

Innovations and Advances to Enable Next Generation Batteries



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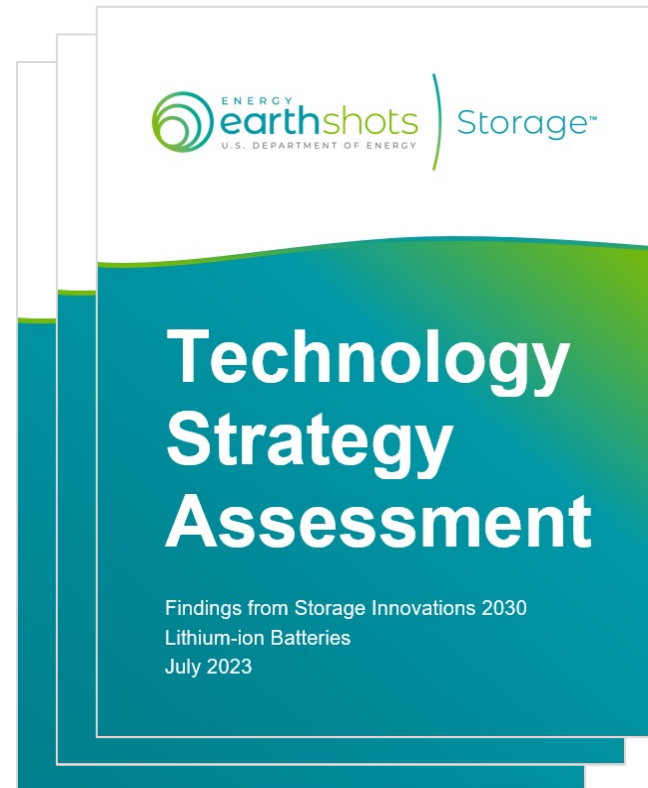


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SI 2030 Technology Strategy Assessments



- Lithium-ion
- Lead-acid
- Flow Batteries
- Zinc Batteries
- Sodium Batteries
- Pumped Storage
Hydropower
- Compressed-Air Energy
Storage
- Bi-Directional Hydrogen
Storage
- Thermal Energy Storage
- Supercapacitors



Diverse Innovations Identified by Industry Stakeholders and Experts

- Access to capital and financing
- Market opportunities
- Technology validation
- Interconnection queues/permitting
- Integrating technologies
- Manufacturing supply chain
- Workforce development
- Standards and codes

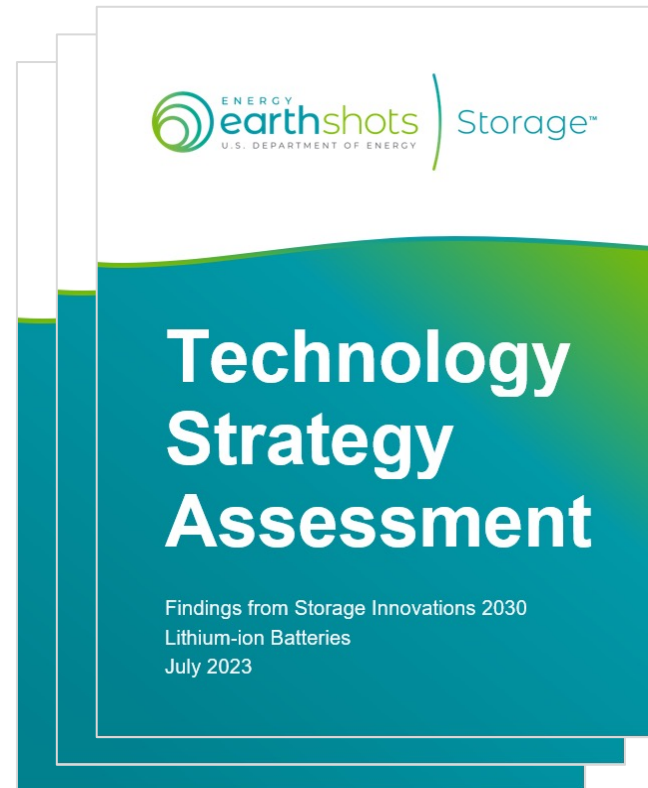


www.energy.gov/oe/storage-innovations-2030

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Flow Batteries

Diverse Chemistries/Formats

- Traditional (Fluid-Fluid)
- Hybrid (Solid-Fluid)
- Aqueous
- Non-Aqueous
- Organic
- Inorganic

Established Commercial Systems

- Vanadium  
- Iron  
- Zn-Br



Emerging Aqueous Organic



Zinc (Zn) Batteries

Commercial/Early Commercial Secondary

- Zn-Br
- Zn-MnO₂
- Zn-Air
- Zn-Ni



Emerging Secondary




- Zn-Ion 
- Zn-CuO 

Primary/Historical

- Zn-Air
- Zn-MnO₂
- Zn-Carbon
- Zn-Ag₂O

Sodium (Na) Batteries

“Mature” High-Temperature Molten Na

- Sodium-Sulfur  
- Molten Salt (ZEBRA) 

Emerging Na Metal Systems

- Low-temperature Molten Salt  
- Molten Sodium-Flow 
- Solid State Batteries  

Sodium-Ion Batteries (NaIBs)

- Layered Oxide
- Polyanion
- Prussian Blue Analogs



Global NaIB production capacity is expected to reach 40-100 GWh by 2030 (Wood Mackenzie, 2023)

Precompetitive Innovations Toward Cost-Effective Deployment



Flow Batteries

Zinc (Zn) Batteries

Sodium (Na) Batteries

R&D Technical Innovations	Non-Technical Advances
<ul style="list-style-type: none"> • Active Materials (Anode, Cathode) • Electrolytes • Power Electronics • Membranes/ Separators • Electrodes, Bipolar plates • Accelerating the Discovery Loop 	<ul style="list-style-type: none"> • Scalable manufacturing • Supply chain analytics/development • Interconnection Queues • Bankability • Standardization • Tax Credits • Regulatory Hurdles • Standardization of the RFB system

R&D Technical Innovations	Non-Technical Advances
<ul style="list-style-type: none"> • Active Materials (Anodes, Cathodes) • Electrolytes • Power Electronics/ Integration • Separators 	<ul style="list-style-type: none"> • Improved/Supported Manufacturing • Education (public relations for Zn batteries) • Zn-Specific Codes, Standards, and Validation • Demonstrations/ Validation Resources • Industry Cooperation • Pack/System Design • Inactive Materials Cost Reduction

R&D Technical Innovations	Non-Technical Advances
<ul style="list-style-type: none"> • Active Materials (Anodes, Cathodes) • Electrolytes • Power Electronics/ Integration • Accelerated Materials R&D 	<ul style="list-style-type: none"> • Manufacturing • Supply Chain • Education (public relations for Na batteries) • Na-Specific Codes, Standards, and Validation • Demonstrations/Testing / Validation Resources • Lifecycle Analyses/ End of Life • Workforce



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