Energy Storage & Conversion Manufacturing

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Why focus on energy storage and conversion?

• Important building blocks for economy-wide decarbonization.
• There are manufacturing challenges that cut across multiple battery and other technologies
  o Addressing common manufacturing technical barriers can help to accelerate full-scale commercialization of recent innovations and emerging technologies.
  o Advances in manufacturing are potentially transferrable elsewhere in the manufacturing sector.

Current Status

• Rich, broad portfolio
• Sharpening strategy and roadmap on battery manufacturing
AMMTO’s Role within the DOE Energy Storage Landscape

**Loan Program Office (LPO)**
Supports debt financing for the commercial deployment of large-scale energy projects to support U.S. manufacturing.

**Office of Manufacturing and Energy Supply Chains (MESC)**
Supports scale-up and deployment of vertically-integrated manufacturing infrastructure (e.g., large-scale facilities, factories, etc.) needed to support clean and equitable energy transition.

**Office of Clean Energy Demonstrations (OCED)**
Supports large-scale clean energy demonstration projects in partnership with the private sector to launch or accelerate market adoption and deployment of technologies.

**Advanced Materials and Manufacturing Technologies Office (AMMTO)**
Supports innovative “applied R&D” and “manufacturing RD&D” focused on:
- Platform manufacturing technologies for processes and scale-up.

**Basic Energy Sciences (BES)**
Supports basic science research to understand, predict, and control the interactions of matter and energy at the electronic, atomic, and molecular levels.

**Advanced Projects Research Agency-Energy (ARPA-E)**
Supports “off-roadmap” transformational R&Ds ranging from basic science research to applied R&Ds that are high-risk, high-payoff transformational energy storage-related activities.

**Vehicle Technologies Office (VTO)**
Supports exploratory research to addresses fundamental issues of materials and electrochemical interactions associated with lithium and beyond-lithium batteries.

**Office of Electricity (OE)**
Supports applied materials R&Ds to identify safe, low-cost, and earth-abundant elements that enable cost-effective long-duration storage.
Supports early adoption by improving storage reliability and safety, applying modeling and analysis, and validating performance for rapid commercialization.

**Office of Manufacturing and Energy Supply Chains (MESC)**
Supports applied R&Ds to focus on optimizing next generation, high-energy lithium ion electrochemistries that incorporate new battery materials.
### Historical FOA and Lab Call Topics

<table>
<thead>
<tr>
<th>Funding</th>
<th>FY</th>
<th>Description</th>
<th>AMMTO Investment</th>
</tr>
</thead>
</table>
| FOA      | 2019 | Subtopic 1.1: Accelerate the Manufacturing Process Design and Development Cycle for Advanced Energy Conversion and Storage Materials  
          |      | Subtopic 1.2: Innovative Manufacturing Processes for Battery Energy Storage  | $8M              |
|          | 2021 | Flow Battery Systems Manufacturing FOA (with OE)                             | $17.9M           |
|          | 2021 | Subtopic 3.1: Structured Electrode Manufacturing for Li-ion Batteries        | $7.5M            |
|          | 2022 | Subtopic 3.1: Advanced Process Manufacturing of Electric Vehicle Cathode Active Materials at Volume | $17.5M           |
| Lab Call | 2020 | Battery Manufacturing Lab Call (with VTO)                                    | $10M             |
|          | 2023 | Solid-state and Flow Battery Manufacturing Lab Call                          | $16M             |
| SBIR     | 2020 | Topic: Hi-T Nano—Thermochemical Energy Storage (with BTO)                    | $1.3M            |
|          | 2022 | Topic: Thermal Energy Storage for building control systems (with BTO)        | $0.8M            |
|          | 2022 | Topic: High Operating Temperature Storage for Manufacturing                  | $0.4M            |
|          | 2023 | Topic: Chemistry-Level Electrode Quality Control for Battery Manufacturing   | (Est. $0.4M) Proposals under review |
| Other    |      | Lab-Embedded Entrepreneurship Program (LEEP) - innovators working on battery technologies | $2.5M            |
Energy Storage/Conversion Manufacturing Strategy

Portfolio objectives

Accelerate innovation to manufacture novel energy storage technologies in support of economy-wide decarbonization.

1. Identify new scalable manufacturing processes
2. Scale up manufacturing processes
3. Lower lifecycle cost to manufacture energy storage/conversion system

Who benefits from the manufacturing innovation?

We are building innovation ecosystem!

Domestic suppliers — AMMTO strengthens domestic material supply chains and improves manufacturing capabilities for energy storage technologies.

Domestic manufacturers — AMMTO helps manufacturers integrate energy storage technologies into their processes to improve resiliency and productivity.
Energy Storge/Conversion Manufacturing Strategy (continued)

What are we trying to do? What problem are we solving?

Energy Storage/Battery Manufacturing RD&D Portfolio is to reduce “time-to-market.”
FY20 AMMTO-VTO Joint Battery Manufacturing Lab Call

AMMTO’s strategic, jointly funded efforts between VTO since 2020. Focused on multiple aspects of EV Battery Manufacturing.

Goal

To establish public-private partnerships that address manufacturing challenges for advanced battery materials and devices, with a focus on de-risking, scaling, and accelerating adoption of new technologies

<table>
<thead>
<tr>
<th>Office</th>
<th>Project Title</th>
<th>National Labs</th>
<th>Industry Partner</th>
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</thead>
<tbody>
<tr>
<td>AMMTO</td>
<td>Advanced Brine Processing to Enable U.S. Lithium Independence</td>
<td>ANL</td>
<td>Albemarle/Ameridia (North Carolina)</td>
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<tr>
<td>($10M)</td>
<td>Scale-up Production of Graphene Monoxide for Next-Generation LIB Anodes</td>
<td>ANL</td>
<td>Connovate LLC (Wisconsin)</td>
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<td></td>
<td>Continuous Flow Reactor Synthesis of Advanced Electrolyte Components for Lithium-Ion Batteries</td>
<td>ANL</td>
<td>Koura Global (MA)</td>
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<tr>
<td></td>
<td>Scaling up of High-Performance Single Crystalline Ni-rich Cathode Materials with Advanced Lithium Salts</td>
<td>PNNL</td>
<td>Albermarle (NC)</td>
</tr>
<tr>
<td></td>
<td>High-Energy and High-Power NMP-Free, Designer NMC 811 Cathodes with Ultra-Thick Architectures Processed by Electrophoretic Deposition</td>
<td>ORNL</td>
<td>PPG (PA)</td>
</tr>
<tr>
<td></td>
<td>High-Throughput Laser Processing and Acoustic Diagnostics for Enhanced Battery Performance and Manufacturing</td>
<td>NREL</td>
<td>Clarios and Amplitude (NY)</td>
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<td>Commercially Viable Process for Surface Conditioning of High-Nickel Low-Cobalt Cathodes - BNL (Prime)</td>
<td>BNL</td>
<td>C4V &amp; Primet (NY)</td>
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<td>Multilayer Electrodes with Metalized Polymer Current Collector for High-Energy Lithium-Ion Batteries with Extreme-Fast-Charging Capability</td>
<td>ORNL</td>
<td>Soteria (SC)</td>
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<td>Hydrothermal Production of Single Crystal Ni-rich Cathodes with Extreme Rate Capability</td>
<td>ANL</td>
<td>Hunt Energy Enterprise (Texas)</td>
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<td>VTO Continuous High Yield Production of Defect-Free, Ultrathin Sulfide Glass Electrolytes for Next Generation Solid State Lithium Metal Batteries</td>
<td>ANL</td>
<td>PolyPlus (CA)</td>
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<tr>
<td>($5M)</td>
<td>Scaling Halide-type Solid Electrolytes for Solid State Batteries</td>
<td>ANL</td>
<td>Saint-Gobain Ceramics &amp; Plastics (PA)</td>
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<tr>
<td></td>
<td>Scale-up of Novel Li-Conducting Halide Solid State Battery Electrolyte</td>
<td>LBNL</td>
<td>Saint-Gobain Research North America (PA)</td>
</tr>
<tr>
<td></td>
<td>Scaling-up and Roll-to-Roll Processing of Highly Conductive Sulfide Solid-State Electrolytes</td>
<td>PNNL</td>
<td>Ampcera Inc. (CA)</td>
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Managed by AMMTO

- ANL
- PNNL
- ORNL
- BNL
- NREL
- LBNL

Managed by VTO

- C4V & Primet
- Koura Global
- PPG/Saint-Gobain
- Saint-Gobain Ceramics & Plastics (PA)
- Saint-Gobain Research North America (PA)
- Ampcera Inc. (CA)

Projects and Statistics

U.S. DEPARTMENT OF ENERGY  OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
FY21 Flow Battery Systems Manufacturing FOA

This FOA aims to bring manufacturable systems from the lab to the marketplace – system prototype demonstration is key. Projects since 2022.

Motivation & Challenges

Motivation: Flow batteries are an ideal solution for grid supporting long duration energy storage.

Manufacturing challenges identified

• Inefficient and expensive manufacturing technologies

• Challenges with manufacturing scale-up of newer system designs & chemistries.

• Lack of robust, standardized supply chains (limited suppliers) and system integration challenges

Collaboration with OE

• AMMTO funds, supports, and manages the selected projects.

• OE will fund the costs of final prototype testing/validation conducted at the National Lab facilities.

Selected Projects (total $18M funding)

01 Largo Clean Energy: Innovative Manufacturing Processes to Enable Flow Batteries with Unmatched Capital Costs (Focus on stack and electrolyte)

02 TreadStone Technologies, Inc.: R2R Manufacturing of Metallic Electrodes and Bipolar Plates for Flow Batteries (focus on bipolar plates)

03 OTORO Energy Inc.: Metal Chelate Flow Battery System Manufacturing (focus on electrolytes)

FY 19 MT-FOA includes

- Subtopic 1.1: Accelerate the Manufacturing Process Design and Development Cycle for Advanced Energy Conversion and Storage Materials (7 projects, $10M)
- Subtopic 1.2: Innovative Manufacturing Processes for Battery Energy Storage (6 projects, $20M + $5M from VTO)

FY 21 MT-FOA includes “Energy Systems” subtopic.

- Innovative micromanufacturing processes for lithium-ion batteries to enhance safety and reduce cost and time-to-market. (6 projects, $7.5M)
### Keep identifying key needs

Challenges and gaps (for example):

- **Need for advanced tooling** to manufacture the high-performance components at scale commensurate with large volume production;

- **Need for precision manufacturing technologies** for energy conversion storage materials; and

- **Need for processing technologies** to develop promising materials/components/systems in the volumes and throughput required for pilot scale

- **Need for micromanufacturing efforts** to harness new innovations

### Focus on

- **Processing level** – innovating in manufacturing processes to improve productivity, quality, and eco-friendliness.

- **Machine level** – creating new manufacturing machinery and improving existing equipment to enhance accuracy and throughput in order to lower the cost of energy storage production.

- **Systems-level** – focusing on the systems used to enable the production process.

- **Clean energy ecosystem level** - promoting manufacturing competitiveness and workforce abilities.

### Future state

1. **Harnessing collaboration** through manufacturing RD&D collaboratories.

2. **Accelerating scale-up of high-volume storage/conversion manufacturing** by:
   1) Building confidence in the use of manufacturing platform technologies;
   2) Developing technical standards to assess the scalability and manufacturability of storage/conversion technologies; and
   3) Promoting the use of platform manufacturing technologies by sharing knowledge through the innovation ecosystem.
## CRADA Lab Call: Focus Area 1

**Solid-State Battery Manufacturing RD&D**

- Translating fundamental solid-state electrolyte R&D into large format/high-volume manufacturing RD&D.
- Enhancing precision processing and fabrication of solid-state batteries in large format cells.
- Verification and validation (V&V) of solid-state battery scalability.

**$8M**

## CRADA Lab Call: Focus Area 2

**Flow Battery Manufacturing RD&D**

- Manufacturing for new (or enhanced) cell/reactor architecture and configuration.
- Developing manufacturing/process standards.

**$8M**

## Li-ion Battery Remanufacturing RD&D

- Room temperature process development for recycling and reuse of electrodes
- Rejuvenation (re-manufacturing) of electrodes for direct reuse
- Recycling of the electrolyte
- Education and workforce development

**$2M**

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Advanced Materials and Manufacturing Technologies Office

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The Advanced Materials & Manufacturing Technologies Office (AMMTO) advances energy-related materials and manufacturing technologies to increase domestic competitiveness and build a clean, decarbonized economy.

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DOE Strategic Support for Battery Innovation, Manufacturing, and Use
Energy Storage Energy Tech Team (SETT) & related coordinating bodies

ESGC
Main coordinating structure for storage

Storage SETT (Prog. Mgr.- Level Technical Execution)

- Technology Development
- Manufacturing & Supply Chain Innovations, Workforce
- Investment, Commercialization, and Scale-Up
- Markets Valuation

Inclusion & Diversity incorporated throughout

- Batteries+
- Thermal+
- Power Electronics
- Storage for Manufacturing
- Manufacturing for Storage
- Supply Chain
- Workforce
- Financial Analysis
- Sector Tracking
- Investment Coordination
- Partnerships

Joint Strategy Team - Batteries establishes technology strategy
LDSS Coordinator ensures progress towards goals

[Align with Departmental TA Initiative]

Hydrogen - In ESGC Scope but coordinated by H2 SETT/JST