U.S. Department of Energy
Advanced Research Projects Agency – Energy

Announcement of Teaming Partner List for Upcoming Funding Opportunity Announcement: *New Program in Domestic EV Battery Supply Chain Circularity*

The Advanced Research Projects Agency – Energy (ARPA-E) is considering issuing a Funding Opportunity Announcement (FOA) to support the development of foundational technologies aimed towards establishing a domestic, circular supply chain for electric vehicle (EV) batteries. As described in more detail below, the purpose of this announcement is to facilitate the formation of new project teams to respond to the potential FOA. The FOA will provide specific program goals, technical metrics, and selection criteria. The FOA terms are controlling.

For purposes of this Teaming Partner List, one of the program's primary objectives would be to maintain in service EV battery materials, cells, and pack components at the highest levels of performance and safety for as long as possible. Technological solutions capable of maximizing the useful service life of battery cells and recovering the manufacturing value of spent battery packs would reduce greenhouse gas (GHG) emissions, minimize energy and material consumption, lower demand for virgin materials, alleviate reliance on key battery material and component imports, and ultimately motivate the creation of a circular and sustainable domestic EV battery supply chain.

The existing supply chain for EV batteries is largely linear and relies on recycling to close the supply loop for critical minerals. The disposal of "spent" batteries is challenging due to fire hazards and/or potential release of toxic chemicals into the environment. A significant increase in the number of EVs is imminent and will be accompanied by large volumes of battery waste, albeit with a ten-to-twenty-year lag, depending on both the type of battery and application. Conventional battery recycling methods such as pyrometallurgy and hydrometallurgy are energy-intensive, produce significant quantities of GHGs, and lead to large volumes of waste deposited in landfills. With few exceptions, these approaches intentionally recover only the most valuable materials (e.g., nickel, cobalt, and copper). Looking to the future, these recycling strategies are expected to endure increasingly challenging economics as battery chemistries that rely on more abundant and/or less expensive materials capture significant market share. Therefore, prolonging the life of EV batteries and recovering manufacturing value to the greatest extent possible through regeneration, repair, and remanufacturing will reduce the domestic energy burden and carbon footprint of the EV battery supply chain. In addition, various strategies used to achieve circularity could be leveraged to facilitate recycling.

Current EV manufacturing practices are well-established in support of the linear economic model of "take, make, use, and dispose" with negligible appreciation for the end of life. This is arguably unsustainable in future scenarios consistent with projected EV market growth. It is critical that innovations are developed to "expand" the chemistry, design, and manufacturing space. The resulting new materials, components, and regeneration methods will efficiently and cost-effectively prolong today's service life of battery cells and packs, without compromising performance or safety.

Such a vision also encompasses reversible manufacturing strategies, sensors, and algorithms for improved monitoring, as well as any other methods that responsibly manage the end of life for manufactured goods, particularly batteries, for transportation.

Strategies that may have merit, either individually or as part of a total solution, include the following:

- Battery materials and cell designs that are amenable to *in situ* regeneration methods;
- Regeneration techniques and protocols that can efficiently and cost-effectively restore battery cells to beginning of life performance and safety;
- Reversible manufacturing materials and methods to facilitate battery module/pack disassembly;
- "Reversibly" bondable adhesives including stimuli-responsive systems;
- Techniques and designs for reversible "joining" of battery cells and modules that do not compromise performance, structural/mechanical integrity, or safety;
- Battery pack designs that are amenable to autonomous robotic disassembly;
- Robotic systems capable of disassembling battery packs, in parts or in full, with the ability to learn autonomously and/or with humans in the loop;
- Sensor platforms and methodologies capable of rapid determination of state of health (SoH) for individual battery cells during use and/or at the end of battery pack life to determine whether the cells should be regenerated, reused, or recycled;
- Seamless and cost-effective integration of sensors in manufacturing of battery cells and packs that can support circularity objectives;
- Battery intelligence systems and data analytics to extend the service life of cells, modules, and packs; and
- Analytical tools capable of quantifying the impact of the program's advancements on pack cost, material use, energy use, and GHG emissions per kilowatt-hour delivered throughout the life of an EV to justify the adoption of these technologies and inform new business models and opportunities.

ARPA-E hosted a "Circular Economic Materials, Design, and Manufacturing of Rechargeable Batteries Workshop" on June 12 and 13, 2023. Information from this workshop can be found at the ARPA-E events webpage (https://arpa-e.energy.gov/events/battery-circularity-workshop). In addition, ARPA-E issued a request for information (RFI) on "Achieving Circularity of the Domestic Battery Supply Chain" (DE-FOA-0003027, https://arpa-e-foa.energy.gov/Default.aspx?foaId=cd9cd241-0872-4832-8e10-8fc5e57b1a1e). A video of the "Batteries & Storage" Fast Pitch Panel from the 2023 ARPA-E Energy Innovation Summit can be viewed on YouTube (https://www.youtube.com/watch?v=ye_yZNcAj30).

Expertise in the following areas may be useful in responding to the potential FOA:

- State-of-the-art battery chemistry and materials research, development, and engineering
- Battery cell and battery pack design and prototyping
- Battery component, battery cell, and battery pack manufacturing
- Chemical, mechanical, and electrical engineering
- Computational modeling and simulation
- Battery management systems hardware and software development and integration
- Cell-level and pack-level battery sensor development, integration, and data analytics
- Manufacturing

- Robotics
- Sustainable design
- Techno-economic analysis (TEA)
- Life cycle analysis (LCA)
- Failure modes and effects analysis (FMEA)

As a general matter, ARPA-E strongly encourages outstanding scientists and engineers from different organizations, scientific disciplines, and technology sectors to form new project teams. Interdisciplinary and cross-sector collaboration spanning organizational boundaries enables and accelerates the achievement of scientific and technological outcomes that were previously viewed as extremely difficult, if not impossible. ARPA-E strongly encourages involving industry partners to advise and collaborate with these project teams, with the goal of achieving successful industry adoption and integration of the innovative technologies these project teams develop.

The Teaming Partner List is being compiled to facilitate the formation of new project teams. The Teaming Partner List will be available on ARPA-E eXCHANGE (http://arpa-e-foa.energy.gov), ARPA-E's online application portal, starting in October 2023. The Teaming Partner List will be updated periodically until the close of the Full Application period to reflect new Teaming Partners who have provided their information.

Any organization that would like to be included on this list should complete all required fields in the following link: https://arpa-e-foa.energy.gov/Applicantprofile.aspx. Required information includes the following: Organization Name, Contact Name, Contact Address, Contact Email, Contact Phone, Organization Type, Area of Technical Expertise, and Brief Description of Capabilities.

By submitting a response to this Notice, you consent to the publication of the above-referenced information. **By facilitating this Teaming Partner List, ARPA-E does not endorse or otherwise evaluate the qualifications of the entities that self-identify for placement on the Teaming Partner List.** ARPA-E will not pay for the provision of any information, nor will it compensate any respondents for the development of such information. Responses submitted to other email addresses or by other means will not be considered. **This list is completely voluntarily to participate in and utilize.** ARPA-E will not identify or facilitate connections through the teaming list and participation in the list has no bearing whatsoever on the evaluation of applications submitted to the potential FOA.

This Notice does not constitute a FOA. No FOA exists at this time. Applicants must refer to the FOA, expected to be issued by November 2023, for instructions on submitting an application and for the terms and conditions of funding.