

# Energy Storage & Conversion Manufacturing

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**AMMTO & IEDO JOINT PEER REVIEW**

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01

## 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
  - Addressing common manufacturing technical barriers can help to accelerate full-scale commercialization of recent innovations and emerging technologies.
  - Advances in manufacturing are potentially transferrable elsewhere in the manufacturing sector.

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## 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.

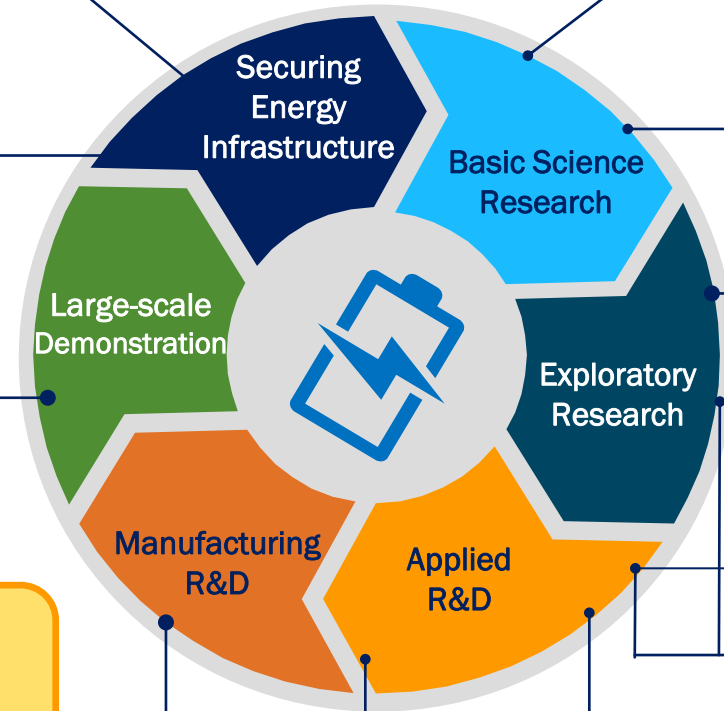
## Office of Clean Energy Demonstrations (OCED)

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 address fundamental issues of materials and electrochemical interactions associated with lithium and beyond-lithium batteries.

Supports applied R&Ds that focus on optimizing next generation, high-energy lithium ion electrochemistries that incorporate new battery materials.

## 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.

# Historical FOA and Lab Call Topics

Funding	FY	Description	AMMTO Investment
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	Since 2015	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?

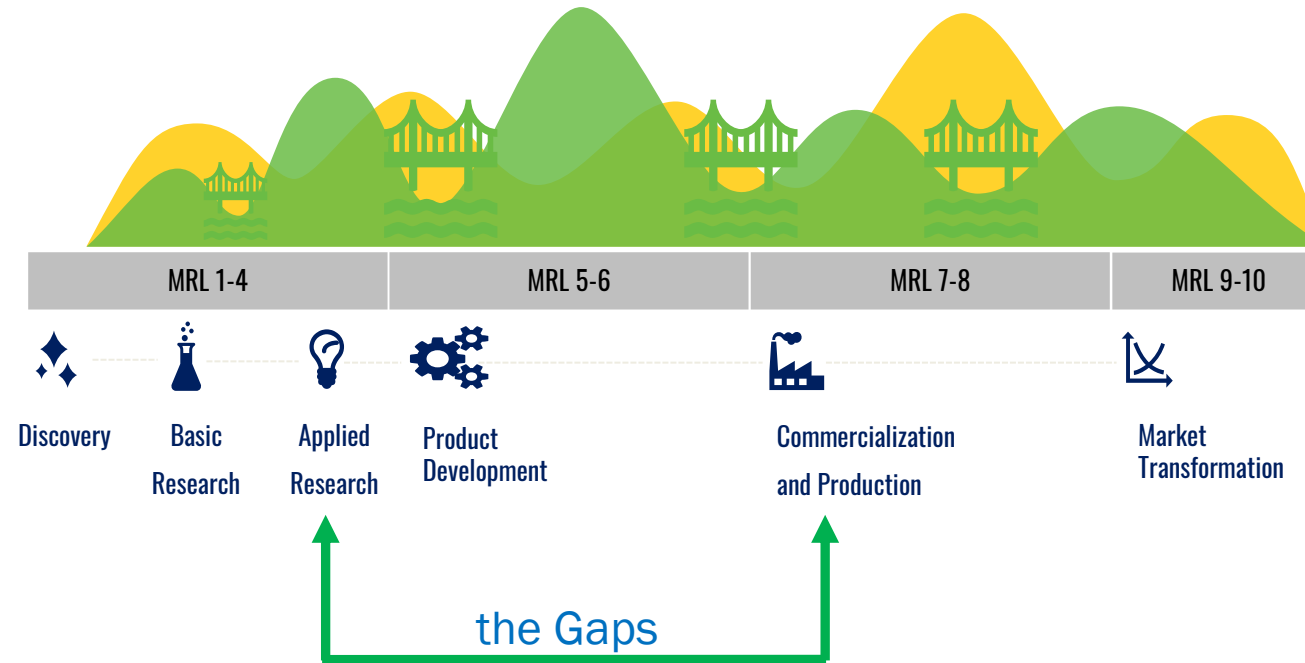
**We are building innovation ecosystem!**

**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 Storage/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

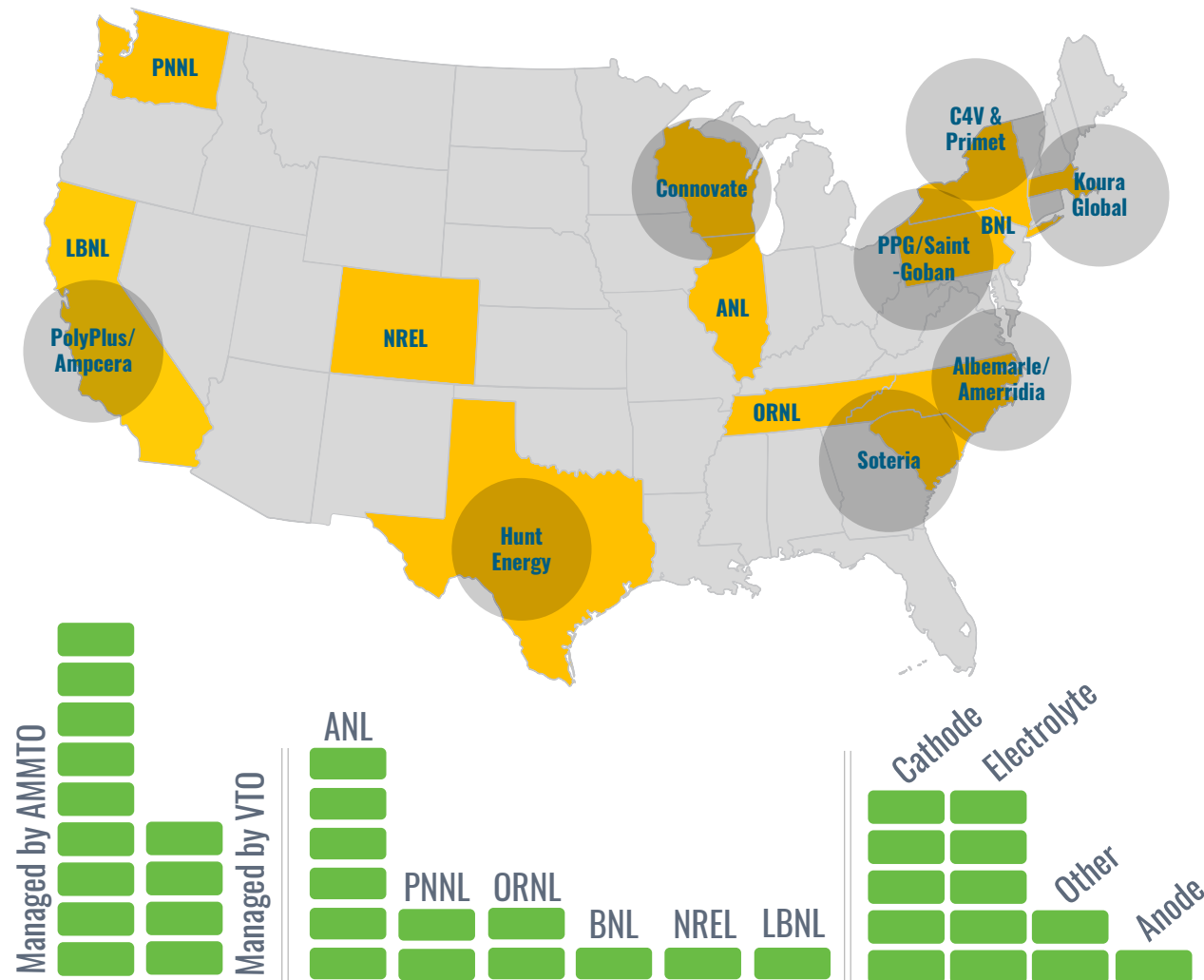
AMMTO's strategic, jointly funded efforts between VTO since 2020. Focused on multiple aspects of EV Battery Manufacturing .

## 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

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

## Projects and Statistics



# 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

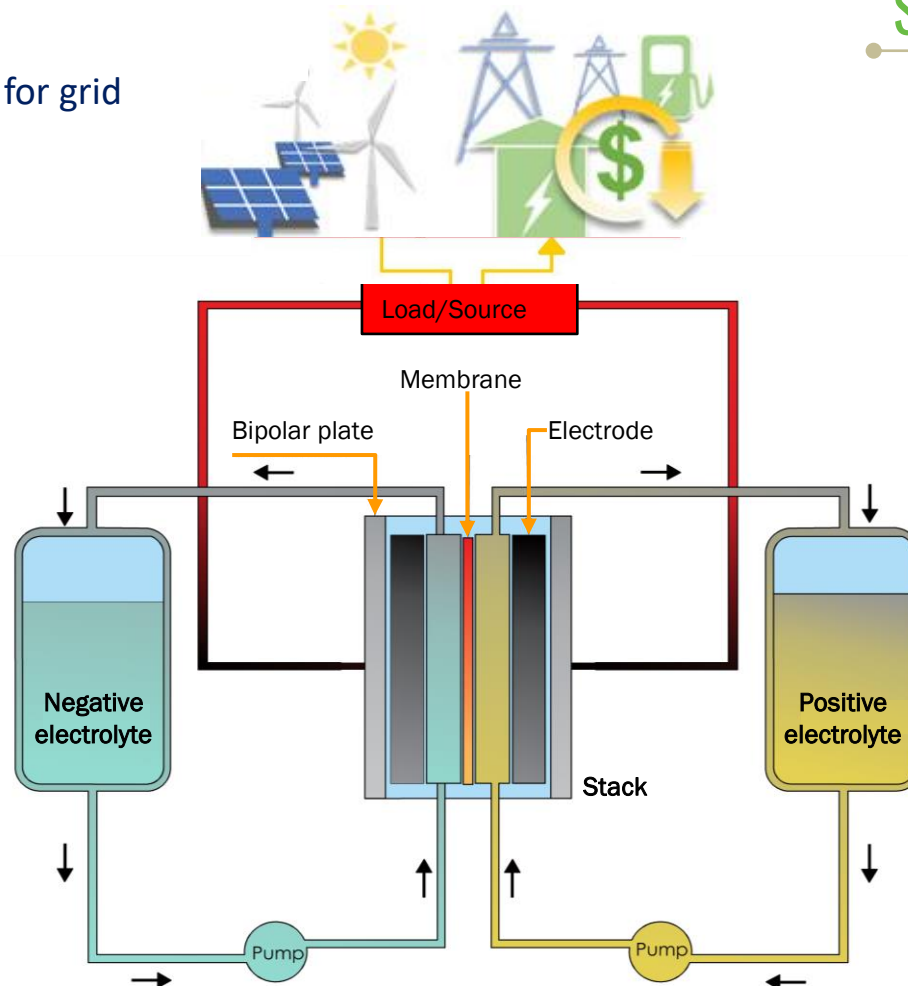
**Motivation:** Flow batteries are an ideal solution for grid supporting long duration energy storage.

### 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 Labs 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)
- 04 Quino Energy Inc.:** Continuous Flow Synthesis of Low-Cost, Long Lifetime Aqueous Organic Flow Battery Reactants (focus on electrolytes)



# FY19 and FY21 Multi-Topic FOAs

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## 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)

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## 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)



PROJECT TITLE	PROJECT LEAD	PROJECT PARTNERS	CITY/STATE
+ CoEx Electrode Structuring for High Energy and Fast Charging Lithium-Ion Batteries	Palo Alto Research Center, Inc.	Oak Ridge National Laboratory	Palo Alto, CA
+ High Throughput Source-less Plasma Deposition of Structured Silicon Anodes for Lithium-Ion Batteries	Amprius Technologies, Inc.	None	Fremont, CA
+ Dry Laser Powder-Bed Fusion for Structured Cathode Manufacturing	Lawrence Livermore National Laboratory	Ampcera	Livermore, CA
+ Acoustic Field-Assisted Additive Manufacturing for Structured Electrode Lithium-ion Batteries: Reliability Characterization and Scale-up	University of Washington	Oak Ridge National Laboratory, University of California, Santa Barbara	Seattle, WA
+ Scalable High-Throughput Open-Air Spray-Plasma Manufacturing of Solid-State Lithium Batteries	Stanford University	None	Redwood City, CA
+ Direct Ink Writing of 3D Architectures for Lithium-Ion Batteries	University of California: Los Angeles	Lawrence Livermore National Laboratory	Los Angeles, CA

# Next Steps: Energy Storage/Conversion Manufacturing

## 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 laboratories.
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.

# FY23: Energy Storage & Conversion Manufacturing

## CRADA Lab Call: Focus Area 1

### Solid-State Battery Manufacturing RD&D

**\$ 8M**

- 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.

## CRADA Lab Call: Focus Area 2

### Flow Battery Manufacturing RD&D

**\$ 8M**

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

## Li-ion battery rejuvenation/ reuse collaboration with ReCell Center

### Li-ion Battery Remanufacturing RD&D

**\$ 2M**

- 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



## Advanced Materials and Manufacturing Technologies Office

Careers and Fellowships

AMMTO News and Events

Funding Opportunities

# Enjoy our accomplishments

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

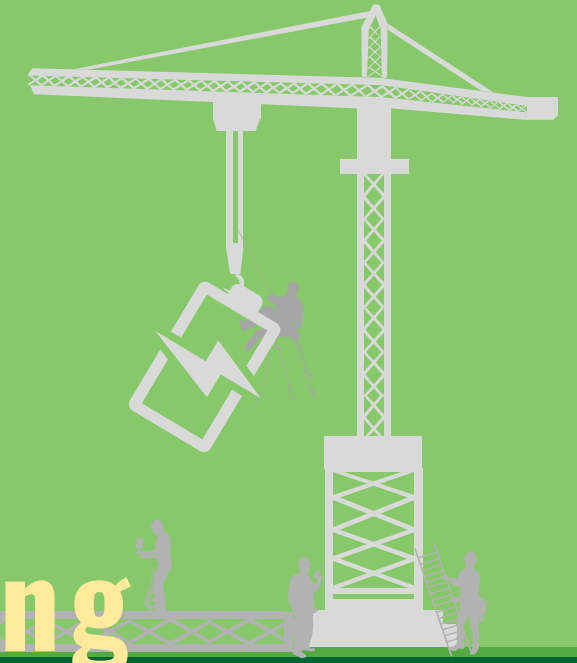
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Stay abreast of the latest developments in Advanced Materials and Manufacturing Technologies.

<https://www.energy.gov/eere/ammtto/advanced-materials-manufacturing-technologies-office>

# Materials and manufacturing



# DOE Strategic Support for Battery Innovation, Manufacturing, and Use



# Energy Storage Energy Tech Team (SETT) & related coordinating bodies

## ESGC

Main coordinating structure for storage

Joint Strategy Team-  
Batteries establishes  
technology strategy

JST

LDSS

LDSS Coordinator ensures  
progress towards goals

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

[Align with  
Departmental  
TA Initiative]

Batteries+

Thermal+

Power Electronics

Storage for Manufacturing

Manufacturing for Storage

Supply Chain

Workforce

Financial Analysis

Sector Tracking

Investment Coordination

Partnerships

FCAB

GMI  
(Grid  
Modernization  
Initiative)

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