



Office of Technology Transitions

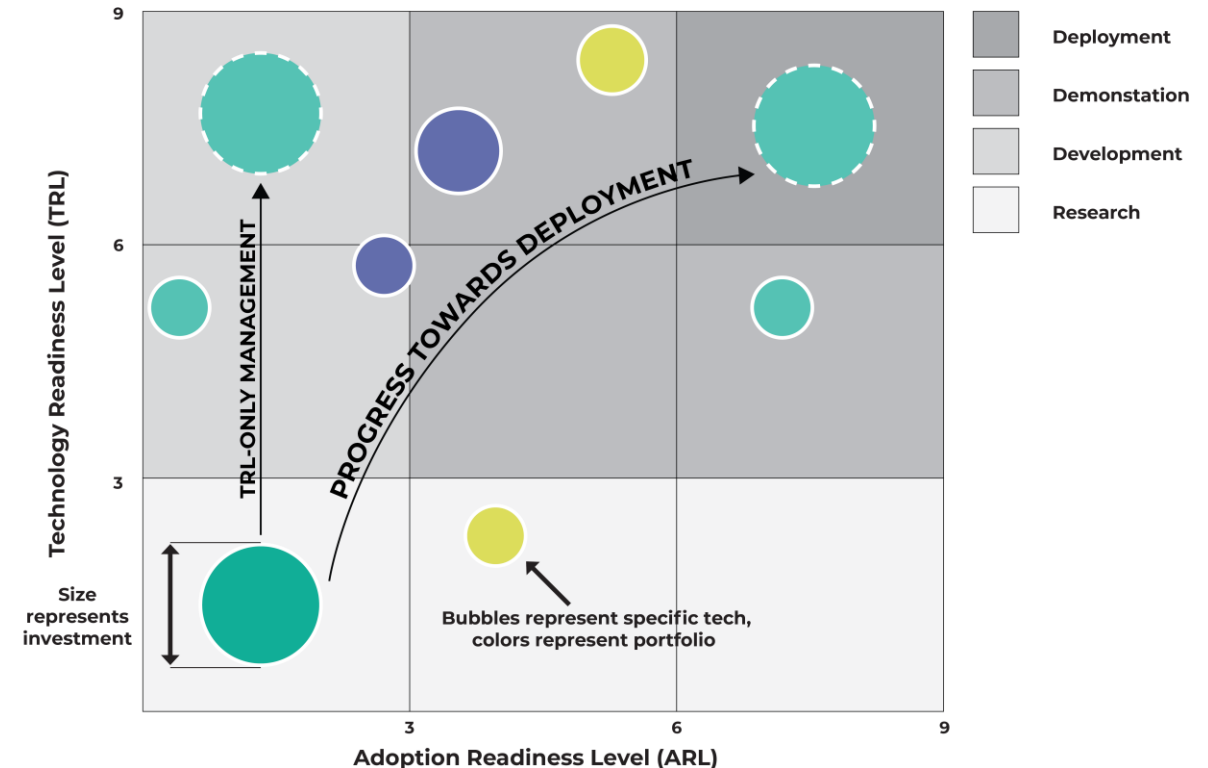
Liftoff Lab Addendum: Adoption Readiness Level of Redox Flow Batteries

ESGC Summit
Friday, August 9th 2024



Throughout RDD&D, risks to commercialization remain high. TRLs aren't enough to drive Deployment - "ARLs" are also required

- Technology Readiness Level does not capture essential tech commercialization risk factors.
- OTT has created "Adoption Readiness Level (ARL) Framework" to describe and assess key adoption risks beyond technology risks.
- We have refined this framework through many industry discussions, as well as through pilot projects



Adoption Readiness Level – Risk Dimensions

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

ARL Pilot: Assessing Commercialization of LDES

Goal: Accelerate the commercialization of RFB technologies through integration and use of the Adoption Readiness Level framework into national lab thinking and activities.



Why?

- Build in-house ARL expertise at PNNL, with a focus on developing a replicable approach to market research.
- Understand the value of ARLs to assessing market risks and identifying the solution space.



What?

- Conduct an ARL assessment of redox flow batteries
- Deliver findings in a Lab Addendum to the Pathways to Commercial Liftoff: LDES report (~Sept. 2024)



How?

- Capitalize on PNNL data collection, as well as publicly available data
- Conduct interviews with relevant stakeholders to confirm findings.



Who?



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Allan Tuan, PhD., MBA
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Methodology: Applying ARLs to LDES

1. Define key technologies & scope



Technology scope, value chain scope, timeline for evaluation



Source: [PNNL](#)

Methodology: Applying ARLs to LDES

1. Define key technologies & scope



Technology scope, value chain scope, timeline for evaluation

2. CARAT assessment



Publicly available reports & data
Latest performance/cost data from PNNL

Commercial Adoption Readiness Assessment Tool

Adoption Risk Dimensions

1. Value Proposition
 - a. Delivered Costs
 - b. Functional Performance
 - c. Ease of Use / Complexity
2. Market Acceptance
 - a. Demand Maturity / Market Openness
 - b. Market Size
 - c. Downstream Value Chain
3. Resource Maturity
 - a. Capital Flow
 - b. Project Development, Integration, & Management
 - c. Infrastructure
 - d. Manufacturing & Supply Chain
 - e. Materials Sourcing
 - f. Workforce
4. License to Operate
 - a. Regulatory Environment
 - b. Policy Environment
 - c. Permitting & Siting
 - d. Environmental & Safety
 - e. Community Perception

Example Adoption Risk Assessment Rubric (4c – Permitting & Siting)

Low
Permitting and siting process is easy, well-understood, timely and repeatable

Medium
Permitting and siting can be time-consuming, but jurisdiction is clear and complexity is low. Speed can be achieved with repetition.

High
Permitting and siting is highly complex and time-consuming, with multiple overlapping jurisdictions.

Adoption Risk Rating	Comments / Rationale	Integration Strategies	Challenges
Low	Technology solution is either: a. currently more cost effective than the incumbent or competing technology; or b. close to cost parity and / or clear cost curve to achieve parity with existing system; and / or there are some fundamental cost components that are at risk of market savings.	Low	Technology solution is either: a. currently more cost effective than the incumbent or competing technology; or b. close to cost parity and / or clear cost curve to achieve parity with existing system; and / or there are some fundamental cost components that are at risk of market savings.
Medium	Technology solution is more than 1 year away from achieving cost parity with incumbent or competing technology but is on a clear pathway to cost competitiveness without substantial additional R&D expenses.	Medium	Technology solution is more than 1 year away from achieving cost parity with incumbent or competing technology but is on a clear pathway to cost competitiveness without substantial additional R&D expenses.
High	Technology solution is more than 2 years away from achieving cost parity with incumbent or competing technology and there is no clear pathway to cost competitiveness without substantial additional R&D expenses.	High	Technology solution is more than 2 years away from achieving cost parity with incumbent or competing technology and there is no clear pathway to cost competitiveness without substantial additional R&D expenses.
Very High	Technology solution is more than 3 years away from achieving cost parity with incumbent or competing technology and there is no clear pathway to cost competitiveness without substantial additional R&D expenses.	Very High	Technology solution is more than 3 years away from achieving cost parity with incumbent or competing technology and there is no clear pathway to cost competitiveness without substantial additional R&D expenses.

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Technology scope, value chain scope, timeline for evaluation



7 tech developers



3 customers
(utilities, industry)

2. CARAT assessment



Publicly available reports & data
Latest performance/cost data from PNNL



2 ISOs

3. Stakeholder engagement



Interviews with tech developers, utilities, potential customers, investors, & subject matter experts



2 investors



4 SMEs
(gov't, thinktanks, consultants)

18 interviews so far

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4. Share results



Briefings, publicly available report, shareable ARL assessment templates



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Preliminary findings suggest RFB face high risks in cost competitiveness, market acceptance, and supply chains to scale.

ARL risk levels (VRFB, Others)

Delivered cost	Red	Yellow
Functional performance	Green	Yellow
Ease of use / complexity	Green	Green
Market openness	Yellow	Yellow
Market Size	Red	Red
Downstream Value Chain	Green	Green
Capital Flow	Yellow	Yellow
Project Dev., Integr., & Mgmt	Yellow	Yellow
Infrastructure	Green	Green
Manuf. & Supply Chain	Red	Red
Materials Sourcing	Yellow	Green
Workforce	Yellow	Yellow
Regulatory Environment	Yellow	Yellow
Policy Environment	Yellow	Yellow
Permitting & Siting	Yellow	Yellow
Environment & Safety	Green	Green
Community Perception	Green	Green

Key challenges

- Steep cost declines for LFP
- Lack of market or regulatory incentives to support inter-day durations
- Limited domestic manufacturing and workforce capacity
- Geopolitical considerations around supply chains for components and vanadium
- Slow down in capital flow

Solutions we've heard work today

- Targeting behind the meter customers where economics already pencil
- Developing strategic partnerships in jurisdictions with decarbonization objectives or locations with fire safety concerns

Suggestions we've heard for tomorrow

- Market redesign (capacity accreditation, changes to modeling methods)
- Regulatory valuation of RFBS (valuing tech's safety)
- Standardize permitting and siting
- Build out of workforce and domestic manufacturing (building resource maturity)

Next steps

- Additional interviews planned through August
- Consolidation of findings published in September, 2024
- ARL assessments of other PNNL technologies

Questions?



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