3RD ANNUAL ENERGY STORAGE GRAND CHALLENGE SUMMIT

Pathways to Commercial Liftoff: Long Duration Energy Storage Opportunities

ENERGY STORAGE GRAND CHALLENGE
U.S. DEPARTMENT OF ENERGY

Vanessa Chan

Chief Commercialization Officer, Director, Office of Technology Transitions, U.S. Department of Energy

Office of Technology Transitions

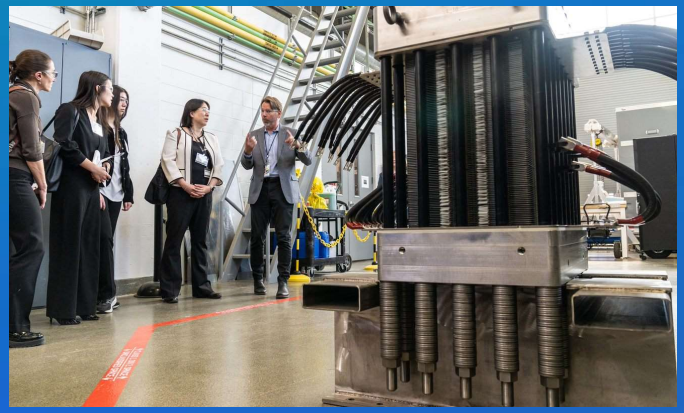
Pathways to Commercial Liftoff: Long Duration Energy Storage

DOE Energy Storage Grand Challenge Summit
July 27th, 2023

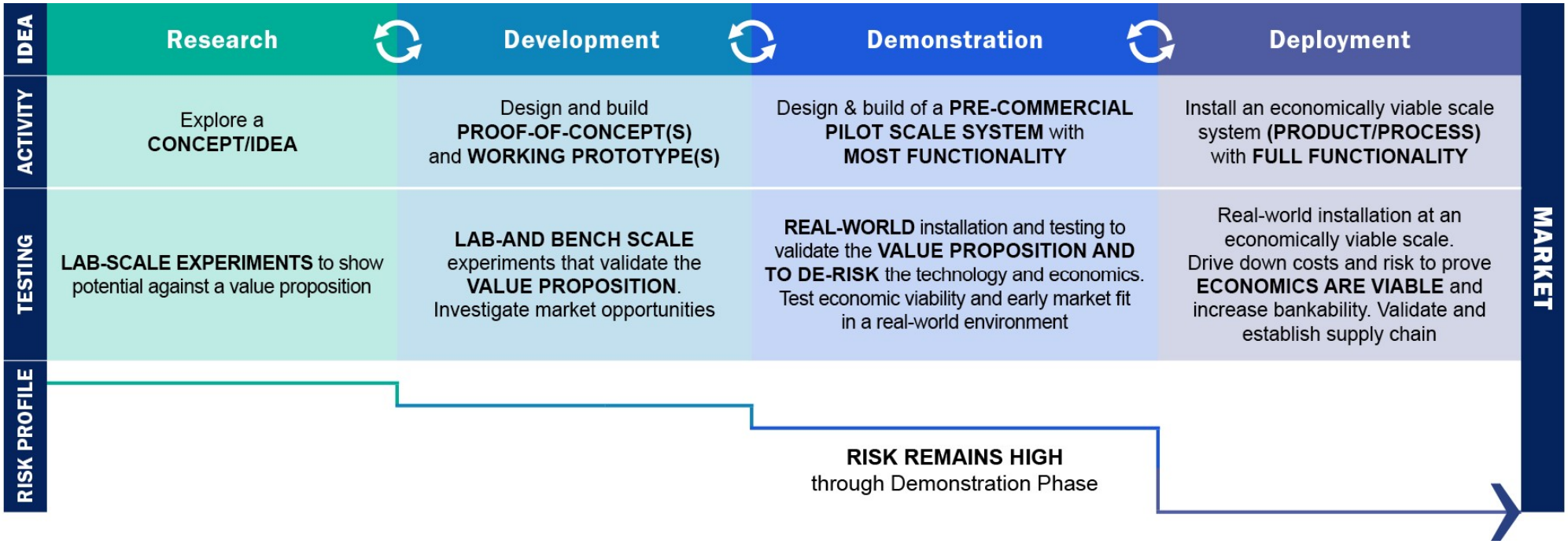
Vanessa Z Chan, Ph.D.
Chief Commercialization Officer &
Director of the Office of Technology Transitions

Our Mission: Steward Commercialization across DOE

- Expand the commercial impact of the research investments of DOE
- Drive private sector uptake of clean energy technologies

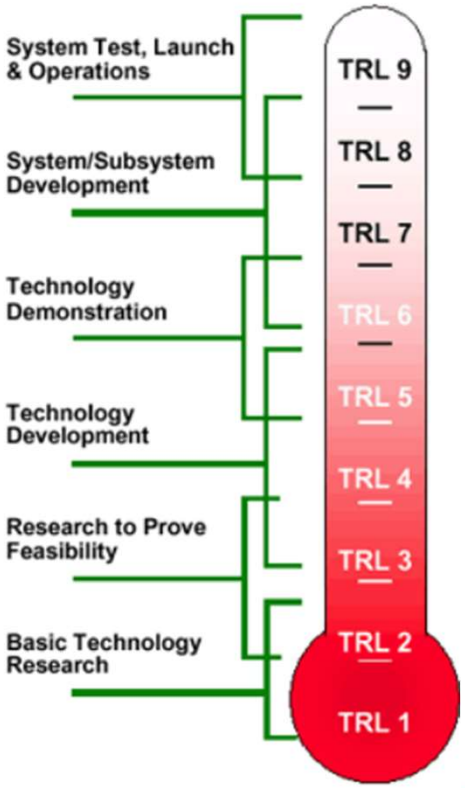


What is Commercialization?



Commercialization requires going beyond TRLs (Technology Readiness Levels)

TRLs developed by NASA



- **TRL does not capture essential tech commercialization risk factors**, such as:
  - product-market fit
  - demand pull
  - supply chain
  - workforce
  - siting & permitting, etc.
- OTT created a **new "Adoption Readiness Level (ARL)"** to **describe and assess key adoption risks beyond technology risks** that impede commercialization

Adoption Readiness Level – Risk Dimensions[1]

Value Proposition	**Delivered Cost** Cost competitiveness when produced at full-scale (incl. amortization of development and capex, and switching costs		**Functional Performance** Performance compared to incumbent solutions or ability to create new end-use materials		**Ease of Use / Complexity** Operational switching costs, ability of new user to adopt and operationalize the technology with limited training, requirements or special resources	
Market Acceptance	**Demand Maturity/ Market Openness** Demand certainty and access to sales & contracting and natural / structural barriers to entry (network effects, first-mover advantages, existing monopolies)		**Market Size** Overall size and certainty of market that can be served by the technology		**Downstream Value Chain** Projected path to get product from producer to customer along the value chain	
Resource Maturity	**Capital Flow** Availability of capital needed to get to production at scale ($ # investors, insurance, speed)	**Project Development** Processes and capabilities to successfully and repeatedly execute projects	**Infrastructure** Large-scale systems needed to facilitate deployment at scale (pipelines, transmission lines, roads)	**Manufacturing & Supply Chain** Entities or processes to get to end product (integrators, component manufacturers)	**Materials Sourcing** Availability of critical materials required (rare earth minerals)	**Workforce** Human capital and capabilities required to design, produce, install, maintain, and operate at scale
License to Operate	**Regulatory** Regulations, requirements/ standards that must be met to deploy at scale	**Policy Environment** Policy actions that can support or hinder adoption at scale	**Permitting & Sitting** Process to secure approvals to site and build equipment/ infrastructure	**Environmental & Safety** Hazardous side effects or adverse events caused by the solution	**Community Perception** Perception by communities of the solution and its risks / impact	

[1] Version as of March 2023. Now available at: https://energy.gov/technologytransitions/arl

Adoption Risks are assessed and then converted into an ARL score

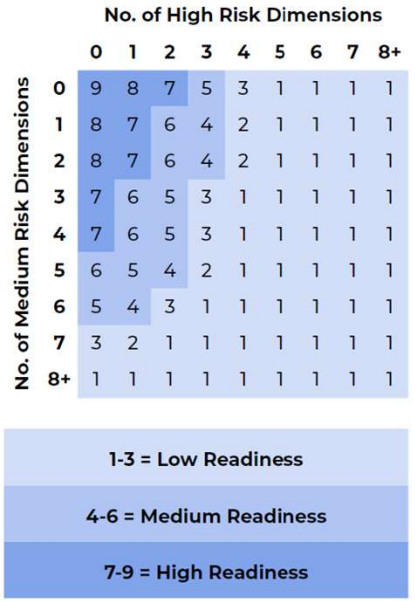
C. Resource Maturity

1. Capital Flow

Risks associated with the availability of capital needed to move the technology solution from its current state to production at scale, including total investment required, availability of willing investors, availability of associated financial & insurance products, and the speed of capital flow.

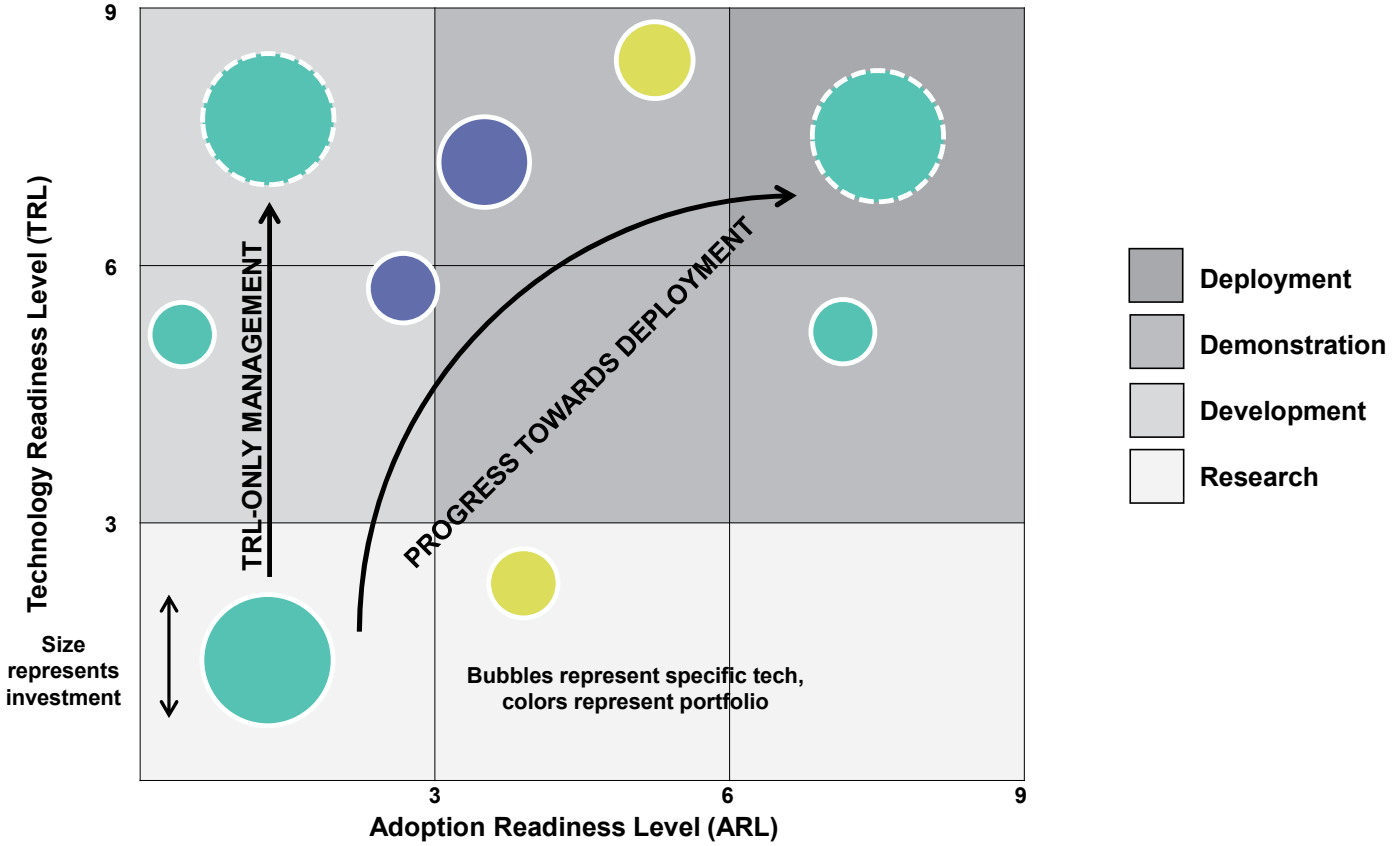
Low	Medium	High	N/A
Institutional investors confirm return profile in this technology solution is commercially competitive with their broader portfolio. Deal flow / risk profile is sufficient to develop regular equity & debt approval processes at relevant investment institutions & ratings agencies. Major risks are insurable.	There exist one or more "valleys of death" along the required capital stack to full deployment, but hurdles can be overcome, and capital flow & financial and insurance availability is beginning to increase.	Significant additional investment from sources of concessionary / patient / high risk pools of capital (e.g., public sector, philanthropic, and catalytic venture capital) required to achieve deployment.	
☐	☐	☐	☐

Assessment identifies, characterizes, and prioritizes key barriers to commercial liftoff for a given technology/sector by providing a common framework to capture industry, investor, and technical expert input



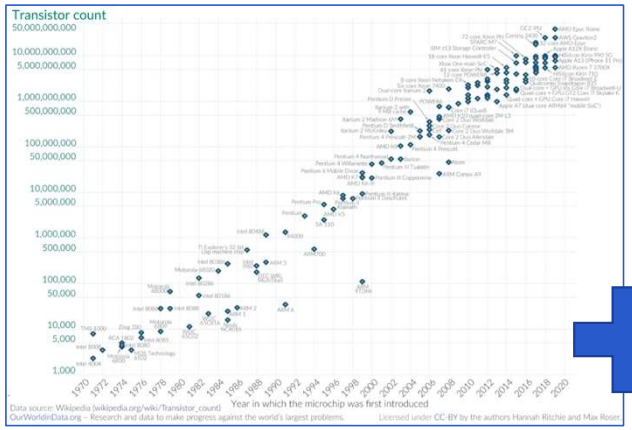
Numerical ARL score determined by aggregating a qualitative but fact-based assessment across distinct adoption risk dimensions

TRLs + ARLs can be used to track progress against RDD&D



Internet search: OTT & ARL for paper..

Pathways to Commercial Liftoff Origins



Commercialization roadmap → Catalyze a nation → Deploy clean energy

liftoff.energy.gov

Source: totalhistory.com & Ourworldindata.org

Pathways to Commercial Liftoff – Status

Currently released on liftoff.energy.gov:

Clean Hydrogen

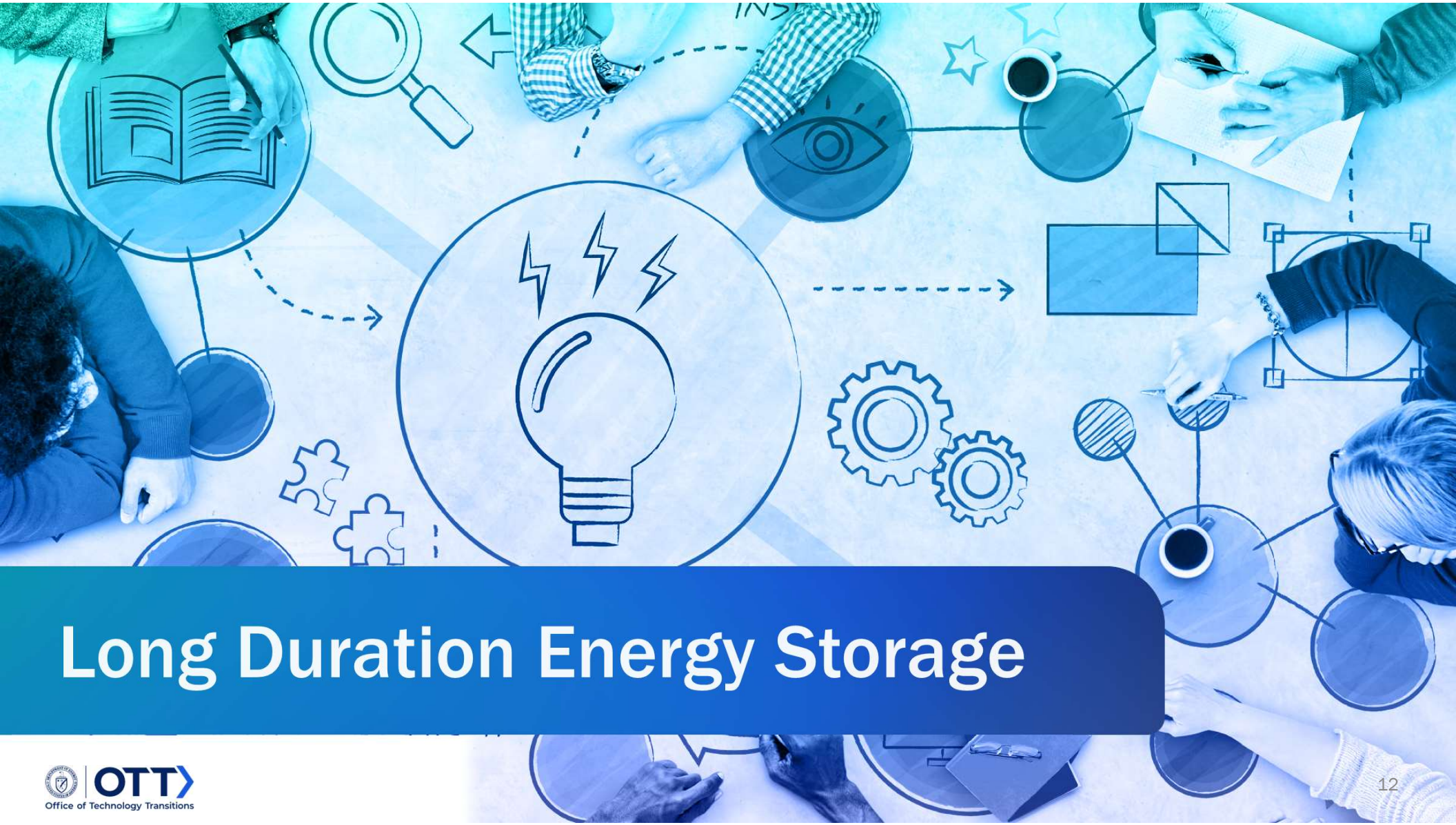
Long Duration Energy Storage (LDES)

Advanced Nuclear

Carbon Management

What's next:

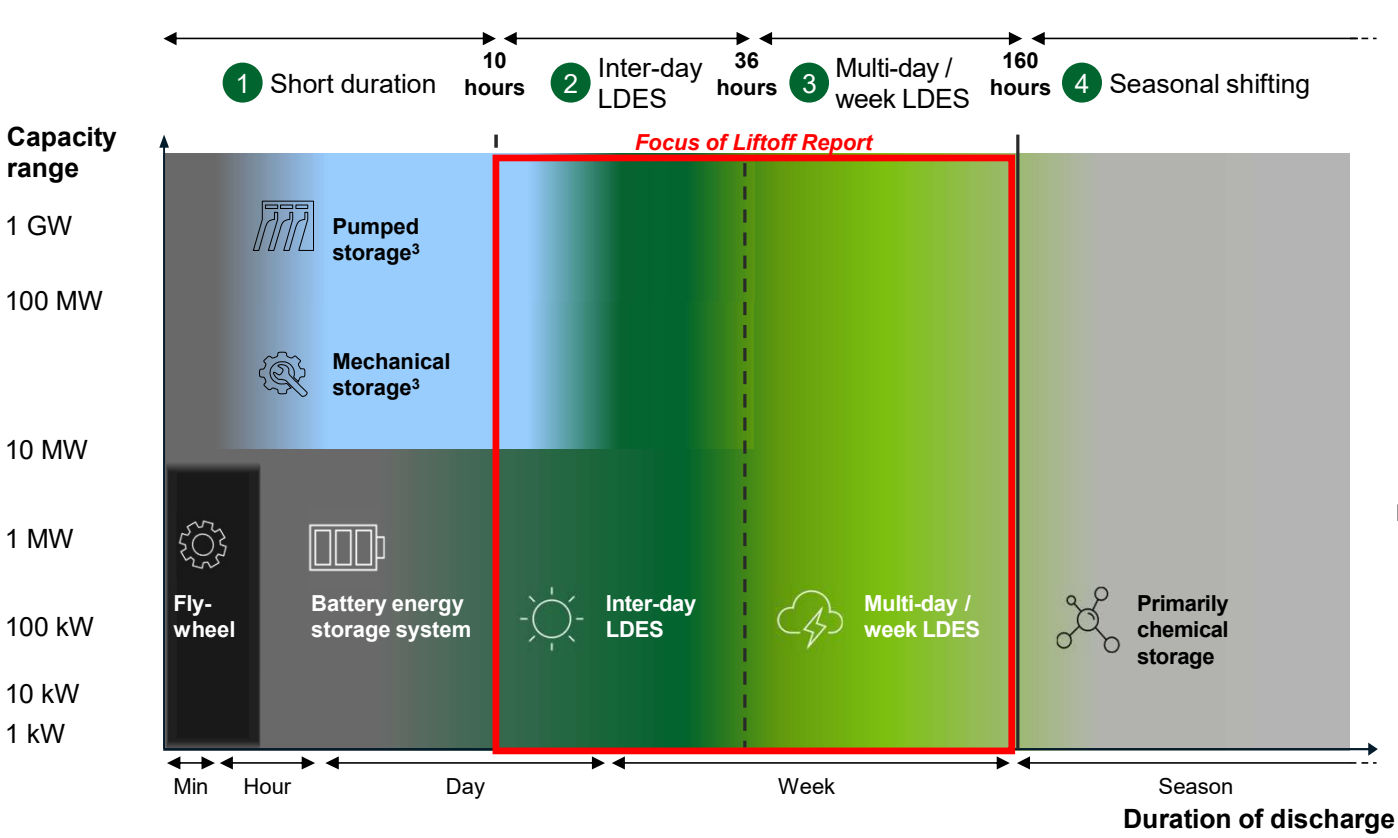
- Industrial decarbonization
  - cross-cutting overview
  - refining & chemicals
  - cement
- Grid
  - VPPs
  - other topics in discussion



Long Duration Energy Storage

Office of Technology Transitions

LDES Segmentation Based on Duration of Dispatch



Codifying the technology

0-10 hours — 1 **Short duration:** Durations up to 10 hours

10-36 hours[2] — 2 **Inter-day LDES:** Sometimes called "diurnal"

36-160 hours[1] — 3 **Multi-day / week LDES:** Commonly called "seasonal"

160+ hours — 4 **Seasonal shifting:** Generally included in "seasonal", but distinct in that this does function as a conventional, storable fuel

LDES Technologies

Less Desirable — More Desirable

△ Faces geologic constraints | Not enough public datapoints to obtain a reliable value | Inter-day | Can function as both | Multi-day / week

Duration	Energy storage form	Technology	Nominal duration, hrs	LCOS[5], $/MWh	Min. deployment size, MW	Average RTE, %	TRL
Inter-day	Mechanical	Traditional pumped hydro (PSH) △	0–15	70–170	200 – 400	70–80	9
		Novel pumped hydro (PSH)	0–15	70–170	10–100	50–80	5-8
		Gravity-based △	0–15	90–120	20–1,000	70–90	6-8
		Compressed air (CAES) △	6–24	80–150	200–500	40–70	7-9
		Liquid air (LAES)	10–25	175–300	50–100	40–70	6-9
		Liquid CO_2	4–24	50–60	10–500	70–80	4-6
Multi-day / week	Thermal	Sensible heat (e.g., molten salts, rock material, concrete)	10-200[2]	300	10–500	55–90	6-9
		Latent heat (e.g., aluminum alloy)	25–100	300	10–100	20–50	3-5
		Thermochemical heat (e.g., zeolites, silica gel)	XX	XX	XX	XX	XX
	Electrochemical	Aqueous electrolyte flow batteries	25–100	100-140	10–100	50–80	4-9
		Metal anode batteries	50–200	100	10–100	40–70	4-9
		Hybrid flow battery, with liquid electrolyte and metal anode (some are Inter-day)	8–50[2]	XX	>100	55–75	4-9

Source: Adapted from LDES Council Net-Zero Power Report 2021, Wood Mackenzie Long Duration Energy Storage Report 2022, Company websites, Academic research

LDES Value Proposition

Enabling high renewable development and enhancing resilience

Reduces the cost and risk associated with high renewable pathways:

- Balances intermittent renewables
- Reduces costs and risks around grid expansion

Enhances local resiliency to extreme weather events.

Reducing the need for new natural gas capacity

Available and cost-effective LDES reduces need for 200 GW+ of new natural gas capacity

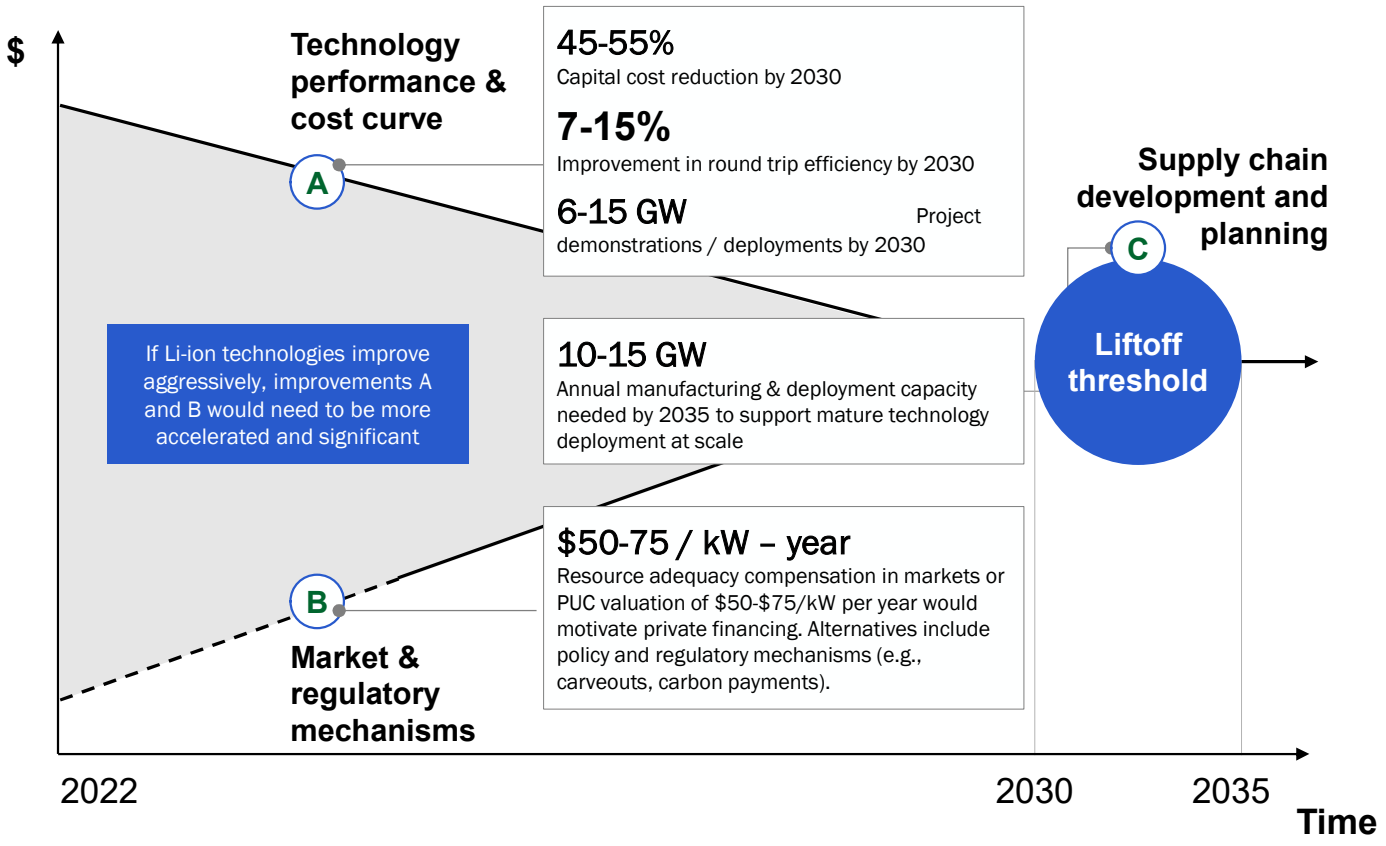
Pathways that leverage LDES projected to deliver ~$10-20B in annual savings by 2050

Diversifying domestic energy storage supply chain

Diversified set of storage technologies reduces risk of net-zero goals contingent on lithium-ion manufacturing buildout

Acknowledges the durable role of LDES even in scenarios with aggressive Li-ion cost improvements.

LDES Liftoff Conditions



- Liftoff occurs when LDES technologies are deployed (without project-specific intervention) at scale across the US power grid
- Within this decade, it is most important that LDES technologies are demonstrated in-field and begin to receive adequate market compensation for the future value they bring to a net-zero grid
- By 2030, an industrial scale manufacturing and deployment base must be forming

LDES Liftoff Priority Actions – Government

- **Transparency on technology cost and performance** to help investors, regulators and policymakers quickly adapt their portfolios.

- **Modeling tools and valuation frameworks** for regulators, ISOs, and commercial customers to evaluate their LDES needs.

- **Financial support,** including grants and loans, for lab-based research to demonstration projects.

LDES Liftoff Priority Actions

ISOs and RTOs

- **Evaluation of grid needs** to maintain flexibility and reliability with higher amounts of variable renewables.
- **Consideration of new mechanisms** (e.g., new capacity market design—potentially duration dependent, longer time horizon resource adequacy studies, interconnection queue reform, and classification of storage assets both as generation and load in transmission planning).

State Policy Makers

- **State Renewable Portfolio Standards** (RPS) could drive additional LDES deployment.
- **Tax breaks or other incentives** to attract early deployments or manufacturing hubs.

Energy Customers

- **Demand for higher-percentage load-following power purchase agreements (PPAs)** (e.g., 24-7 time matching).
- **Consideration of LDES deployments** on their own in applicable on-site, behind-the-meter use cases.

LDES Liftoff Priority Actions

State Public Utility Commissions

- **Updated integrated resource planning and resource adequacy methodologies** (e.g., lengthen duration of IRP assessments).
- **Updated rate base guidance or mandates** on LDES investments.
- **Approval of early investments** within rate-base (e.g., grid-scale pilots) to accelerate market transformation and reduce longer-term customer costs.

Developers and Investors

- **Publicity of successful LDES projects** including use of LDES revenue mechanisms (e.g., capacity payments), new business models and financial products.
- **Data transparency around specific projects** (e.g., uptime rate, cashflows) to allow capital providers with differing risk profiles to assess technical, project, and market risks.
- **Pilots of LDES add-ons** at larger sites to help developers better understand LDES's system integration and operations implications.

Pathways to Commercial Liftoff – Impacts

Secretary Jennifer Granholm:
"This effort will "help drive engagement between government and industry to unlock exciting new opportunities and ensure America is the global leader in the next generation of clean energy technologies."

Robinson Meyer:
"The most detailed guide yet to how the Biden administration plans to conduct industrial policy for the most advanced — and the most fledgling — energy technologies in its arsenal."

From Politico's EnergyWire:
"Developed in part for private investors, the three reports lay out the chief barriers for the three technologies along with possible solutions and rough timelines for their emergence in the 2020s and beyond."

We will continue a steady drumbeat of communications highlighting key insights from reports already released, announcing the release of new reports, and through industry events.

Office of Technology Transitions

Pathways to Commercial Liftoff

liftoff.energy.gov
liftoff@hq.doe.gov