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# Energy Storage at Sandia National Laboratories
# Hawaii Senate Committee on Energy and Environment

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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# Introduction

## *Presentation at a Glance*

- Technical Categories of Energy Storage
- Financial Stakeholders
- Market Forecast for Storage
- Currently deployed Energy Storage System units
- Reliability and Testing
- Applied Research for Battery Storage
- Applied Research for Non-Battery Storage
- Basic Research for Energy Storage

# Classifying Energy Storage

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## Mechanical

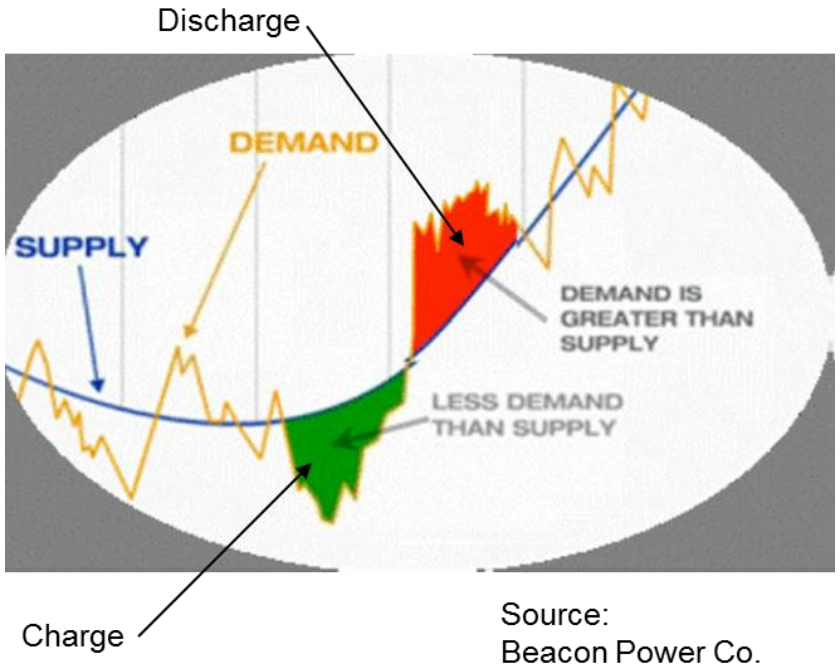
- Pumped Hydro
- Compressed Air Energy Storage
- Flywheels

## Electrical

- Capacitors
- Superconductors

## Electrochemical

- Batteries



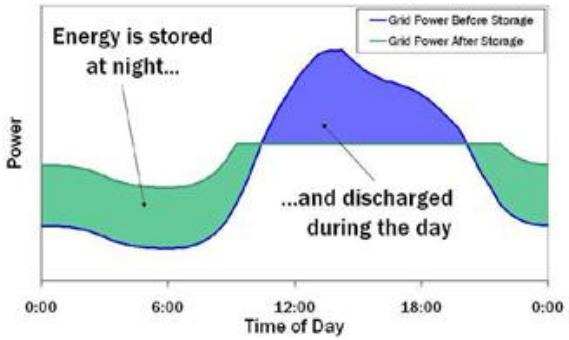

Source:
Beacon Power Co.

**All Energy Storage can be further categorized as emphasizing either:**

**ENERGY** store larger amounts of energy for later use

OR

**POWER** oscillate power to balance load and generation



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# FINANCIAL STAKEHOLDERS

# Commercial Stakeholders in Grid Energy Storage

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| Storage Manufacturers* | Current Developers/Suppliers* |
|---|---|
| Aqueous Sodium | 1 |
| CAES | 14 |
| Siteable CAES | 1 |
| Electro-chemical Capacitors | 6 |
| Flow | 7 +3 |
| Flywheel | 6 |
| Li-ion | 14 |
| Lead Acid | >8 |
| Metal- Air | 9 +2 |
| Pumped Hydro | 2 |
| Sodium Sulfur | 1 |
| Solid State | 1 |
| **Power Electronics** | |
| Inverters, Controllers | |
| Integrators | |
| **Other** | |
| Electrical Equip. Manufacturer | |
| Engineering& Construction | |

## Clients

| Developers |
|---|
| Renewables |
| Community/City |
| **Utilities** |
| Distribution |
| Transmission |
| Generation |
| **End Users** |
| Commercial |
| Industrial |
| First Responders |
| Microgrids |
| Residential |
| **Military** |
| Forward Operating Bases |
| Military Base Microgrids |

*** Information provided by ESA www.electricitystorage.org**

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# MARKET AND FORECAST

# Storage Project Development: Progress to Date

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- Approximately 128 GW worldwide (99% of which is pumped hydro)
  Source: CleanEdge, Clean Energy Trends 2012 (citing EPRI)
- Approximately 25 GW installed in the U.S. (including 22 GW pumped hydro)
  Source: Arthur O'Donnell, "Energy Storage at the CPUC" presentation to Infocast Storage Week Summit (June 26, 2012) (citing Pike Research)
- Trend: combined renewable storage projects
  (e.g. CSP/molten salt (BrightSource), wind/batteries (AES/A123)

Data compiled for ESTAP Webinar July 12, 2012 by Wilson Sonsini Goodrich & Rosati

# Market Analysis and Projections

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| Region | Market Share in 2017 (%) | Market Share in 2017 (US$ Billion) |
|---|---|---|
| US | 23% | 25.7 |
| Japan | 18% | 20.3 |
| China | 18% | 20.0 |
| UK | 9% | 10.7 |
| Germany | 9% | 10.0 |

**Source: SAND2004-6177**

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# CURRENTLY DEPLOYED ENERGY STORAGE SYSTEM UNITS

# Electricity Storage – Today

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## % of Electricity that is stored

**World-wide** 2.2%

- **Japan** 8.9%

- **Europe** 4.7%

- **USA** 2.2%

Source: 2011 EIA - Total Capacity 2009

# Storage on the Grid Today

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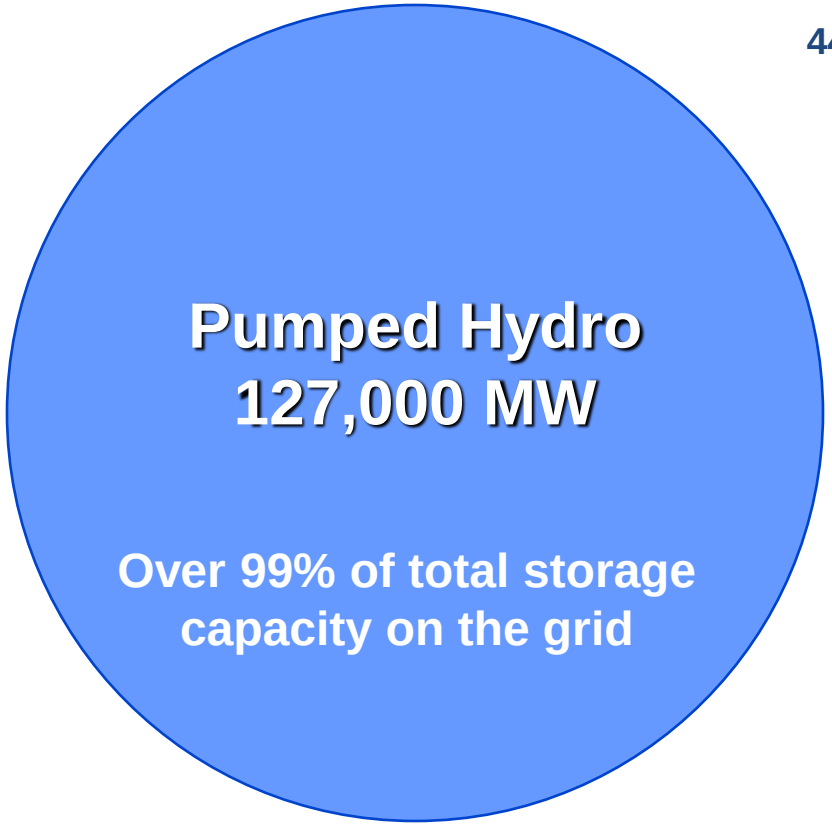
## Worldwide installed storage capacity for electrical energy




440 MW Compressed Air Energy Storage

375 MW Sodium Beta Batteries

90 MW Lithium Ion Battery

70 MW Lead-Acid Battery

27 MW Nickel-Cadmium Battery

< 5 MW Flow Battery

Source: Fraunhofer Institute, EPRI

# US Deployed Electricity Storage Systems

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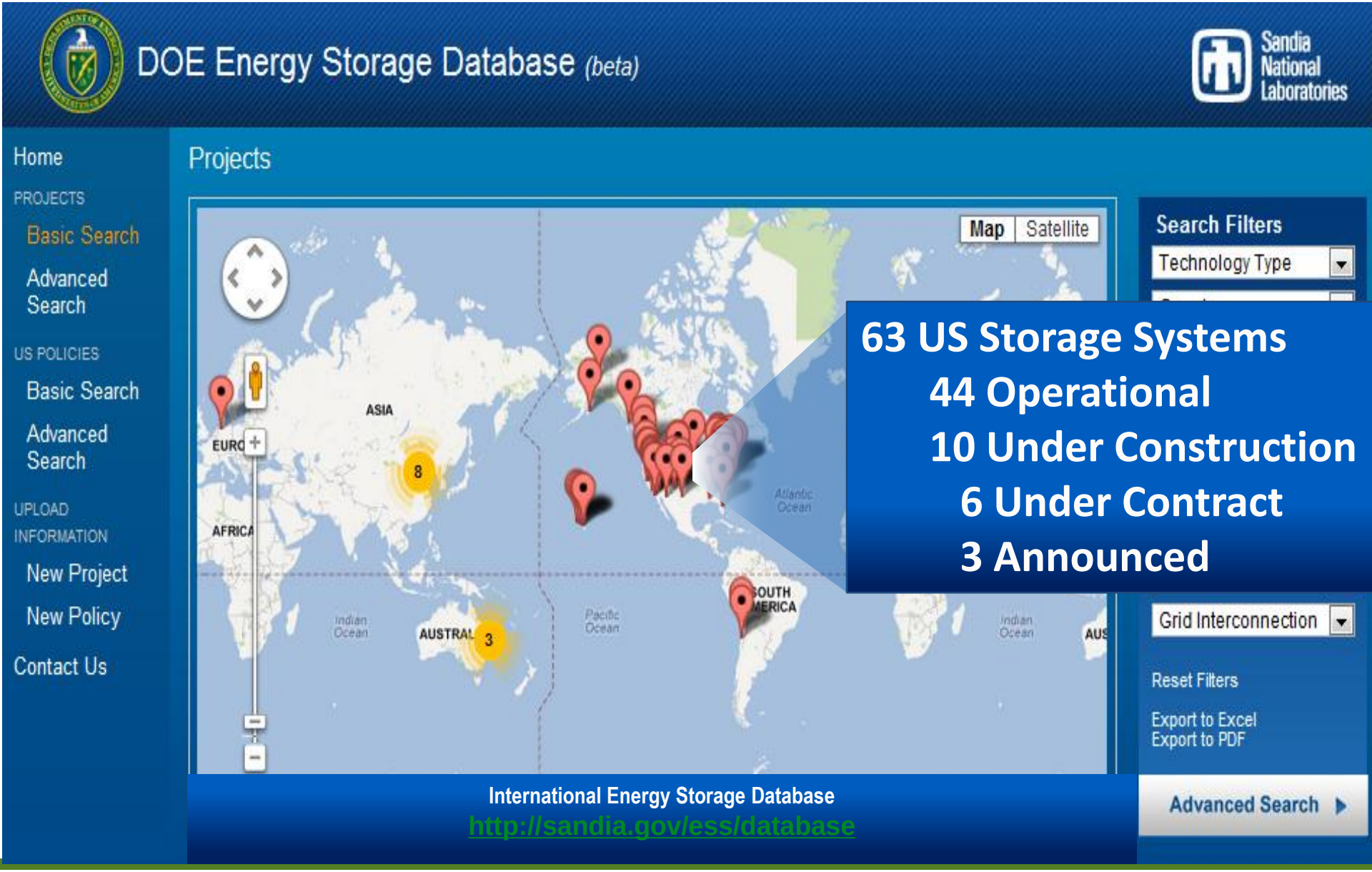

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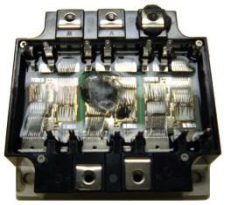
# RELIABILITY & TESTING

# Power Electronics Reliability

- High reliability of components doesn't always translate to high system level reliability – system reliability in the field not well understood and is site specific
- Lack of confidence or poor understanding of the reliability of energy storage system and its associated components can add to initial and long term costs – high project financing and insurance rates
- Low reliability leads to high operation, maintenance, and system replacement costs  and low system availability
- Inverters commonly noted cause of system incidents triggered in the field – not all are necessarily inverter failures
- No concerted effort to develop system level inverter reliability testing to date



Semiconductor switch failure

Circuit board failure

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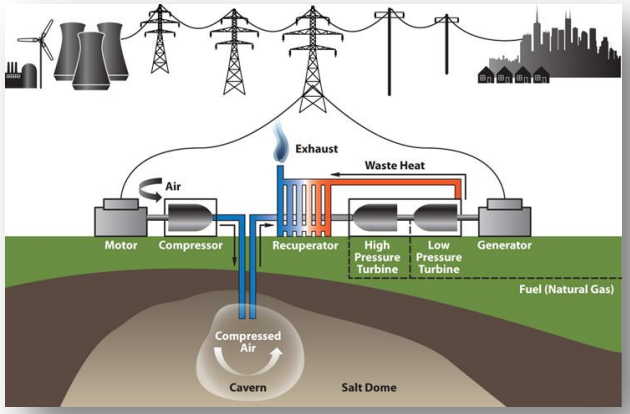
# APPLIED RESEARCH FOR NON BATTERY STORAGE

# Applied Research for Storage

## (Non-Battery)

- Flywheels
  - Lower cost
  - Increase material strengths
- Compressed Air Energy Storage
  - Geological research to determine long term viability of storage
  - High Efficiency Above-Ground CAES
- Capacitors
  - High temperature, low material cost
- Pumped Hydro (very little R&D needed)
- Analytics
  - Value Propositions, stacked benefits, policy analysis, advanced technical uses, market structures
- Power Electronics



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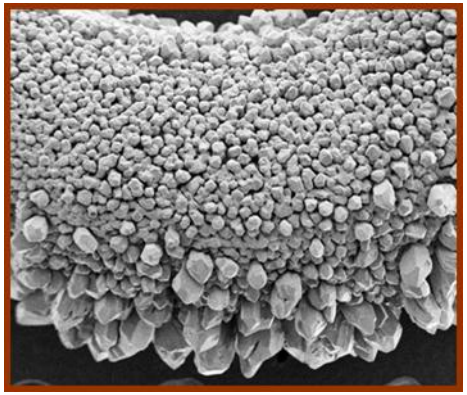
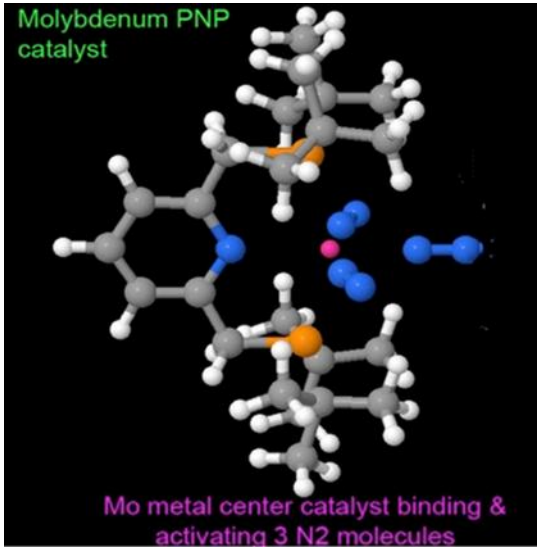
# APPLIED RESEARCH FOR BATTERY STORAGE

# Grid Based Battery Research

***These efforts are focused on developing new battery subcomponents and new types of batteries***



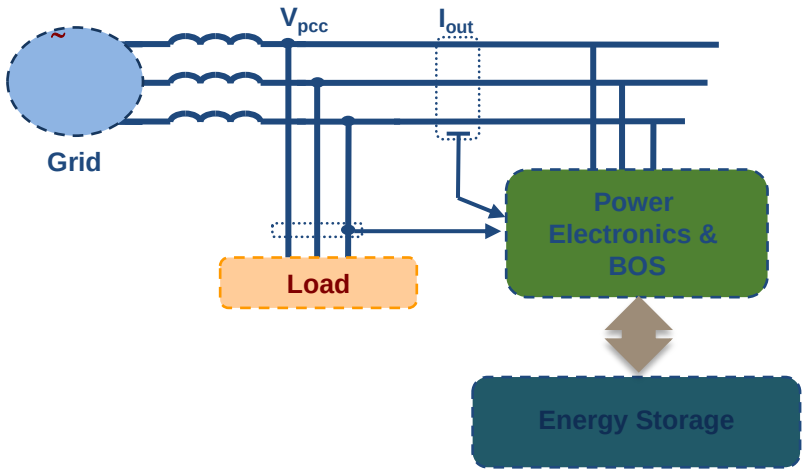
**Solid Metallic Anodes**

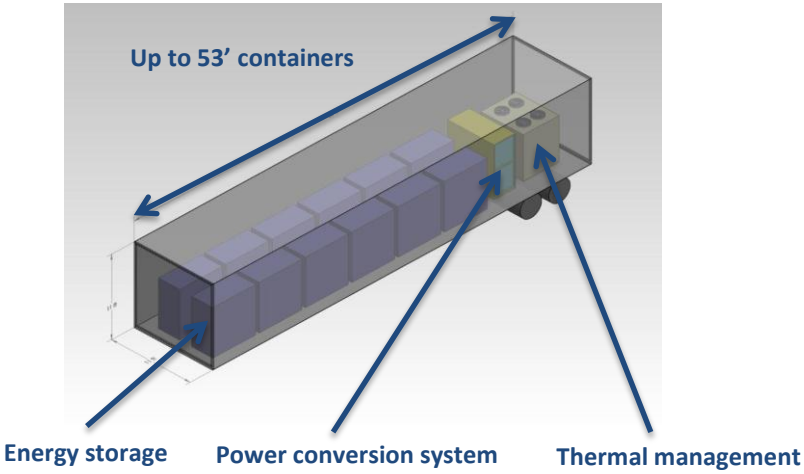




**N2-O2 Battery**

# Energy Storage Power Electronics

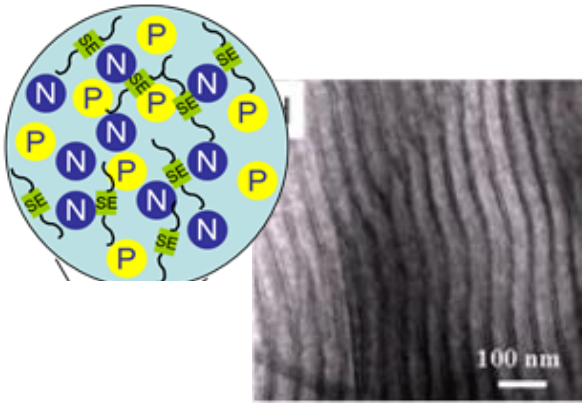
- Enabling technology for energy storage grid integration
- Can represent 20 to 60% of total system cost
- Balance of system (BOS) typically consist of DC and AC disconnect switches, transformers, and filters
- Controls proper charging and discharging of energy storage device along with grid support
- Most energy storage systems and power electronics are packaged in shipping containers for ease of shipment and reduced installation cost



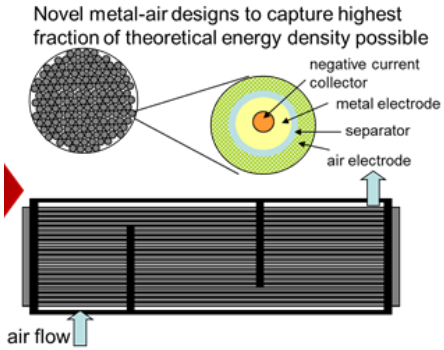



# Energy Storage Hub

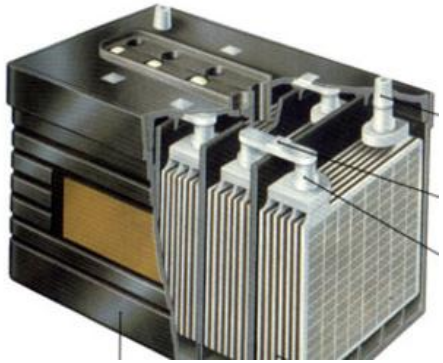
"World-class researchers, entrepreneurs, and experts from industry, academia, and national laboratories will invent, innovate, and commercialize revolutionary energy storage technologies"




New Chemistries




New Designs



New Manufacturing

New Methods for Simulation and Prediction

***Seeks to understand fundamental mechanisms, allowing new materials with better capacity, power, and reliability***