U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Overview of Office Of Electricity's Storage Activities

Hydrogen Infrastructure Strategies to Enable Deployment in High-Impact Sectors

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January 2024

Topics

Storage landscape and path to 2030

DOE and Office of Electricity (OE)

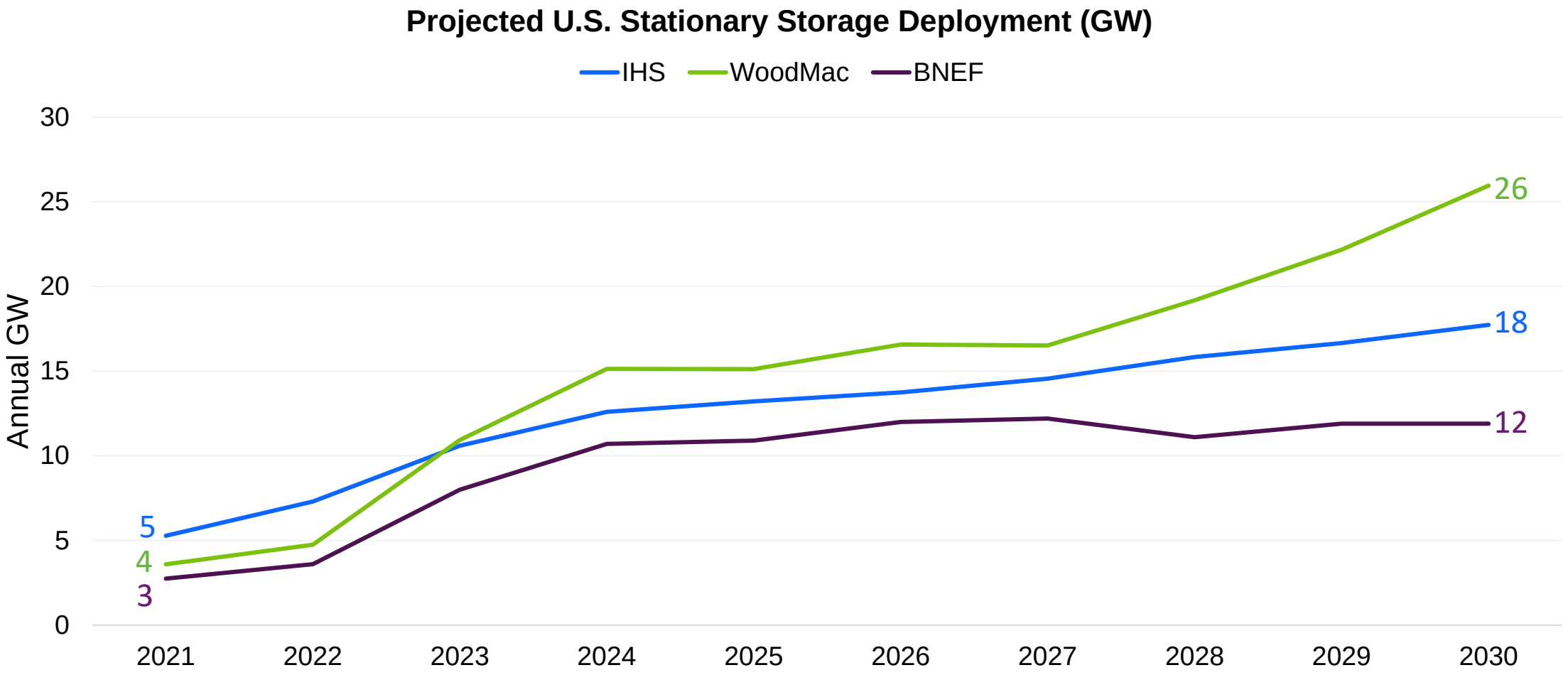
Energy Storage Grand Challenge (ESGC)

Long Duration Storage Shot (LDSS)

Storage Innovations for reducing energy storage costs

Additional OE Initiatives

Grid storage deployment is projected to rapidly grow



Diverse technology options provide a means to improve the resiliency of grid storage supply chains

Lithium-ion Battery Supply Chain Risk Assessment

Product/ Components	Are U.S. suppliers competitive in the global market?	Is the supply chain secure b/c material is NOT on the proposed or current Critical Materials List? OR b/c the U.S. does NOT import > 50%?
Lithium	No	No
Cobalt	No	No
Nickel	No	No
Manganese	No	No
Iron	Yes	Yes
Natural Graphite	No	No
Silicon	Yes	Yes
Refined LiOH/ Li2CO3	No	No
Refined CoSO4	No	No
Refined NiSO4/ C1 Ni	No	No
Refined Manganese	No	No
Synthetic Graphite Anode Materials	No	No
Natural Graphite Anode Materials	No	No
CAM/ p-CAM	No	No
LIB Cathodes	No	No
Graphite Anodes	No	No
Silicon-based anodes	Maybe	No
Separators	No	No
Electrolytes	No	No
Cells	No	No
Modules/Packs/ Racks	Yes	No
Energy Storage System Packages	Maybe	No
Cells/ Packs	Yes	No
Metals	No	No

Flow Battery Supply Chain Risk Assessment

Product/ Components	Are U.S. suppliers competitive in the global market?	Is the supply chain secure b/c material is NOT on the proposed or current Critical Materials List? OR b/c the U.S. does NOT import > 50%?
Iron	Yes	Yes
Vanadium	No	Yes
Zinc	Yes	Yes
Manganese	No	No
Sulfuric Acid	Yes	Yes
Refined Iron	Yes	Yes
Refined Vanadium	No	Yes
Refined Zinc	Yes	Yes
Hydrochloric Acid	Yes	Yes
Graphite	No	Maybe
Sulfuric Acid	Yes	Yes
Polyethylene	Yes	Yes
Separator - Polyethylene	No	No
Pumps	Yes	Yes
Heat exchangers	Yes	Yes
Electrolytes	Maybe	Maybe
Iron Flow Batteries/ Systems	Yes	Yes
Vanadium Flow Batteries/ Systems	No	Maybe
Zinc Flow Batteries/ Systems	No	Maybe

Lead-acid Battery Supply Chain Risk Assessment

Product/ Components	Are U.S. suppliers competitive in the global market?	Is the supply chain secure b/c material is NOT on the proposed or current Critical Materials List? OR b/c the U.S. does NOT import > 50%?
Lead	Yes	Yes
Sulfur	Yes	Yes
Refined Lead	Yes	Yes
Sulfuric Acid	Yes	Yes
Polyolefin	Yes	Yes
Separator	Yes	Yes
Electrolyte	Yes	Yes
Electrolyte Salts	Yes	Yes
Electrolyte Solvents	Yes	Yes
Lead Acid Batteries	Yes	Yes
Lead Acid ESS	Maybe	Yes
Lead	Yes	Yes

No

Yes

Maybe

Adapted from DOE Grid Energy Storage Supply Chain Deep Dive Assessment, February 2022; update in progress

DOE supports a variety (30+) of storage technologies

Bidirectional Electric Storage

- **Electrochemical**
  - Li-Ion & Li-Metal
  - Na-Ion
  - Na-Metal
  - Lead Acid
  - Zinc
  - Other Metals (Mg, Al)
  - Redox Flow
  - Reversible Fuel Cells
  - Electro-Chemical Capacitors
- **Electromechanical**
  - Pumped Storage Hydro
  - Compressed Air
  - Liquid Air
  - Flywheels
  - Geomechanical
  - Gravitational

Crosscutting

- **Power Electronics**
  - Power Electronic Systems

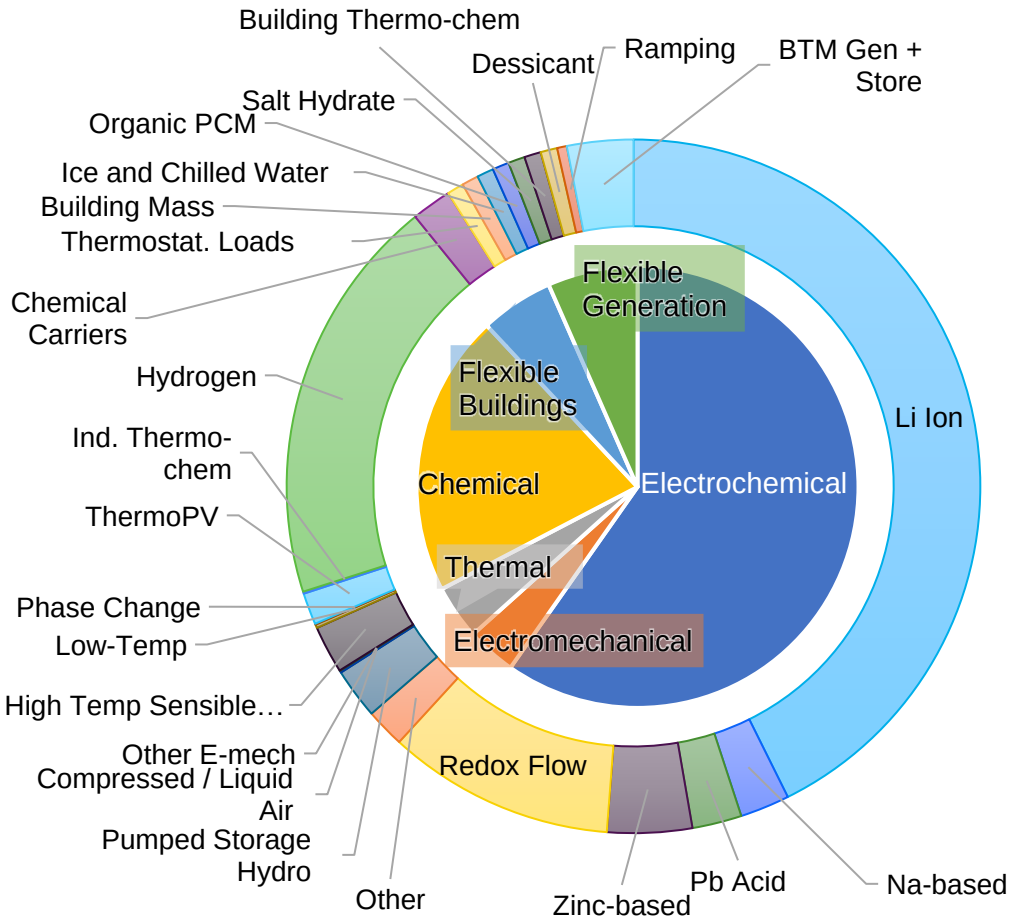
Thermal & Chemical

- **Thermal**
  - High-Temperature Sensible Heat
  - Phase Change
  - Low-Temperature Storage
  - Thermo-Photovoltaic
  - Thermochemical
- **Chemical**
  - Chemical Carriers (e.g., Ammonia)
  - Hydrogen

Flexible Generation & Loads

- **Flexible Buildings**
  - Thermostatically Controlled Loads
  - Building Mass
  - Ice & Chilled Water
  - Organic Phase Change Material
  - Salt Hydrate
  - Thermochemical
  - Desiccant
- **Flexible Generation**
  - Ramping
  - Behind-the-Meter Generation + Storage

DOE Funding Shares by Technology



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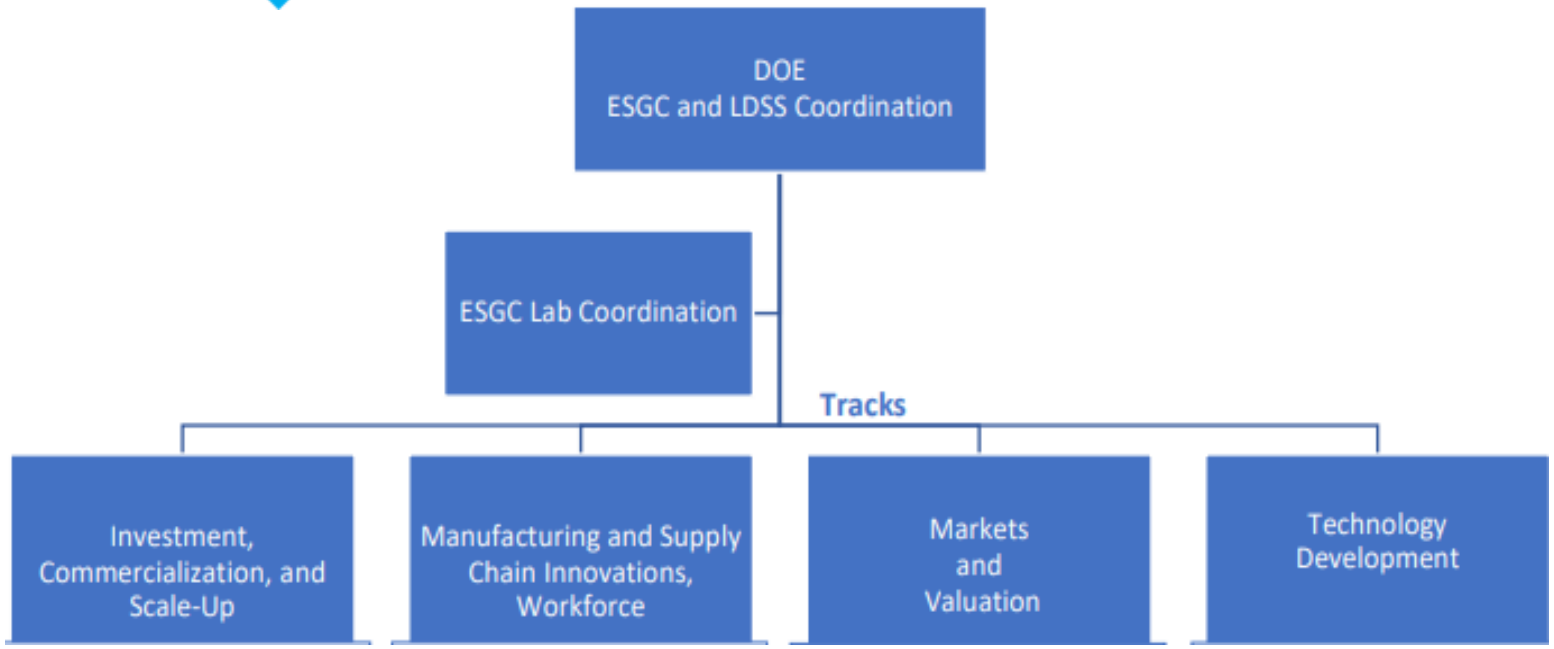
OE's Storage Division accelerates bi-directional electrical storage as a key component of the future-ready grid

- Applied materials development to identify safe, low-cost, and earth-abundant elements that enable cost-effective long-duration storage
- Improving storage reliability and safety
- Applying modeling and analysis
- Validating performance for rapid commercialization
- Energy Storage for Social Equity (ES4SE)
- International relationships
- Workforce development
- + more

The Energy Storage Grand Challenge (ESGC) accelerates the development, commercialization, and utilization of next-generation storage

ENERGY STORAGE GRAND CHALLENGE
U.S. DEPARTMENT OF ENERGY



Through the ESGC, OE and EERE co-lead grid storage efforts

Technology	Materials	Components & Devices	System Design	Grid & System Integration	Supply Chain & Manuf.	Operations	End of Life	Investment & Finance	Markets & Value	Workforce
Electro-chemical	VTO, ARPA-E, SC-BES	AMO, VTO, ARPA-E	VTO, ARPA-E, SETO	AMMTO, VTO	AMMTO, MESC	OCED	VTO	LPO, OTT, OCED, AMMTO, LPO, SETO	OTT, EERE-SA, GTO, WPTO, SETO, IEDO, BTO	AMMTO, VTO, OP, OTT
Electro-mechanical	ARPA-E, WPTO	ARPA-E, WPTO	ARPA-E, WPTO	WPTO	WPTO, AMMTO	OCED				
Thermal	ARPA-E, SETO, SC-BES, BTO	SETO, BTO	SETO, BTO	SETO, BTO	AMMTO, BTO	OCED, SETO	SETO			
Chemical	HFTO, SC-BES, ARPA-E	HFTO	HFTO	HFTO	AMMTO	OCED				
Power Electronics	SC-BES, ARPA-E	ARPA-E, AMMTO, VTO	AMO, VTO, CESER	VTO, CESER	AMMTO					

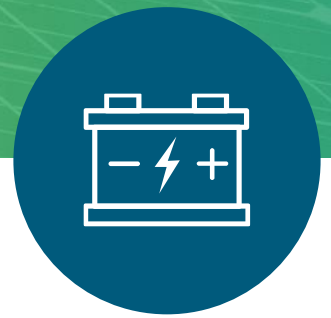
OE

ARPA-E: Advanced Research Projects Agency–Energy, AMMTO: Advanced Materials and Manufacturing Technologies Office, BTO: Building Technologies Office, FE: Office of Fossil Energy, GTO: Geothermal Technologies Office, HFTO: Hydrogen and Fuel Cell Technologies Office, IEDO: Industrial Efficiency and Decarbonization Office, OE: Office of Electricity, OP: Office of Policy, SETO: Solar Energy Technologies Office, LPO: Loan Programs Office, SC-BES: Office of Science Basic Energy Sciences, VTO: Vehicle Technologies Office, WETO: Wind Energy Technologies Office, WPTO: Water Power Technologies Office

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Storage™

LONG DURATION STORAGE SHOT TARGET

Reduce storage costs by **90%** from a 2020 Li-ion baseline...

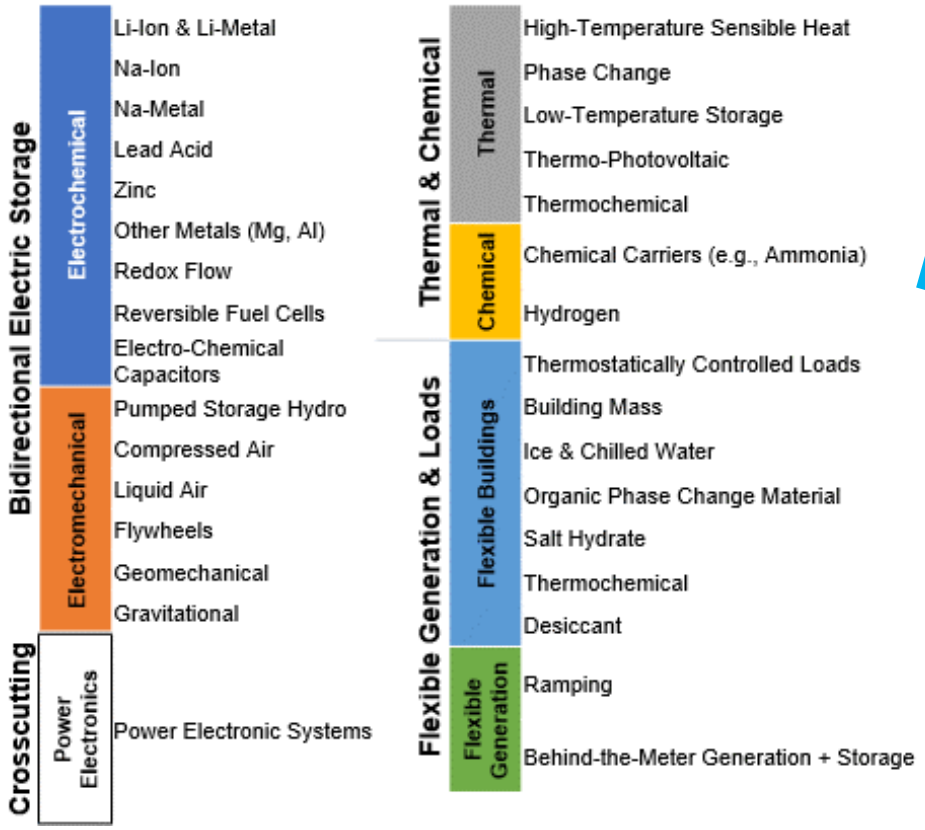


...in storage systems that deliver **10+** hours of duration

...in **1** decade

Affordable grid storage for clean power – any time, anywhere

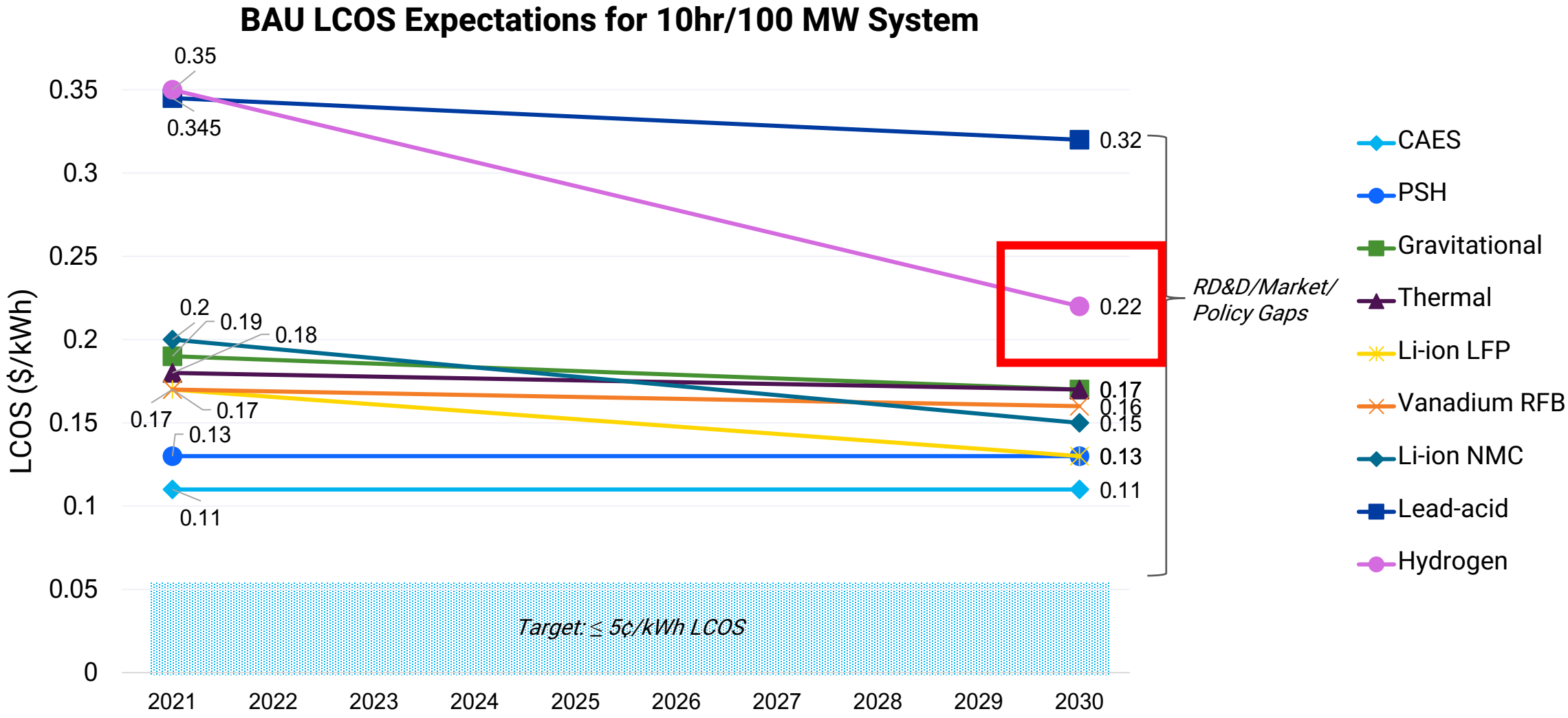
What RD&D pathways get us to the Long Duration Storage Shot (LDSS)?



2030

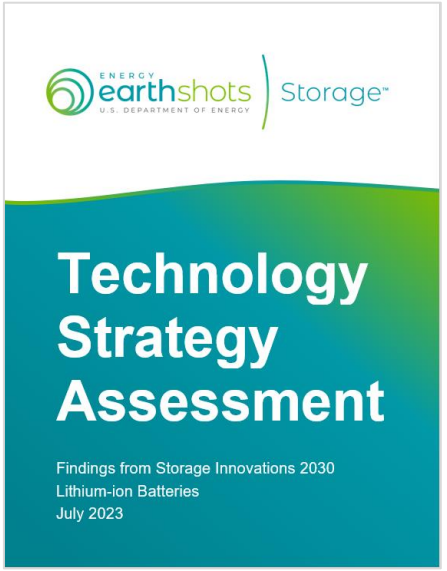
Long Duration Storage Shot:
$0.05/kWh
Levelized Cost of Storage (LCOS)

Business-as-usual conditions alone won't achieve $0.05/kWh LCOS



OE developed and analyzed Innovation Portfolios for 10 technologies, including bidirectional hydrogen storage

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

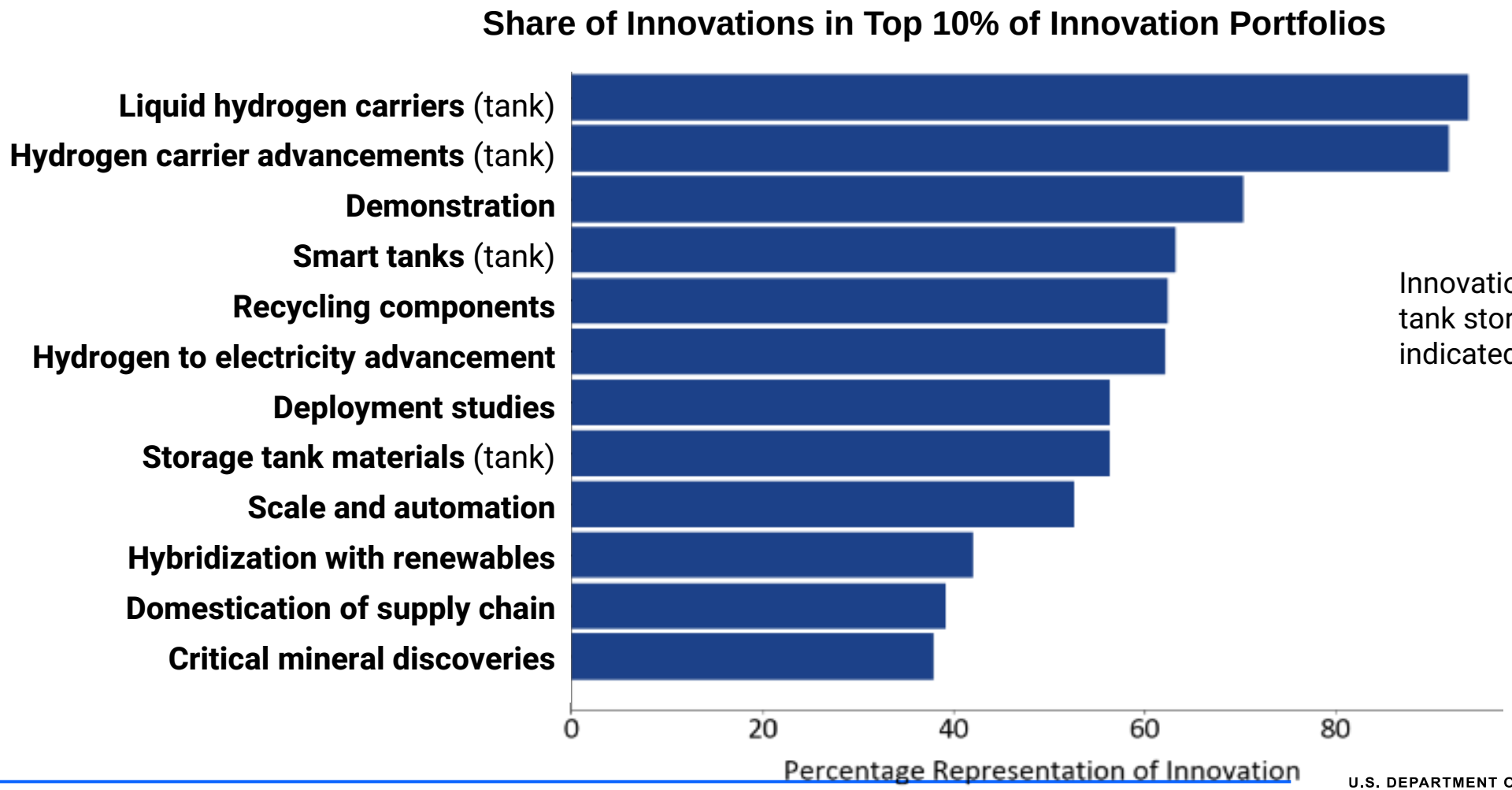


10 LDSS Technology Strategy Assessment Reports

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

Overview of methods used across the LDSS Technology Strategy Assessments

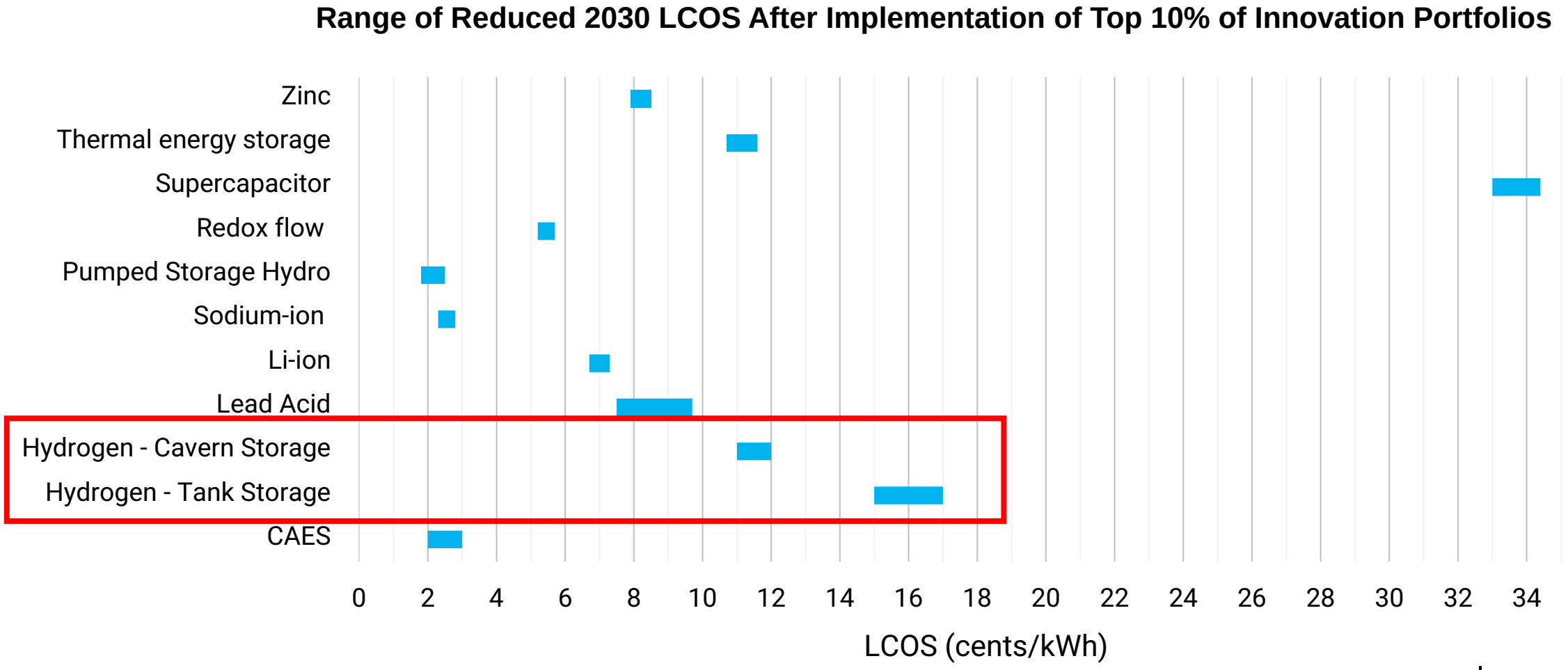
Innovations that reduce the cost of bidirectional hydrogen storage in high pressure tanks had a larger impact



Innovations apply only to tank storage where indicated

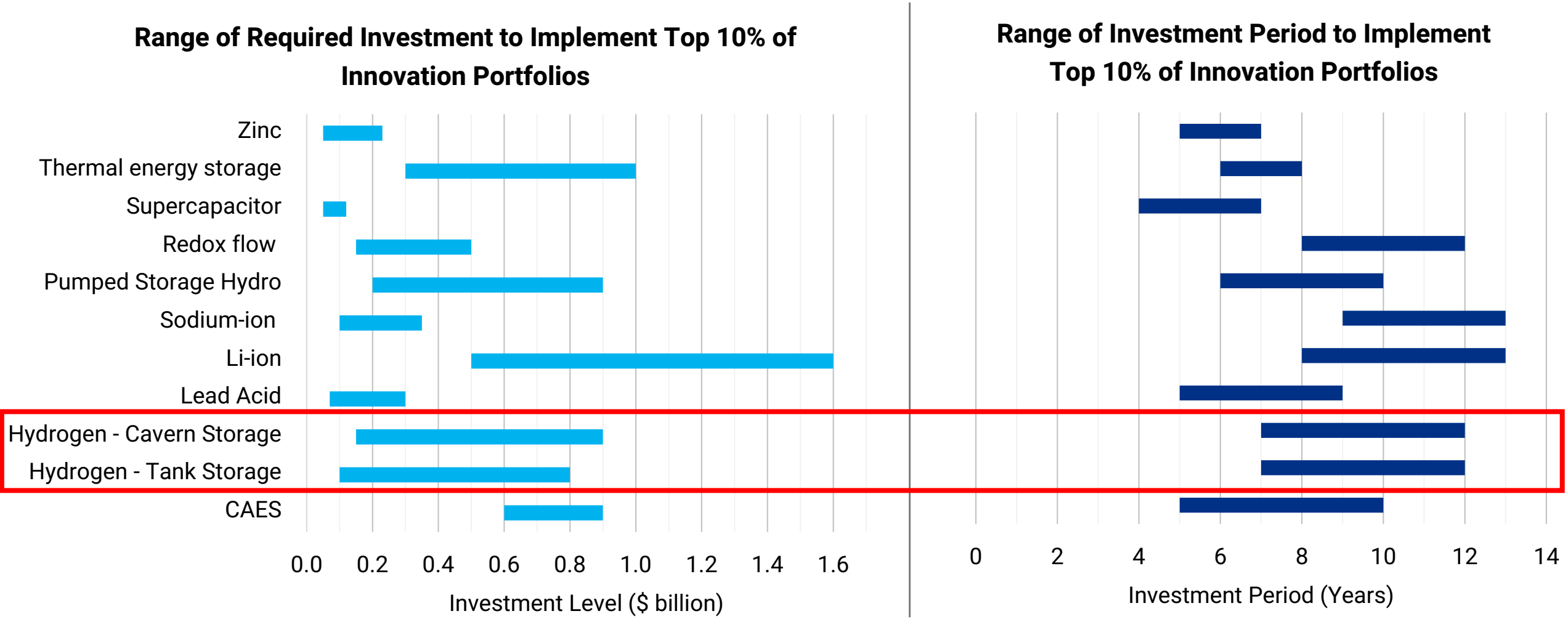
Adapted from Findings from Storage Innovations 2030: Bidirectional Hydrogen Storage, July 2022

The improved 2030 LCOS for hydrogen storage could drop to ~$0.11/kWh (cavern) and ~$0.16 cents/kWh (tank)



Adapted from Storage Innovations 2030: Exploring the Results, July 2022

Investment to reach improved 2030 LCOS levels could range from ~$100M-$900M and take 7-12 years

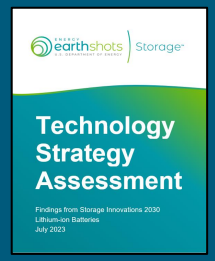


Adapted from Storage Innovations 2030: Exploring the Results, July 2022

To complement hydrogen storage, OE supports diverse storage technologies through a variety of initiatives

In 2023, OE announced **$30 M** to enable the LDSS through the two key ESGC initiatives

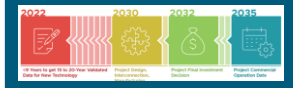
ESGC



Driving down LCOS

10 Long Duration Storage Shot Technology Strategy Assessment reports

$15 million Storage Innovations Technology Liftoff FOA



Validating ES performance

Rapid Operational Validation Initiative (ROVI)

$15 million Demonstration and Validation FOA

$0.05/ kWh Levelized Cost of Storage

DOE/OE have a growing workforce portfolio

Battery Workforce Initiative™


Grid Storage Launchpad

U.S. DEPARTMENT OF ENERGY | LEEP
Lab-Embedded Entrepreneurship Program

CHAIN REACTION INNOVATIONS
Entrepreneurship at Argonne

INNOVATION CROSSROADS

cyclotronroad

WEST GATE

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The Grid Storage Launchpad (GSL) is a new signature facility for storage advancement

- 90,000 sq. ft facility
- Systematic and independent validation of new grid storage technologies
- Basic materials and components, through prototyping under grid operating conditions (<100kW)

$75M TOTAL ESTIMATED FACILITYCOST

100 WORKSTATIONS

30+ LAB MODULES

$35M NON-FEDERAL INVESTMENTS

$15M LDRD

$7M

$8M

$5M BATTELLE

Ways to engage with OE

OPPORTUNITIES

FOA EXCHANGE

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EVENTS

ENERGY STORAGE GRAND CHALLENGE SUMMIT

OE PEER REVIEW

EMAIL LISTS

ENERGY STORAGE

GRAND CHALLENGE

WEBINARS

REACH OUT

Meet OE's Energy Storage Division

Eric Hsieh
Deputy Assistant Secretary

Imre Gyuk
Chief Scientist

Caitlin Callaghan
Director, Storage Materials & Systems

Mo Kamaludeen
Director, Storage Validation

Ben Shrager
Storage Analysis

Nyla Khan
Storage Materials & Systems

Vinod Siberry
Storage Validation

Thank you

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