battery materials, chemistries, and designs that are capable of simultaneously providing superior performance (i.e., fast-charging, improved low temperature performance, longer cycle life) and economic benefits compared to state-of-the-art (SoA) LiB are desperately needed to accelerate and broaden domestic EV adoption.

Fast charging and improved battery performance at cold temperatures are the pillars of the EVs4ALL program. However, it is not the intention for these advancements to become premium features affordable to only a small percentage of the population. Foundational to this program are the principles of EV affordability and battery resilience, while abundant, inexpensive materials and range retention are regarded as central elements for achieving the ultimate vision of EVs for all.

Safety

Since its successful commercial launch (1991), LiB safety has been the subject of relentless scrutiny due to high-profile incidents on the global stage.[32] Although support for the assertion that EV fires are far less common than fires involving ICE vehicles exists,[33] significantly more media attention appears to focus on stories involving EV battery incidents. In addition, rapid dissemination of stories involving LiB "failures" is possible more now than ever through global internet news and social media channels. Regardless, this does not change the simple reality that next generation storage solutions for EVs must demonstrate a level of safety that is equivalent, preferably superior to, SoA LiB.

Battery events that escalate to fire, explosion, projectile expulsion, and/or the release of toxic gases must be prevented. Such incidents may be the direct result of misuse, abuse, and/or virtually imperceptible manufacturing-level defects that can cause a disastrous internal short during the life of a battery. LiB thermal runaway has been extensively studied and its multiple, cascading reactions are now well understood. In addition to conventional safety abuse protocols used in verification and validation testing (e.g., hot box, crush, impact, nail penetration, short circuit, overcharge and overdischarge, etc.), other techniques have been deployed to study the complex interplay between reactions and mechanisms that govern the safety of electrochemical systems. Such techniques may include, but are not limited to, Differential Scanning Calorimetry (DSC), Accelerated Rate Calorimetry (ARC), Synchrotron X-

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[32] Including a Sony Corporation battery factory fire (1995), Boeing's 787 Dreamliner issues (2013), and the widespread Samsung Galaxy recalls (2017), among others.

[33] https://www.autoinsuranceez.com/gas-vs-electric-car-fires/

Ray, pressure measurements, gas analysis, and modeling - in addition to the wide array of available electrochemical testing methods.

Technical State of the Art

The combination of graphite anodes and layered oxide-based cathodes has dominated the high energy density battery landscape for decades, during which time it has benefitted from a multitude of improvements to lithium-ion intercalation chemistry. Lithium metal plating on the anode, which primarily proceeds during scenarios that include rapid charging and/or charging at low temperatures, continues to limit the performance of SoA LiB. At the same time, the fast charge capability of cathodes may be inherently limited, which is evidenced by particle cracking[34] in response to expansion and contraction that occurs during cycling, and which is exacerbated by fast charging protocols.

Anode:

As an alternative to graphite, lithium titanium oxide (LTO) is a promising material from rate capability, low temperature performance, and cycling stability perspectives;[35] however, the lower energy density and higher cost make it impractical in most large markets, though it has been adopted in hybrid electric buses. Meanwhile, silicon-containing anodes appear promising and have recently been commercialized in consumer applications,[36] and many groups are actively conducting research in this rapidly emerging space. At the same time, strategies that include addition of silicon to enhance anode performance exist on many customer roadmaps and are a central pillar of the U.S. Department of Energy's Vehicle Technologies Office's (VTO)'s medium term strategy. Prospects for silicon-containing anodes remain encouraging in terms of energy density and charge rate, though the current consensus (at least on the academic level) is that additional progress is required to improve calendar life and abuse tolerance.[37]

The use of a lithium metal anode is attractive since it provides the highest possible material energy[38] and can enable cell energy densities > 400 Wh/kg and > 1000 Wh/liter (L). However, the high surface energy of lithium metal acts as a barrier to atomic diffusion during lithium plating, while the formation of dendrites and inactive lithium are endemic problems. Admittedly, progress on mitigating the issue of dendrites has been made *via* approaches that rely on mechanically robust structures to physically block the propagation of dendrites from anode to cathode.[39] Rather than attempting to manage dendrites after formation, recent investigations for lithium metal anodes have explored strategies to (1) prevent dendrite

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[34] Raj, M.-T. F. Rodrigues, and D. P. Abraham, *J. Electrochem. Soc.*, 2020, 167, 120517.

[35] J. Liu, X. Wei, and F. Meng in *Advanced Battery Materials,* C. Sun (ed.), J. Wiley and Sons, New York, 2019.

[36] Nano Sila Nanotechnologies: A Next-Gen Lithium-Ion Battery Solution (azonano.com)

[37] B. Zhu, X. Wang, P. Yao, J. Li and J. Zhu, *Chem. Sci.*, 2019, 10, 7132-7148.

[38] Y. Yu, Y. Liu, and J. Xie, *ACS Appl. Mater. Inter.*, 2021, 13, 18-33.

[39] Partha Mukherjee, Technical Presentation at the *High Energy, Fast Charging Batteries for EV Applications Workshop*, October 2021 https://arpa-e.energy.gov/sites/default/files/Day%201_1445%20Partha%20Mukherjee-Public-Release.pdf

formation from initiating at all,[40] (2) intentionally leverage dendrite formation to create beneficial three-dimensional structures,[41] or (3) modify the anode architecture altogether.[42] Reducing, distributing, or redirecting the high surface energy of lithium appears to be a promising approach thus far. In contrast, it has become increasingly clear that strategies intended to achieve perfectly planar and defect-free lithium metal surfaces are likely to be difficult, especially in the case of high plating current densities and/or low temperature charging.

Cathode:

Cathode development is still a fertile area for investigation and numerous compositions are possible, with current efforts tending towards a focus on high energy and/or lower cost. High manganese content solutions have received significant attention over the last 20+ years, though issues with lifetime persist.[43] Sulfur is considered a compelling long-term solution and is in theory very low cost, yet problems primarily associated with the well-documented "polysulfide shuttle" have severely limited commercial viability.[44] Disordered rock-salt cathodes and conversion cathodes based on transition metal fluorides have received increasing levels of attention recently,[45] though the main motivations in these cases are abundant materials and high energy density. Finally, LFP demonstrates a respectable discharge rate capability but has failed to demonstrate attractive performance in the low temperature and/or fast charging regimes.[46] Historically, LFP has been disadvantaged by a lower energy relative to conventional oxide cathodes, but recent improvements have achieved values for specific energy approaching 200 Wh/kg with a graphite anode.[47] LFP has enjoyed broad success as a stationary energy storage platform in grid-scale applications since energy density is not such a limitation while excellent round trip efficiency is an asset. Despite the significant activity in cathode development, the practical requirement for low cobalt/nickel compositions to simultaneously achieve superior charging rate capabilities and low temperature performance appears to be a clear area of opportunity.

D. PROGRAM OBJECTIVES

The overarching goal of the EVs4ALL program is to leverage new battery innovations at the material, electrode, and cell design level to mitigate the primary EV adoption detractors to the

[40] G. Liu, D. Wang, J. Zhang, A. Kim, and W. Lu, *ACS Materials Lett.,* 2019, 1, 5, 498-505.
[41] Y. Liu, Q. Liu, L. Xin, Y. Liu, F. Yang, E. A. Stach, and J. Xie, *Nat. Energy,* 2017, 2, 17083.
[42] X.-L. Zhang, Z.-Q. Ruan, Q.-T. He, X.-J. Hong, X. Song, Q.-F. Zheng, J.-H. Nie, Y.-P. Cai, and H. Wang, *ACS Appl. Mater. Inter.*, 2021, 13, 3078-3088.
[43] G. Hao, Q. Lai, and H. Zhang, *J. Energy Chem.*, 2021, 59, 547-571.
[44] Z. Han, S. Li, Y. Wu, C. Yu, S. Chenga, and J. Xie, *J. Mater. Chem. A*, 2021, 9, 24215-24240.
[45] Md. M. Rahman and F. Lin, *Matter*, 2021, 4, 490-527.
[46] Z. Ahsan, B. Ding, Z. Cai, C. Wen, W. Yang, Y. Ma, S. Zhang, G. Song, and Md. S. Javed, *J. Electrochem. En. Conv. Stor.*, 2021, 18, 010801.
[47] Lithium-Ion Batteries State of the Industry 2021, *BNEF Insights,* James Firth, Sept. 2021

greatest extent possible. Specific program objectives considered to be critical for accomplishing this mission include the following:

i) Achieve a charge rate that is equivalent to restoring 80% of cell nominal capacity [80% Δ state-of-charge (SOC)] in 5-15 minutes.
ii) Reduce low temperature battery performance losses by at least 50%.
iii) Retain a minimum of 90% capacity (relative to initial values) after the battery has delivered 200,000 miles of equivalent and cumulative range.
iv) Identify a compelling pathway to a battery cost of < $75/kWh at credible commercial scale.
v) Implement both new and existing test protocols to verify safety of new battery chemistries and cell designs.

The EVs4ALL program structure acknowledges the existence of different market needs in terms of EV range. Consequently, the battery development focus is divided into two discrete development tracks (Categories 1 and 2) defined primarily by cell-level energy density, charge rate, low temperature performance losses and cycle life targets, and a third parallel and complementary track (Category 3) focused on safety. Specifically:

(1) Category 1, which includes cells that can be charged safely at exceptionally high rates;
(2) Category 2, which includes higher energy cells that can be charged rapidly, yet at lower rates compared to Category 1.
(3) Category 3 will explore the topic of safety in parallel and complementary to the battery cell development tracks (Categories 1 and 2), with the intent to de-risk those chemistries with commercial potential developed under this program by the early application of competent and intentional failure analysis, Failure Mode Effects Analysis (FMEA), and deployment of new testing protocols and techniques.

While high level descriptions of Categories 1, 2 and 3 are included immediately below, a detailed treatment of objectives, technical performance targets, expectations, and deliverables for the EVs4ALL program are provided in Sections I.E and I.F. **Note that teams are welcome to submit proposals that target Category 1, Category 2, or both. However, applicants are not permitted to submit proposals that simultaneously target a combination of Category 3 and Category 1 or 2.**

<u>Categories 1 and 2</u>

While specific program-level targets are defined, the EVs4ALL program makes no attempt to be overly prescriptive regarding potential solutions. Rather, the intention is to encourage a broader range of battery cell chemistries, materials, and designs than are currently deployed to achieve the program-level goals. Additionally, the specification of energy densities and charge times for Categories 1 and 2 does not rule out equally transformational technologies with adjacent performance. As indicated in Figure 2, battery cells that can achieve a combination of 300 Wh/kg and 7.5-minute charging or, alternatively, 550 Wh/Kg and 20-minute charging are also within program scope. The solution space of the EVs4ALL program is illustrated in Figure 2, in the shaded or green regions.

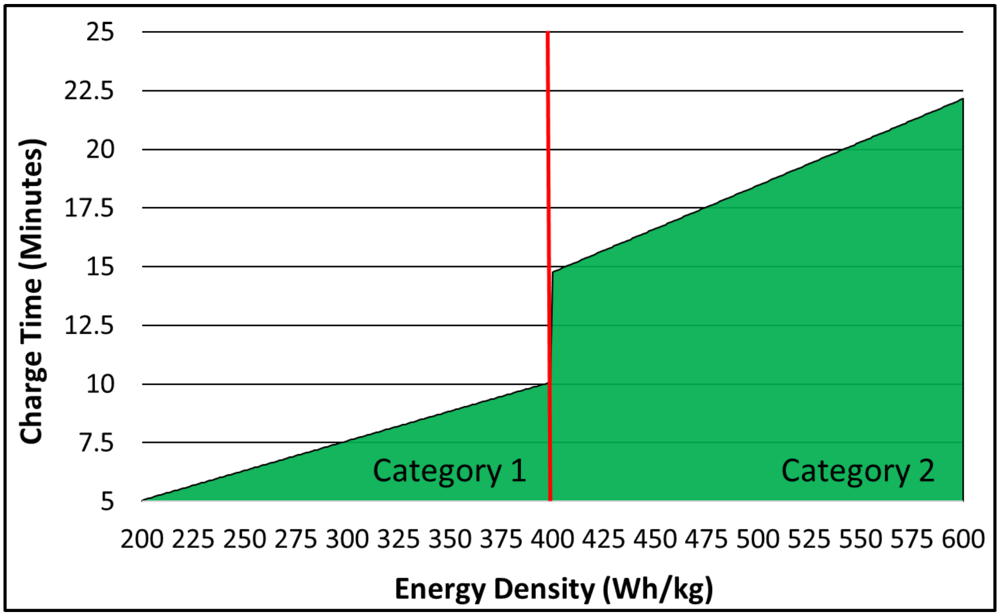

Figure 2. Energy density-charge time space for Categories 1 and 2 of the EVs4ALL program. Charge time values (minutes) for Category 1 and Category 2 were calculated individually based on charge power (see Section 1.F., Table 1) and assumes restoring 80% of nominal capacity [80% Δ SOC] during charge. For Category 1, a charge power of 1.9 kW/kg was used for gravimetric energy densities in the ≥ 200 Wh/kg to < 400 Wh/kg range. For Category 2, a charge power of 1.3 kW/kg was used for energy densities in the ≥ 400 Wh/kg to ≤ 600 Wh/kg range.

Proposals that emphasize a single cell component or a limited cell-level solution for investigation will be considered, though the primary performance targets for Categories 1 and 2 are relevant to full cells, and thus the interactions between all cell components, including interfaces, must be incorporated into the full cell thinking. Stated alternatively, a "total cell solution" (i.e., combination of anode, cathode, and electrolyte in a commercially viable package) will likely be required to achieve the primary EVs4ALL program objectives for projects in Categories 1 and 2.

Furthermore, this program aims to deliver battery technologies to enable broad access to EVs and thus cost is a critical consideration. While proposals are unlikely to be able to provide precise cost estimates, they will be expected to include a credible directional cost estimate. Cost calculations provided in the proposal, and conducted throughout the program, are expected to be performed using industry standard tools, such as the opensource Argonne

BatPaC model.[48] The initial focus for all cost assessments should be on the unit costs ($/kWh) of the cell materials (anode, cathode, separator, electrolyte, current collectors, and packaging). In the latest version of the BatPaC model, for existing lithium-ion chemistries, cell material costs are in the range of $60-80/kWh for 20 amp-hour (Ah) cells. To realistically be able to achieve the < $75/kWh cost target for this program, solutions are expected to have cell material costs of less than $50/kWh.

Additionally, assumptions regarding whether the proposed technology can be produced using existing scaled battery production processes should be carefully considered. Scaling novel manufacturing processes can present significant barriers to commercialization, and thus teams whose technology requires entirely new methods of manufacturing will be expected to provide well-considered risk mitigation plans and cost-scaling pathways to address this obstacle. This analysis must include estimated initial low-volume manufacturing costs and clearly defined target early adoption market(s) willing to absorb the initially higher prices.

Category 3

The EVs4ALL program intends to fund the development of next-generation high power and/or high energy storage solutions which rely on chemistries and designs that are likely to deviate significantly from commercially prevalent, well understood LiB systems. For novel technologies that achieve transformational performance results, it is essential to de-risk the corresponding safety profiles at an early stage, prior to advancing toward any commercial venture. Such de-risking is the primary objective of the Category 3 track of the program, which is anticipated to span 24 months and is defined by the structure and elements in Section 1.F. Note, for planning purposes, that Category 1 and Category 2 projects will ultimately be classified into 4-6 discrete "themes" based upon consideration of primary characteristics including specific battery chemistry. Contingent upon availability of funding and other factors, additional support may be directed towards actual physical testing of battery cells developed under Category 1 and/or Category 2 awards, which would take place after the original 24-month period for Category 3 projects. Therefore, proposal submissions to the Category 3 topic are encouraged to include a detailed description of organizational experience, expertise, and capabilities (including available resources such as equipment and supporting infrastructures) to carry out battery verification and validation.

E. TECHNICAL CATEGORIES OF INTEREST

Example technologies specifically of interest, either as standalone solutions or in combination, include, but may not be limited to the following:

- Cell chemistries that can be packaged in pouch, prismatic or cylindrical formats and that have a nominal (Open Circuit) voltage ranging from 2.0 V to 5.5 V

[48] BatPaC Model Software | Argonne National Laboratory (anl.gov)

- Anode materials based on alkali or alkaline earth metals [e.g., lithium (Li), sodium (Na), potassium (K), magnesium (Mg), calcium (Ca)]
- Oxide-based anodes
- Three-dimensional anode architectures
- Coatings on separators, cathodes and/or anodes that usefully transform the interfaces between these individual elements [e.g., maintain area specific resistance (ASR), reduce loss of active material, etc.]
- No/low cobalt and no/low nickel-content cathodes [e.g., sulfur-based, highly abundant/low-cost transition metal oxides, halides, sulfides, phosphates, and new organic/inorganic hosts]
- Practical cell designs that mitigate/manage all determinant variables so that the target metrics can be achieved [e.g., pressure, temperature, surface, and materials transport variations, etc.]
- Innovative cell/battery designs and materials that can achieve the key metrics [e.g., bipolar, shared cell/pack structures, high current distribution, advanced thermal management, etc.]
- The EVs4ALL program is generally ambivalent towards electrolyte “type” [e.g., liquid, solid-state, polymer or hybrid (combinations of liquids and/or polymers and/or solid-state components)]. A level of safety that is equivalent (or superior) to SoA LiB is the overriding requirement.
- New battery technologies that, if successful, can be manufactured using existing commercial processes, equipment, and infrastructures. These processes may come from battery or non-battery operations.

Please note that the above is not intended to be a comprehensive list but rather is intended to highlight examples of technical opportunities.

F. TECHNICAL PERFORMANCE TARGETS

Categories 1 and 2

The primary cell-level performance metrics for Categories 1 and 2 of the EVs4ALL program are summarized in Table 1. Additional details, including definitions of individual metrics in the table, are provided below. Furthermore, program expectations include the requirements that (1) individual test cells will be able to achieve all the primary performance targets simultaneously and (2) a statistically significant number of cells will be tested to build confidence in the validity of experimental data. ***A comprehensive treatment of all topics in Table 1 (numbered 1 through 6) is required at the concept paper phase.***

Table 1. Primary cell performance metrics for the EVs4ALL program (Categories 1 and 2).

	Cell-Level Performance Metrics	**Category 1 (*High Power*)**	**Category 2 (*High Energy*)**
1	Gravimetric Energy Density (Wh/kg)	**≥ 200**	**≥ 400**
2	Volumetric Energy Density (Wh/L)	≥ 500	≥ 900
3	Charge Power/Acceptance (kW/kg)	**≥ 1.9**	**≥ 1.3**
4	(%) Performance Loss per °C [≤ 30 °C to -20 °C]	≤ 0.3	≤ 0.4
5	Cycle Life – 90% of initial capacity (80% SOC swing)	≥ 1500	≥ 750
6	Cell Cost Target ($/kWh)	≤ 60	≤ 60

1) ***Gravimetric energy density*** is defined as energy (Watt-hour, Wh) delivered per kilogram (kg) at a C/3 discharge rate (@ 30 °C) for a cell charged to the recommended charge voltage for a C/3 charge rate. The cell includes all functional materials, components, and packaging [i.e., active materials, substrates, separator, electrolyte, container, tabs, tapes, and all other elements located within the cell envelope]. Further, the packaging component includes any required stack pressure device(s); supporting discussion within the application proposal is highly encouraged. Additional clarification can be obtained from the USABC procedure.[49]
2) ***Volumetric energy density*** is defined as energy (Wh) delivered per liter (L) at a C/3 discharge rate (30 °C) for a cell charged to the recommended charge voltage for a C/3 charge rate. This parameter encompasses all materials and components within the cell envelope including any innate porosity or bulging and should be calculated for the point at which the cell reaches a maximum value for volume during the cycling process. Further, the packaging component includes any required stack pressure device(s); supporting discussion within the application proposal is highly encouraged. Additional clarification can be obtained from the USABC procedure.[49]
3) (a) ***Charge power*** relates to charge time by the simple formula:
   Charge Power = (0.048 x gravimetric energy density) divided by (charge-time in minutes for 80% of nominal capacity).
   Note: 0.048 = 80% x 60 x 0.001 and allows charge power expressed as kW/kg to be calculated from gravimetric energy density in Wh/kg and charge time in minutes.
   (b) Charge power relates to input into the cell and must be maintained as an *average* across 80% of the total 100% nominal capacity [e.g., a 400 Wh/kg cell must have a charge acceptance of 320 Wh/kg when charged in 15 minutes].
   (c) Since deliverable charge power shows a dependence on temperature, it is expected that temperature will influence the charge power capability of a proposed solution.

[49] https://uscar.org/usabc/

Therefore, proposals that communicate an understanding of this relationship and can achieve the charge power targets at lower temperatures are preferred.

4) ***% Performance loss*** is defined as the energy loss at a C/3 discharge rate over a range of temperatures starting from ≤ 30 °C to -20 °C. For example, the performance loss target for Category 1 technology at -7 °C (20 °F) is 0.3 x [30 - (-7)] = 11%. It is expected that improvements to cell charge rate will also benefit the broader range of low temperature behaviors.
5) a) The program acknowledges that cell charging to 100% should be avoided due to increased degradation at high SOC. Analogously, exhaustive discharge to 0% SOC is impractical and would not occur in realistic scenarios, (EVs, for example) since this would render the battery as "dead". Therefore, ***cycle life*** will be demonstrated by cycling with an 80% SOC "swing" between 5% and 95% SOC [e.g., 5% to 85%, 10% to 90%, or 15% to 95%].
   b) It is understood that fast charging will reduce the achievable cycle life. For the stated metric, applicants should assume a cycling regimen of 25% fast charge cycles equally interspersed with 75% slower charging cycles at a minimum charge rate of C/3.
6) Cell level costs according to the Argonne BatPaC model for a 20 Ah cell.[48]

Program Considerations Beyond Primary Metrics (Categories 1 and 2)

In addition to the primary cell-level performance metrics in the preceding section, other expectations and considerations are included below for the purposes of more clearly defining the discrete boundaries of the EVs4ALL program. Table 2 outlines the specific expectations for Categories 1 and 2; detailed descriptions of individual entries included in the table are provided in the section that immediately follows. ***Although a comprehensive treatment of all topics in Table 2 (numbered 7 through 20) may not be possible at the concept paper phase, applicants are strongly encouraged to address them in satisfactory detail in full application proposal submissions.***

Table 2. Specific program considerations beyond primary performance metrics (Categories 1 and 2).

	Expectation/Consideration	Description
7	Pack integration	Opportunities, challenges, and enablers
8	Minimum 15-year calendar life (coupled with cycle life)	Include ALT for verification
9	Cell hardware deliverable	≥ 10 Wh cell (pouch, prismatic or cylindrical)
10	Wh round trip efficiency (RTE)	≥ 80% (C/3 discharge, fast charge)
11	CO_2 emissions for battery manufacture	≤ 100 kg/kWh
12	Interdependence of power, energy, and life	Modeling
13	Safety	≥ SoA LiB

14	Dendrite tolerance	No dendrite formation within operational window
15	Segue to volume manufacturing	Established manufacturing processes
16	Sustainability	Raw materials abundance, availability, security, and cost; recycling strategy
17	Cell testing protocols	Testing per USABC
18	Cost calculations	Argonne BatPaC Model[48]
19	Thermal management	Heat evolution, especially during fast charge
20	Equivalent circuit	Cell characterization for system design

Notes: [each note addresses the equivalent number in Table 2, above]:

7) The primary objective of this program is to develop solutions appropriate for EVs that can ultimately be integrated into battery packs. Therefore, applicants are highly encouraged to contemplate how the technology will impact battery pack design and battery management system (BMS) algorithms & architecture. Opportunistically, the specific cell chemistry solution may enable less complex or less expensive battery pack and BMS designs, through for example, less cells, safer cells, more facile balancing, structural synergies, etc.].
8) 15-year calendar life is specified per USABC and is consistent with ICE vehicle life. For proposal submissions, especially those emphasizing an investigation of new chemistries, there must be an explicit intention to determine degradation mechanisms both as a function of time (calendar life) and cycling (cycle life), which may include Accelerated Life Test (ALT) protocols. While calendar life is not explicitly identified as a quantitative primary metric for the EVs4ALL program, the expectation is that an understanding of calendar life as it pertains to the chemistries under investigation will be advanced by the end of project. Stated alternatively, compelling evidence to support a conclusion that calendar life is not expected to be a technology "showstopper".
9) While small cells, including coin cells, are acceptable test vehicles to support early development, and therefore are permitted in the work plan, the project must ultimately demonstrate a transition to a cell building block that is appropriate for production consideration by the latter stages of the project (≥ 10 Wh cell in pouch, prismatic or cylindrical format).
10) RTE (Wh) less than 80% is likely to be an untenable thermal management challenge.
11) According to the IVL Swedish Environmental Research Institute Ltd.,[50] an estimate of 61-106 kg CO_2-eq/kWh battery capacity was calculated for the most common chemistry (NMC) where the difference in the range was primarily dependent on the variation in electricity mixture for cell production.

[50] "Lithium-Ion Vehicle Battery Production, Status 2019 on Energy Use, CO_2 Emissions, Use of Metals, Products Environmental Footprint, and Recycling", ISBN 978-91-7883-112-8.

12) Power, energy, and lifetime coexist in a trade-off relationship with one another. Within the context of a proposed technology, this relationship must be discussed, and examples provided for different performance options. Clearly state whether this technology can achieve both the cell gravimetric energy density and charge power targets as required by the primary metrics for Category 1 or 2.
13) Appropriate standard LiB testing protocols may be employed or can serve as inspiration for development of new battery chemistry-specific techniques for probing cell safety. Additional testing protocols may be developed as part of Category 3, though these are not expected to be available at the outset of the program. Nonetheless, teams leading projects that are selected for funding in Categories 1 and 2 are strongly encouraged to collaborate with those working on projects in Category 3.
14) Numerous solutions have been proposed for blocking dendrite formation, growth, and propagation from anode to cathode. As an alternative to physical blocking of dendritic structures following formation at the anode surface, this program seeks to promote a range of solutions to eliminate dendrite formation entirely or, alternatively, implement strategies to exploit dendrites as a beneficial resource. Solutions limited to physical blocking of dendrites are not of interest.
15) LiB technology has been commercially manufactured for 30 years, so it has the benefit of scale, learning curve, and numerous engineering improvements. Admittedly, new battery technologies that deviate from conventional LiB processes may encounter early manufacturing challenges. Although a requirement for new manufacturing processes, equipment, and/or infrastructures is not disqualifying, established manufacturing processes and techniques are preferred.
16) Abundance, availability, security, and cost of materials, as well as recycling outlook for the proposed technology must be considered.
17) USABC protocols must be adopted as the primary framework for experimental test methods.
18) Argonne BatPaC model[48] should be used for cost calculations. For unit costs of all input materials, teams are encouraged to use the costs that can be obtained today for production volumes, through existing supply chains. If the proposed technology relies on materials that are not currently produced at scale today, costs for initial small-scale production (MWhs) should be estimated. GWh scale cost-estimates for novel materials should not be used, as a credible cost and supply chain pathway that allows for initial market entry must be presented.
19) Round trip inefficiency = heat. Consideration of heat generation, particularly during fast charge cycles, must be addressed in the proposal both as (1) total amount of heat and (2) temperature at different cell locations. This discussion may be supplemented with a treatment of potential cell design features or heat management enablers, whether internal and/or external to the cell.
20) During the course of the project individual materials and components will be characterized and Electrochemical Impedance Spectroscopy (EIS) is a tool that may be utilized. To summarize the characterization of full cells and as a deliverable for potential

customers, teams are encouraged to develop an equivalent circuit diagram for their cell as a final project deliverable. How this changes with cycling will also be useful.

Category 3

The primary expectations for projects funded within Category 3 of the EVs4ALL program include the following:

i. Classify non-LiB battery technologies into themes based on chemistry, potential energy release, cascading reactions, voltage, power, energy, etc. (note that specific technical categories of interest for Categories 1 and 2 are discussed in section I.E). Specific examples of possible individual themes include:
    - Lithium metal batteries *containing* liquid electrolyte
    - Lithium metal batteries *excluding* liquid electrolyte
    - Batteries containing metal anodes other than lithium
    - Batteries with non-commercial cathodes

ii. Develop and/or adapt "generic" safety models appropriate for individual themes (cells, modules, and packs) using LiB as a starting point.

iii. Determine primary metrics that should be used to "quantify" safety of new battery chemistries, including those that may be critical for making confident conclusions regarding safety of new chemistries compared to SoA LiB [e.g., total heat and rate of heat release, total quantity of gas release and rate of gas release, toxicity of liberated materials, etc.].

iv. Identify existing and/or exploratory capabilities (techniques, equipment, etc.) to enable comprehensive safety characterization of key materials in isolation as well as interactions between cell materials.

v. Perform safety characterization of materials and components provided by Category 1 and Category 2 teams.

vi. Translate capabilities and preliminary results to standard abuse tests.

vii. Confirm applicability of standard tests to new battery technologies and propose new test protocols as appropriate; use hazard criteria as per EUCAR (European Council for Automotive R&D).

viii. Provide recommendations, including explanation, regarding module and pack design in terms of required architecture [e.g., whether the same level of battery management system (BMS) is required, if the technology may allow closer cell spacing, etc.]

ix. In collaboration with Category 1 and Category 2 teams, conduct a FMEA to determine the probability and severity of a safety incident with due consideration of design, process, and use case.

x. Final deliverables for each technology theme include: FMEA, modeling framework, safety testing manual (documentation), and energy release diagram.[51,52]

Furthermore, it is expected that teams working in Category 3 of the program will collaborate closely with teams executing projects in Categories 1 and 2, in a manner that is consistent with the matrix outlined in Table 3.

Such collaboration may include the sharing of technical data, the testing of materials, components or cell hardware and providing suggestions regarding possible improvements to a specific Category 1 or 2 awardee's technology. Category 3 awardees will be required to agree that any Category 1 or 2 awardees' data provided to a Category 3 awardee will be treated by the Category 3 awardee as confidential information, unless this requirement is altered by written agreement between Category 3 awardee and the affected Category 1 or 2 awardee. A Category 3 awardee will be required to treat all data generated under their award as SBIR/STTR data for 20 years. No data provided to or generated by a Category 3 awardee that is related to an affected Category 1 or 2 awardee will be provided to another Category 1 or 2 awardee.

For Category 3 awardees that may suggest improvements to a specific Category 1 or 2 awardee's technology: a written agreement addressing intellectual property issues must first be executed with the affected Category 1 or 2 awardee(s). Agreement examples include an Intellectual Property Management Agreement, or Cooperative Research and Development Agreement (CRADA) if a Federal Lab is the Category 3 awardee. Such agreements shall include sufficient rights for the Category 1 or 2 awardee(s) to fully commercialize their technologies with the suggested improvements.

Table 3. Expected collaborative responsibilities among Category 1, 2, and 3 teams in the EVs4ALL program.

Level	Level of Safety Engagement and Experience	Activity and Responsibility (Category 1 and 2 Teams)	Activity and Responsibility (Category 3 Teams)
1	*Safety science:* thermodynamics, chemistry, physics, electrochemistry, modeling	Discussion with Category 3 teams regarding "science" of projects	Understand science of Category 1 and 2 themes with respect to LiB as reference system
2	*Laboratory characterization:* calorimetry, gas analysis, toxicity evaluation, lower explosive limit (LEL), upper explosive limit (UEL), etc.	Provide key materials and components to Category 3 team for testing and analysis.	Develop and conduct science-based lab analysis; determine critical evaluation criteria

[51] A. M. Bates, Y. Preger, L. Torres-Castro, K. L. Harrison, S. J. Harris, and J. Hewson, *Joule*, 2020, 6, 1-14.
[52] X. Feng, M. Ouyang, X. Liu, L. Lu, Y. Xia, and X. He, *Energy Storage Mater.*, 2018, 10, 246–267.

3	*Standard abuse tests:* nail penetration, hot box, crush, overcharge testing, temperature, venting, etc.	Awareness; delivery of 1 Wh cells for characterization (24 months) and 10 Wh (36 months)	Addition, modification or confirmation by technology theme
4	*Manufacturing:* safety assurance process control, inspection, audit	Collaborate with Category 3 teams as warranted for FMEA and critical characteristic analysis	Understanding, risk analysis and direction post-FMEA; consequences for modules and packs
5	*Application safety experience:* Fires, emissions, explosions, and public perception	Awareness of history and experience	Education and understanding within context of FMEA

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $45 million available for new awards, to be shared between FOAs DE-FOA-0002760 and DE-FOA-0002761, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 10-12 awards under FOAs DE-FOA-0002760 and DE-FOA-0002761. ARPA-E may, at its discretion, issue one, multiple, or no awards.

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

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

Applicants must apply for a Combined Phase I/II/IIS Award. Combined Phase I/II/IIS Awards are intended to develop transformational technologies with disruptive commercial potential. Such commercial potential may be evidenced by (1) the likelihood of follow-on funding by private or non-SBIR/STTR sources if the project is successful, or (2) the Small Business Concern's record of successfully commercializing technologies developed under prior SBIR/STTR awards. Phase IIS awards are a "sequential" (i.e., additional) Phase II award, intended to allow the continued development of promising energy technologies. Combined Phase I/II/IIS awards may be funded up to $3,952,638. Funding amounts will be consistent with the Phase I and Phase II limits posted on the SBA's website.[53]

ARPA-E reserves the right to select all or part of a proposed project (i.e. only Phase I, or only Phase I and Phase II). In the event that ARPA-E selects Phase I only or Phase I/II only, then the maximum award amount for a Phase I award is $275,766 and the maximum amount for a Phase I/II award is $2,114,202.

The period of performance for funding agreements may not exceed 48 months for a Combined Phase I/II/IIS Award. ARPA-E expects the start date for funding agreements to be March 2023, or as negotiated.

B. RENEWAL AWARDS

At ARPA-E's sole discretion, awards resulting from this FOA may be renewed by adding one or more budget periods, extending the period of performance of the initial award, or issuing a new award. Renewal funding is contingent on: (1) availability of funds appropriated by Congress for

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

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."[54] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.D below.

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.

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

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

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

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

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 – 200.343.
- 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[55] 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.

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

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. SBIR ELIGIBILITY

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

A Small Business Concern[56] may apply as a Standalone Applicant[57] or as the lead organization for a Project Team.[58] If applying as the lead organization, the Small Business Concern must perform at least 66.7% of the work in Phase I and at least 50% of the work in Phase II and Phase IIS, as measured by the Total Project Cost.[59]

For information on eligibility as a Small Business Concern, please refer to SBA's website (https://www.sba.gov/content/am-i-small-business-concern).

2. STTR ELIGIBILITY

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

Only a Small Business Concern may apply as the lead organization for a Project Team. The Small Business Concern must perform at least 40% of the work in Phase I, Phase II, and/or Phase IIS, as measured by the Total Project Cost. A single Research Institution must perform at least 30% of the work in Phase I, Phase II, and/or Phase IIS, as measured by the Total Project

[56] A Small Business Concern is a for-profit entity that: (1) maintains a place of business located in the United States; (2) operates primarily within the United States or makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor; (3) is an individual proprietorship, partnership, corporation, limited liability company, joint venture, association, trust, or cooperative; and (4) meets the size eligibility requirements set forth in 13 C.F.R. § 121.702. Where the entity is formed as a joint venture, there can be no more than 49% participation by foreign business entities in the joint venture. Small Business Concerns that are majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms are eligible to apply to this FOA.

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

[58] The term "Project Team" is used to mean any entity with multiple players working collaboratively and could encompass anything from an existing organization to an ad hoc teaming arrangement. A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.

[59] 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, FFRDCs, and GOCOs.

Cost. Please refer to Section III.B.1 of the FOA for guidance on Research Institutions' participation in STTR projects.

For information on eligibility as a Small Business Concern, please refer to SBA's website (https://www.sba.gov/content/am-i-small-business-concern).

3. Joint SBIR and STTR Eligibility

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

- The Small Business Concern is partnered with a Research Institution;
- The Small Business Concern performs at least 66.7% of the work in Phase I and at least 50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost;
- The partnering Research Institution performs 30-33.3% of the work in Phase I and 30-50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost; and
- The Principal Investigator (PI) is employed by the Small Business Concern. If the PI is employed by the Research Institution, submissions will be considered only under the STTR program.

B. Eligible Subrecipients

1. Research Institutions

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

2. Other Project Team Members

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

- For-profit entities, including Small Business Concerns

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

- Nonprofits other than Research Institutions[61]
- Government-Owned, Government Operated laboratories (GOGOs)
- State, local, and tribal government entities
- Foreign entities[62]

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

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

C. ELIGIBLE PRINCIPAL INVESTIGATORS

1. SBIR

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

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

2. STTR

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

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

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

[62] All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (see Section IV.G.6 of the FOA). However, the Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form submitted with the Full Application.

D. <u>ELIGIBILITY OF PRIOR SBIR AND STTR AWARDEES: SBA BENCHMARKS ON PROGRESS TOWARDS COMMERCIALIZATION</u>

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

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

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

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

- The Commercialization Rate Benchmark sets the minimum Phase III[63] commercialization results that an Applicant must have achieved from work it performed under prior Phase II awards (i.e. this measures an Applicant's progress from Phase II or Phase IIS to Phase III awards). **This benchmark requirement applies only to Applicants that have received more than 15 Phase II awards during the last 10 fiscal years, excluding the two most recently completed fiscal years.**

[63] Phase III refers to work that derives from, extends or completes an effort made under prior SBIR/STTR funding agreements, but is funded by sources other than the SBIR/STTR Program. Phase III work is typically oriented towards commercialization of SBIR/STTR research or technology. For more information please refer to the Small Business Administration's "Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program Program Policy Directive" at https://www.sbir.gov/sites/default/files/SBIR-STTR_Policy_Directive_2019.pdf.

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

- On June 1 of each year, SBIR/STTR awardees registered on SBIR.gov are assessed to determine if they meet the Phase II Transition Rate Benchmark requirement. (At this time, SBA is not identifying companies that fail to meet the Commercialization Rate Benchmark requirement). Companies that fail to meet the Phase II Transition Rate Benchmark as of June 1 of a given year will not be eligible to apply to an SBIR/STTR FOA for the following year. For example, if SBA determined on June 1, 2017 that a small business failed to meet the Phase II Transition Rate Benchmark requirement, that small business would not be eligible to apply to an ARPA-E SBIR/STTR FOA from June 1, 2017 to May 31, 2018.

E. Cost Sharing

Cost sharing is not required for this FOA.

F. 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.
- Submissions that do not propose a Combined Phase I/II/IIS Award, as described in Section II.A of the FOA.

3. Submissions Specifically not of Interest

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

- Submissions that propose incremental improvements to SoA LiB.
- Submissions limited to computational approaches and that exclude physical experimentation/testing as a primary component of the technology development plan.
- Approaches that rely solely on physical blocking of lithium dendrites.
- Approaches that include chemicals or materials that have known toxicity or environmental issues [e.g., arsenic (As), cyanide, lead (Pb), cadmium (Cd), etc.].
- Approaches that rely on elements or materials that have a USGS profile that is less favorable than the elements and materials used in commercial batteries today. Teams must use their best judgement here and assess element favorability based on reserves, current production, price, and security of U.S. access; cobalt and nickel may be used as references.
- Submissions that propose battery technologies that will require substantially specialized manufacturing processes and equipment development.
- Submissions that propose solutions with smaller safety margins compared to SoA LIB [e.g., less temperature safety margin between operating temperatures and thermal runaway trigger temperatures].

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.

However, small businesses that qualify as a "Small Business Concern" may apply to only one of the two ARPA-E EVs4ALL FOAs: ARPA-E FOA DE-FOA-0002761 (SBIR/STTR), EVs4ALL (SBIR/STTR), or ARPA-E FOA DE-FOA-0002761, EVs4ALL. Small businesses that qualify as "Small Business Concerns" are strongly encouraged to apply under the former (SBIR/STTR FOA). To determine eligibility as a "Small Business Concern" under DE-FOA-0002761, please review the eligibility requirements in Sections III.A – III.D above.

IV. Application and Submission Information

A. Application Process Overview

1. Registration in SBA Company Registry

The first step in applying to this FOA is registering in the U.S. Small Business Administration (SBA) Company Registry (http://sbir.gov/registration). Upon completing registration, Applicants will receive a unique small business Control ID and Registration Certificate in Adobe PDF format, which may be used at any participating SBIR and STTR agencies. Applicants that have previously registered in the SBA Company Registry need not register again.

Applicants that are sole proprietors and do not have an Employer Identification Number may use social security numbers for purposes of registering in the SBA Company Registry. Applicants that do not possess a Dun and Bradstreet Data Universal Numbering System (DUNS) number may also use their social security number in the SBA Company Registry.

Applicants must submit their Registration Certificate in ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov) as part of their Full Application (see Section IV.D.6 of the FOA).

2. 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).

3. 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.F 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.

4. 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.F 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.

5. 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.F.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.

6. 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.

7. 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.F of the FOA).

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

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

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

1. Concept Paper

a. Concept Summary

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

b. Innovation and Impact

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

c. Proposed Work

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

d. Team Organization and Capabilities

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

D. Content and Form of Full Applications

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2022]

E. Content and Form of Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 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 AUGUST 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.F.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.F 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 AUGUST 2022]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 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 Project Impact Relative to Project Cost.**

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

2. ARPA-E Reviewers

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

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

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

3. ARPA-E Support Contractor

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

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

C. Anticipated Announcement and Award Dates

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 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 <u>not</u> authorize the Applicant to commence performance of the project. Please refer to Section IV.G of the FOA for guidance on pre-award costs.

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2022]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 2022]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN AUGUST 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: Pursuant to special statutory authority for SBIR/STTR awards, data generated under ARPA-E SBIR/STTR awards may be protected from public disclosure for twenty years from the date of award in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

D. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

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

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

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. ADDITIONAL NOTICES

- This FOA is intended for informational purposes and reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR or STTR funding agreement, the terms of the funding agreement are controlling.
- Before award of an SBIR or STTR funding agreement, ARPA-E may request the selectee to submit certain organizational, management, personnel, and financial information to assure responsibility of the Prime Recipient. In addition, selectees will be required to make certain legal commitments at the time of execution of funding agreements resulting from this FOA. ARPA-E encourages Prime Recipients to review the Model Cooperative Agreement for SBIR/STTR Awards, which is available at https://arpa-e.energy.gov/?q=site-page/funding-agreements.
- Actual or suspected fraud, waste, or abuse may be reported to the DOE Office of Inspector General (OIG) at 1-800-541-1625.

K. 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.

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

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

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

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.

SBA: U.S. Small Business Administration.

SBIR: Small Business Innovation Research Program.

Small Business: Small businesses are domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards).

Small Business Concern: A for-profit entity that: (1) maintains a place of business located in the United States; (2) operates primarily within the United States or makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor; (3) is an individual proprietorship, partnership, corporation, limited liability company, joint venture, association, trust, or cooperative; and (4) meets the size eligibility requirements set forth in 13 C.F.R. § 121.702. Where the entity is formed as a joint venture, there can be no more than 49% participation by foreign business entities in the joint venture. Such joint ventures must submit the VCOC/FJV Certification (the seventh component of the Full Application).

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

STTR: Small Business Technology Transfer Program.

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

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

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).