2ND ANNUAL ENERGY STORAGE GRAND CHALLENGE SUMMIT

Storage Innovations 2030

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U.S. DEPARTMENT OF ENERGY

Storage Innovations 2030

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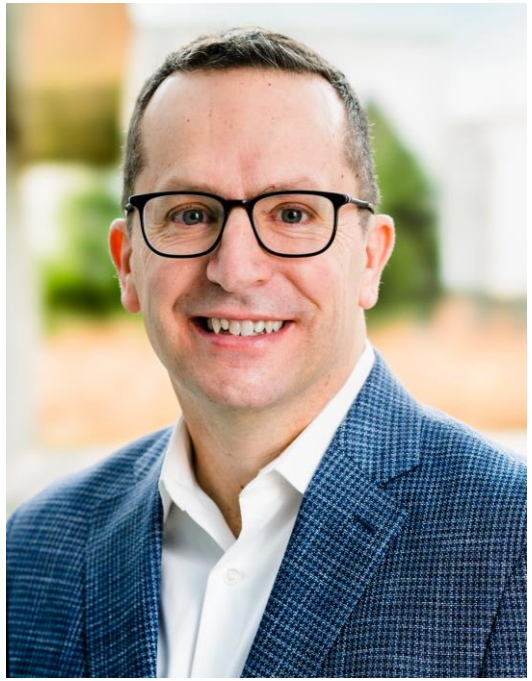

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Ben Shrager, DOE OE

Patrick Balducci, ANL

Thomas Mosier, INL

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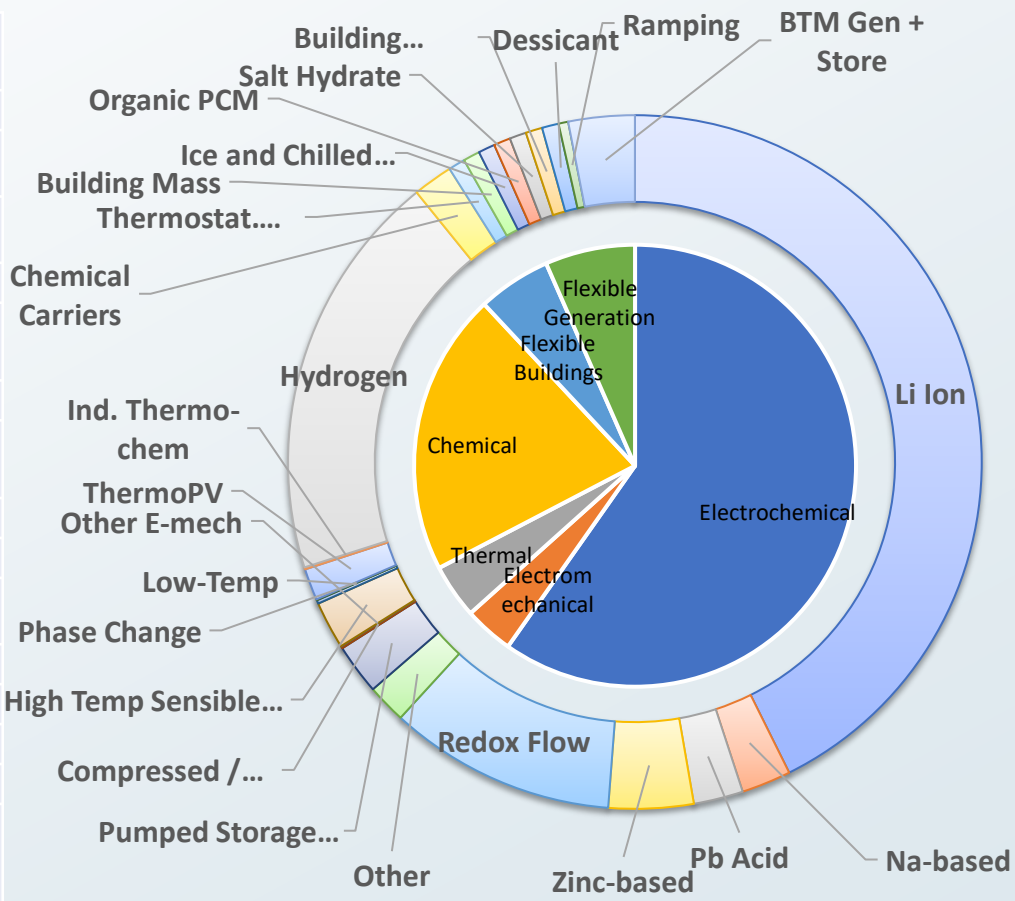
DOE has supported 30+ storage technologies

orage	ochemical	Li-Ion & Li-Metal
		Na-Ion
		Na-Metal
		Lead Acid
		Zinc
& Chemical	Thermal	High-Temperature Sensible Heat
		Phase Change
		Low-Temperature Storage
Flexible Ge		Thermochemical
		Desiccant
	Flexible Generation	Ramping
		Behind-the-Meter Generation Plus Storage
Crosscutting	Power Electronics	Power Electronic Systems

Needed: A specific, actionable roadmap to develop, scale, and deploy the most promising technologies that will meet the 2030 Long Duration Storage Shot goal.



Statutory Directive for Strategic Planning

Needed: A specific, actionable roadmap to develop, scale, and deploy the most promising technologies that will meet the 2030 Long Duration Storage Shot goal.

Department of Energy Research and Innovation Act, 2018:

- *"develop a planning, evaluation, and technical assessment framework for setting objective long-term strategic goals and evaluating progress"*
- *"identify programs that may be more effectively left to the States, industry, nongovernmental organizations, institutions of higher education, or other stakeholders."*

Consolidated Appropriations Act, 2021:

- *"Energy storage strategic plan" … "develop a 10-year strategic plan for the program"*
- *"include metrics that can be used to evaluate storage technologies"*

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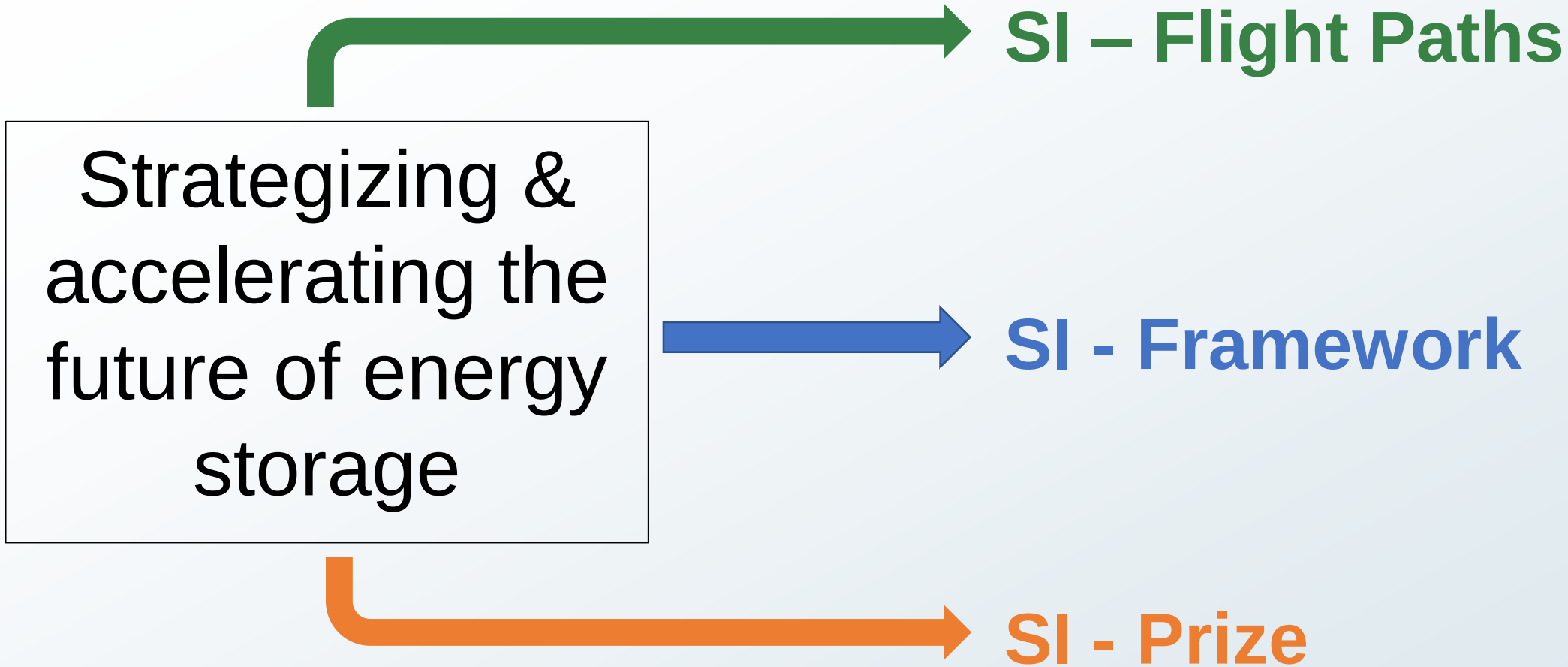
Strategizing & accelerating the future of energy storage

Developing industry consortia and enhancing collaboration

Quantifying the benefits of RD&D activities for mature technologies

Enabling emerging technologies

Storage Innovations 2030



Storage Innovations 2030

Strategizing & accelerating the future of energy storage

SI – Flight Paths

SI - Framework

SI - Prize

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Energy Storage 2030 – Framework and Preliminary Results for Lithium-ion and Lead Batteries

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DOE Storage Summit
September 28, 2022

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[4]U.S. Department of Energy

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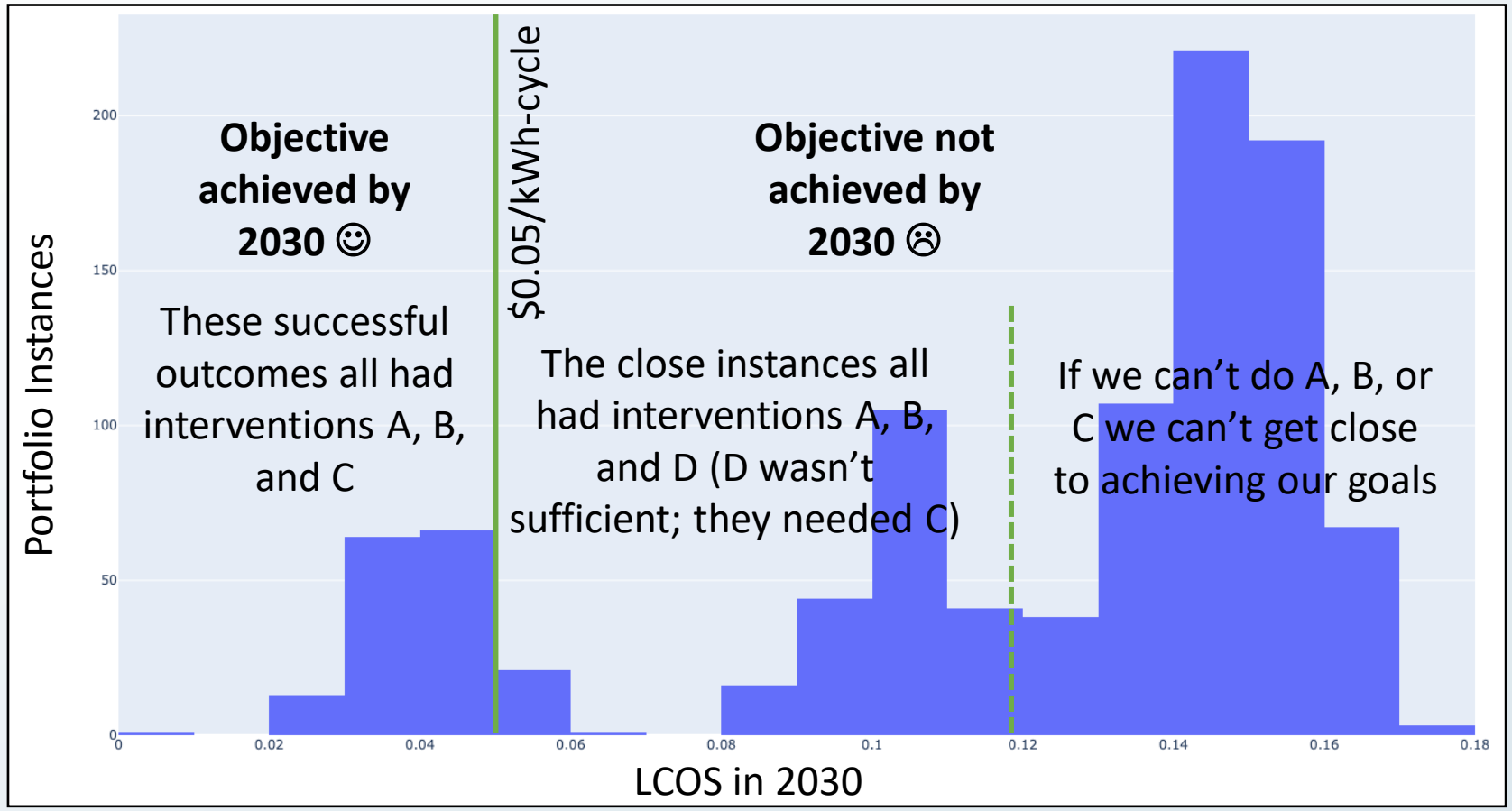
Outline

- Framework outline
- Lead Acid Results
- Li-ion Results
- Synthesis

Our Objective is to Identify Portfolios of Innovations That are Efficient at Achieving LCOS Reductions

"Portfolios" are sets of interventions by DOE (e.g., specific R&D activities, demonstrations, loans for scale-up)



We are Implementing a Framework to Develop These Intervention Portfolios

Identify individual innovation opportunities

Step 1: Assess R&D trajectory status quo
Step 2: Assess gaps with respect to improving technology cost/performance
Step 3: Define DOE interventions that could be relevant to energy storage gaps
Step 4: Assess potential impacts of DOE interventions

Assess portfolios of interventions

Step 5: Implement Monte Carlo model
Step 6: Evaluate portfolios of interventions

Analyze modeled outcomes

Step 7: Conduct suitability evaluations
Step 8: Report on metrics

Innovations Distilled from Interviews Used for Portfolio Analysis

Lead-acid

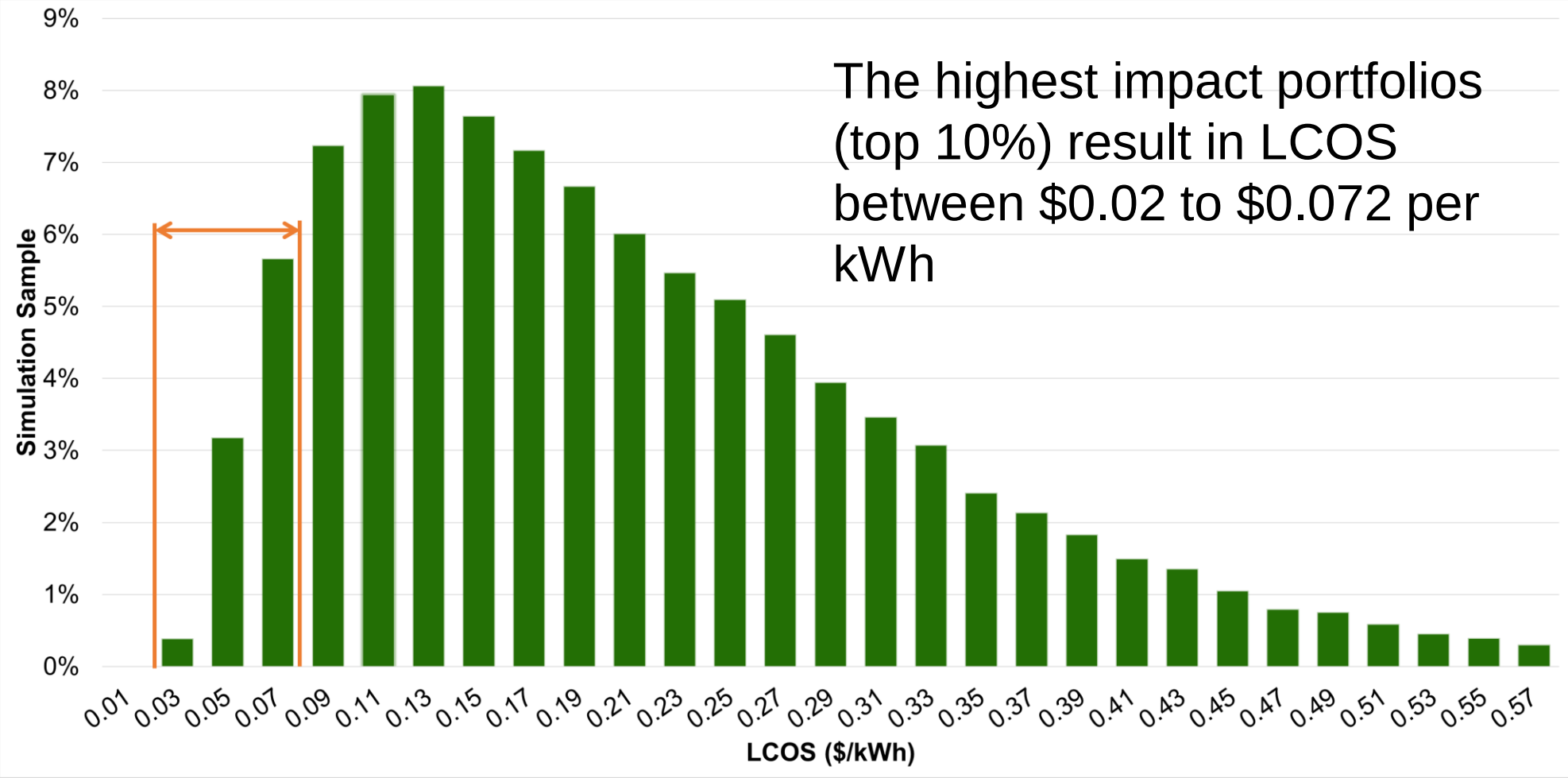
Innovation Category	Innovation
Raw materials sourcing	Mining and metallurgy improvements
	Alloying in lead sources
Supply chain	Supply chain analytics
Advance material development	Novel active material
	Improving paste additives - carbon
	Improving paste additives - expanders or other
	Novel electrolytes
Technology components	Re-design of standard current collectors
	AGM-type separator
	Minimizing water loss from the battery
Manufacturing	Advanced manufacturing for lead-acid batteries
Deployment	Scaling and managing the energy storage system
	Demonstration projects
End of life	Enhancing domestic recycling

Li-ion

Innovation Category	Innovation
Raw materials sourcing	Cathode material mining
	Domestic sourcing of Lithium
Supply chain	Anode material production
	Mining permitting
	Co-locating manufacturing and mines
Advanced material development	Solid-state electrolyte improvements
	Anode innovations
	Electrode and electrolyte innovations
	Atomic-level cell dynamics studies
	Fundamental material research
Technology components	Sensor and monitoring technologies
Manufacturing	Foundational manufacturing R&D
	Manufacturing process scale-up
	Data-driven manufacturing improvements
	Manufacturing workforce development
Deployment	Controls to improve cycle life
	Deployment policies
	Demonstration
	Deployment efficiency
End of life	Recycling defective cells
	Recycling degraded cells
	Impurities reduction technique
	Rapid battery health assessment

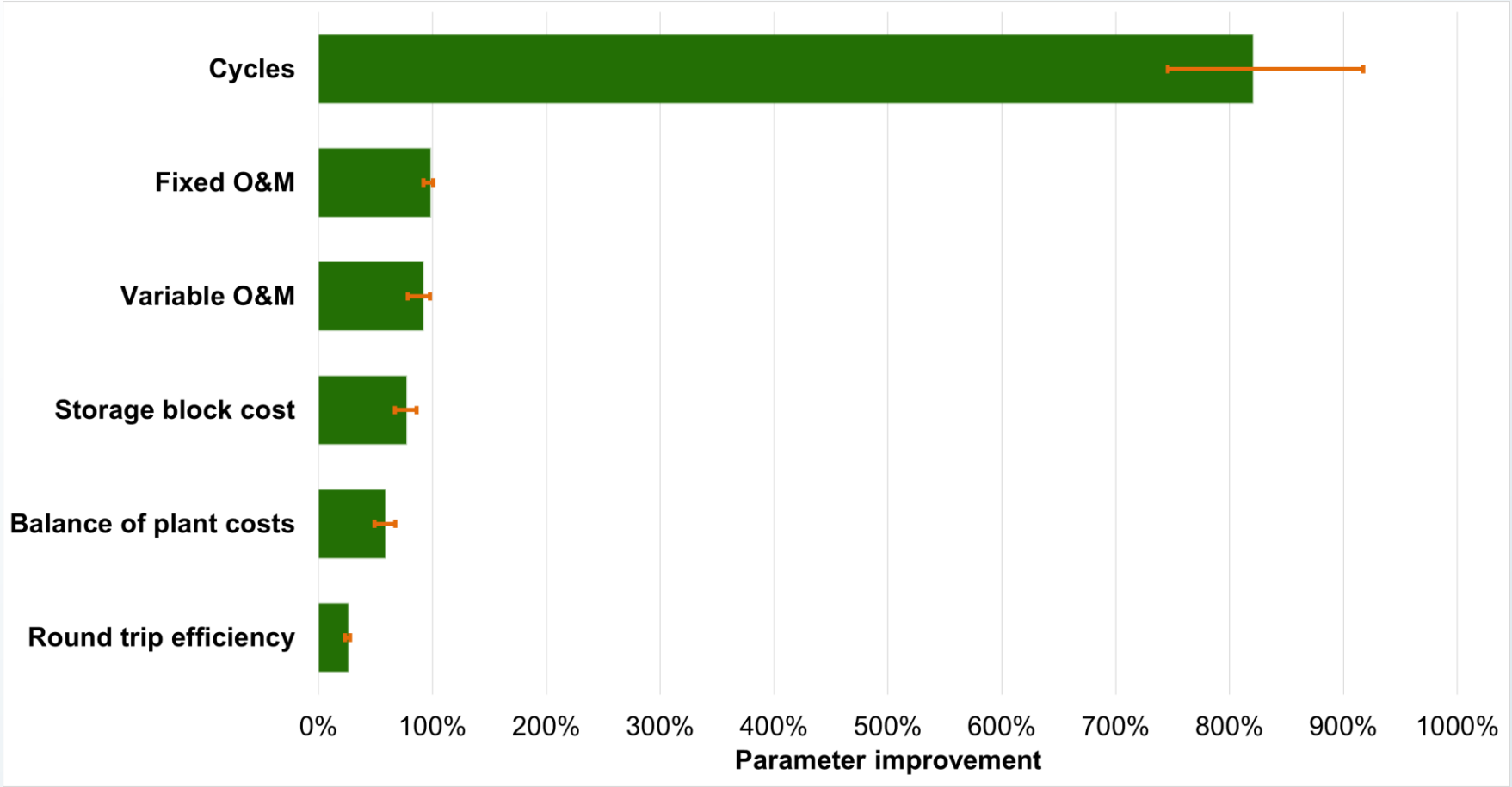
Lead-acid Battery Results

Some Innovation Portfolios Substantially Reduce LCOS

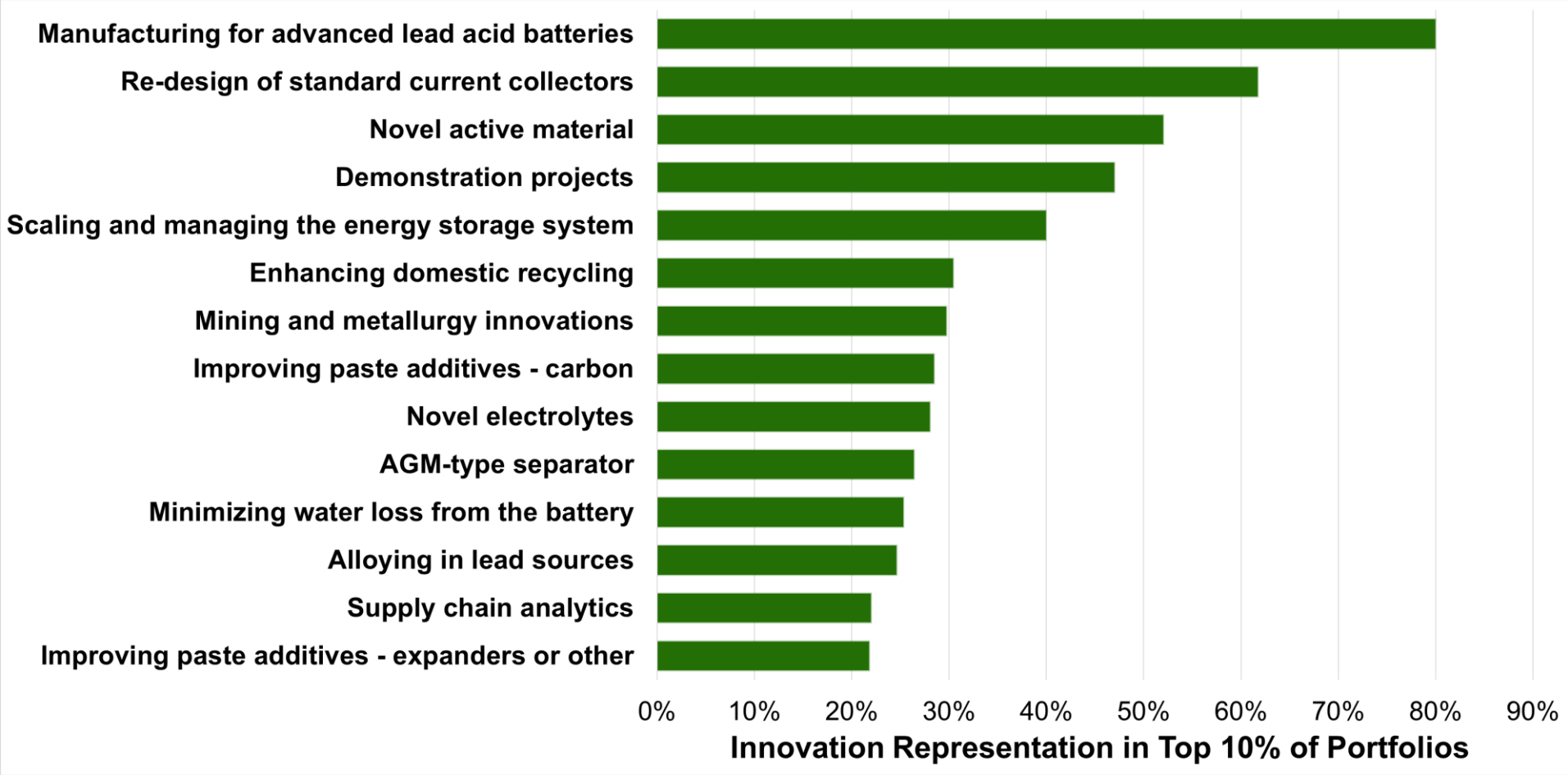


The highest impact portfolios (top 10%) result in LCOS between $0.02 to $0.072 per kWh

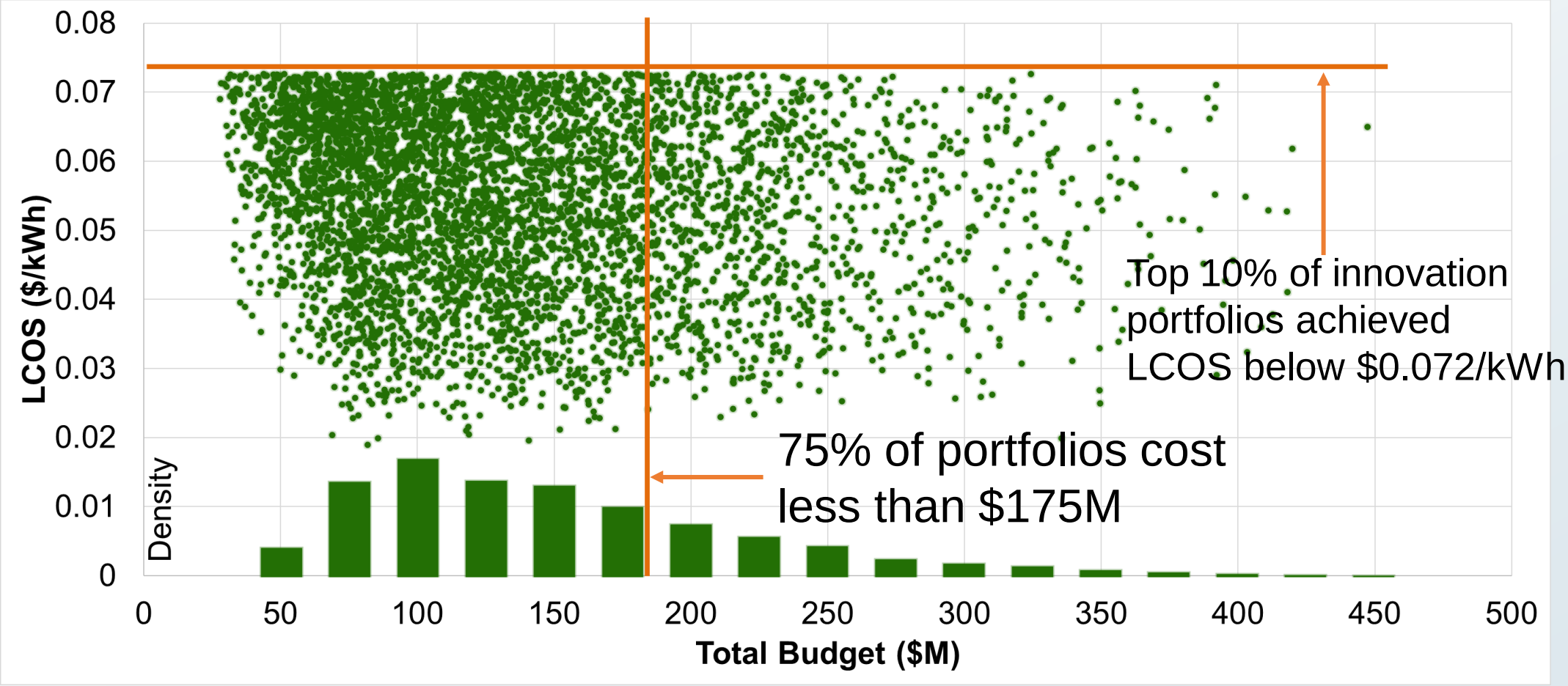
Achieving This Dramatic LCOS Reduction Would Require a Dramatic Improvement to Cycles



Manufacturing Innovations Required for Deep Cost Reductions but Other Innovations Yield High ROI

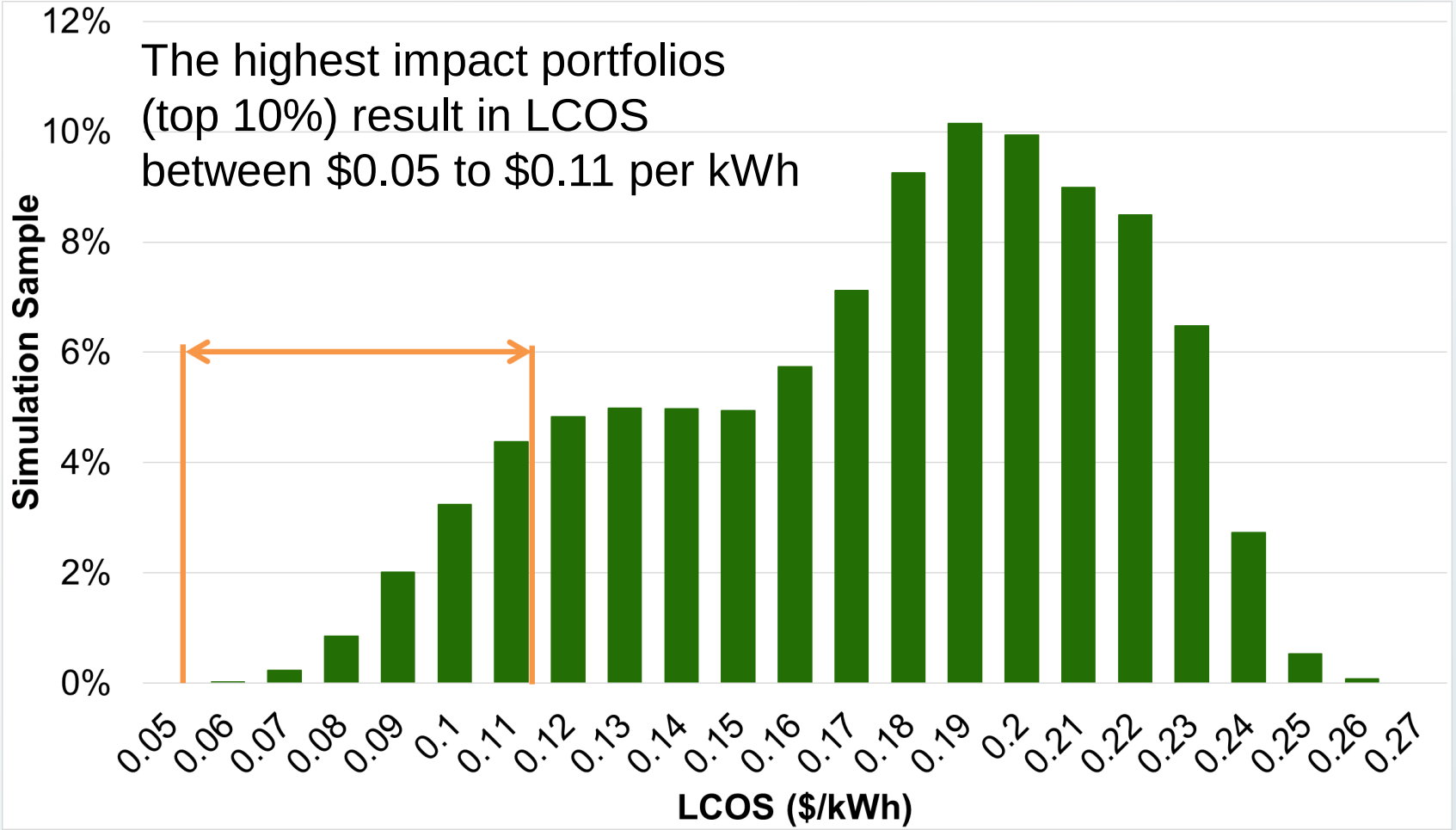


Significant Number of High Impact Portfolios Cost Less than $150M

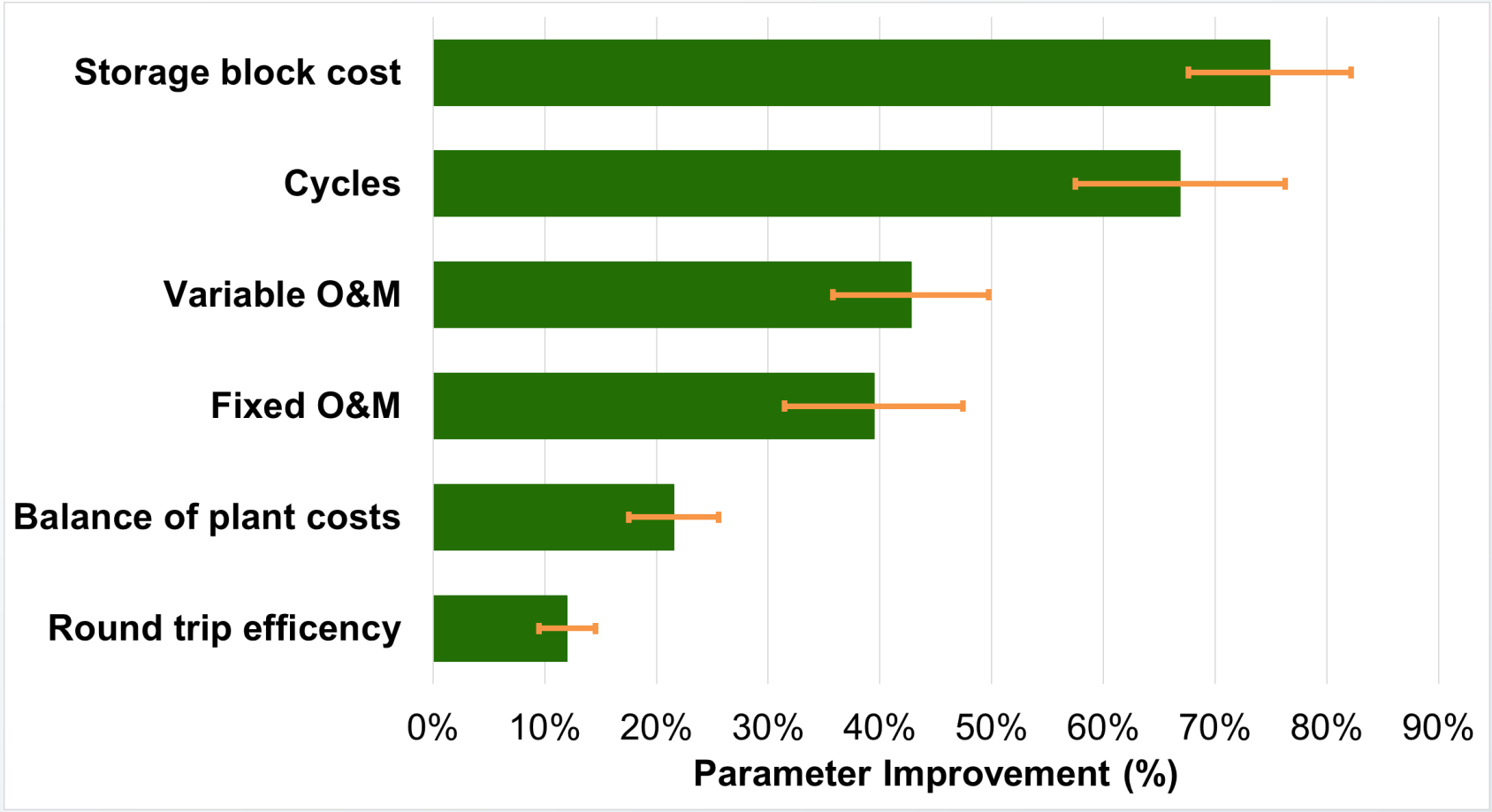


Lithium-ion Battery Results

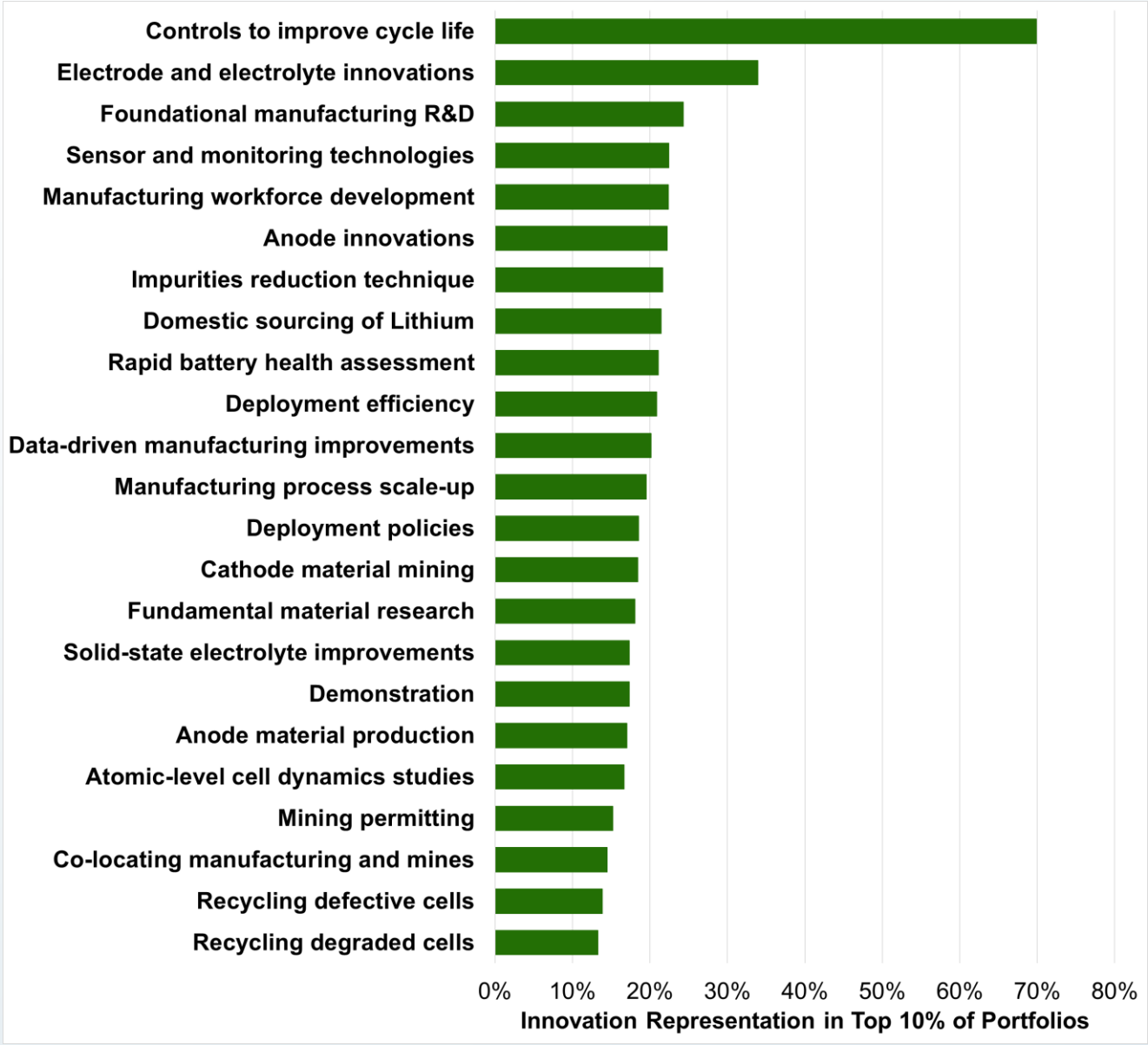
Deepest LCOS Reductions Require Significant Intentionality



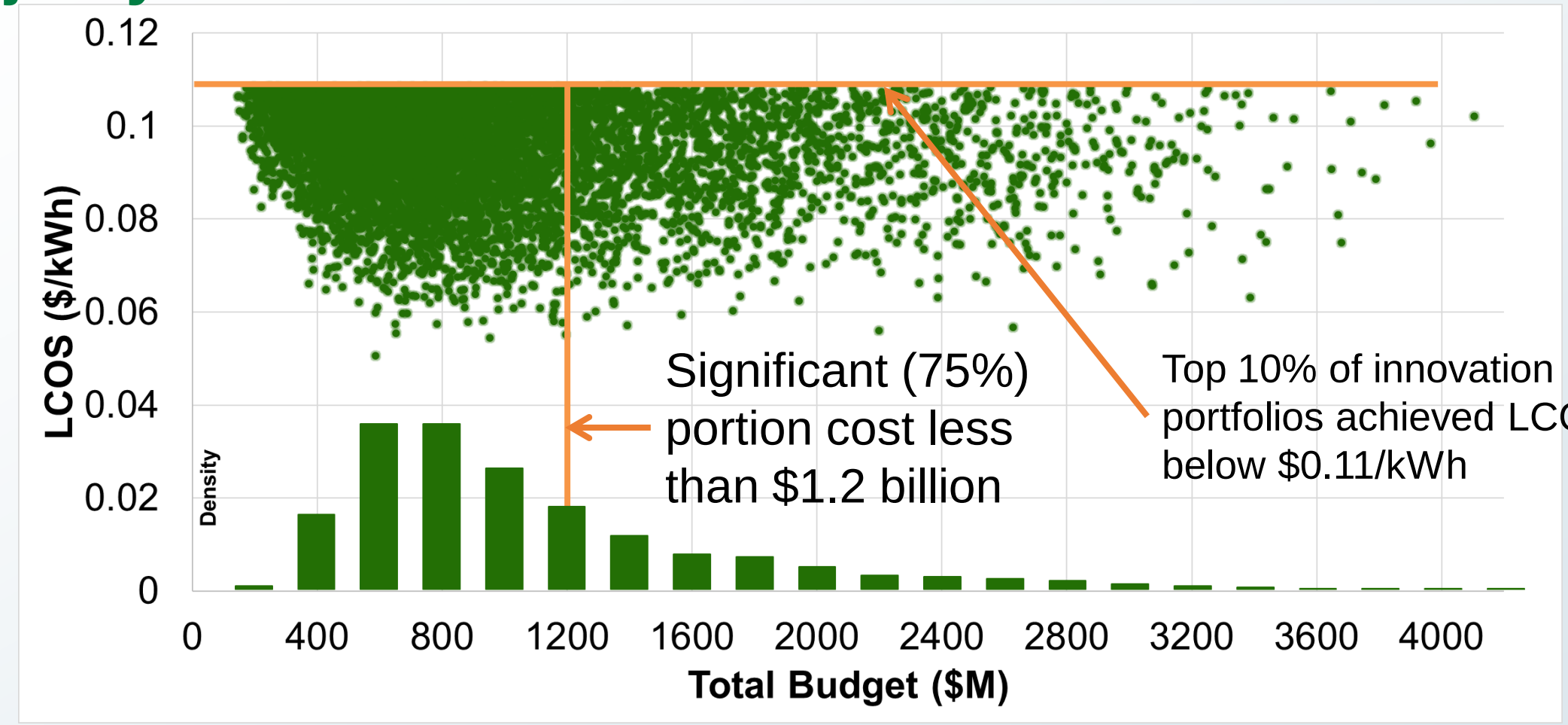
Storage Block and Cycles Key to Achieving Deepest LCOS Reductions



Deployment and Advanced Materials Are Key to Highest Impact Portfolios

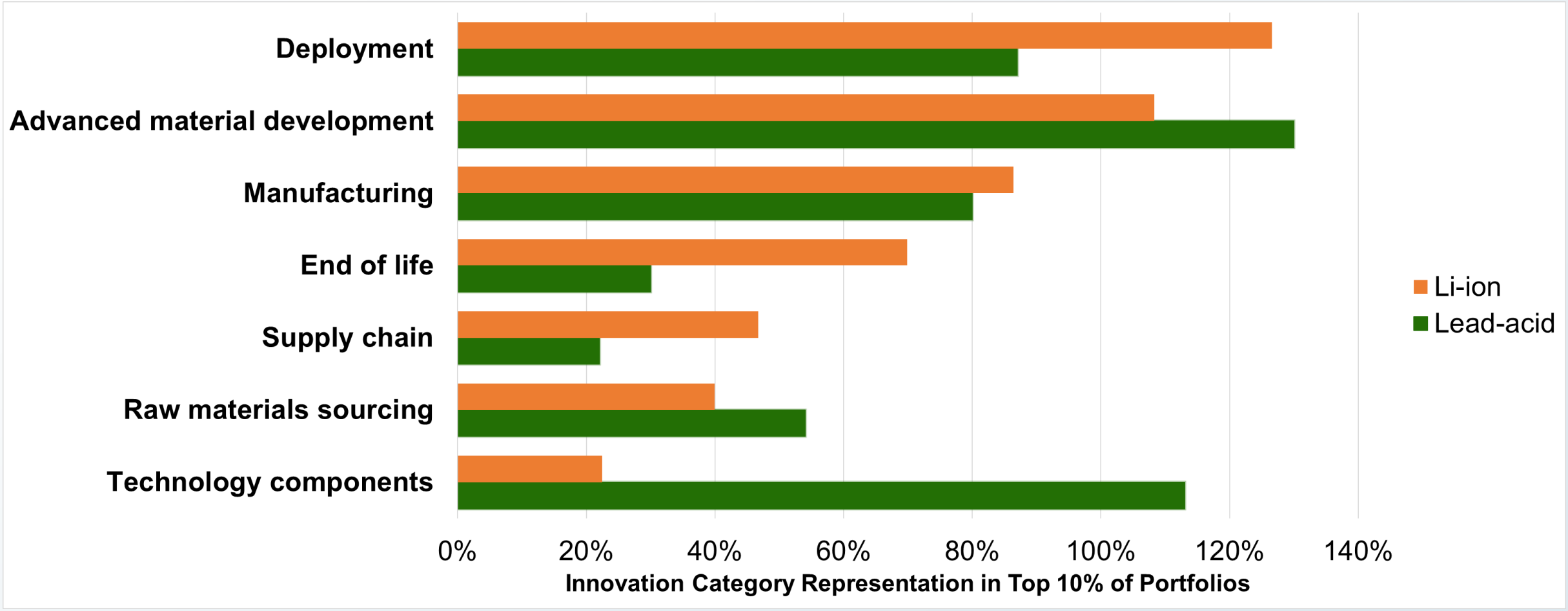


Li-ion Innovation Portfolios Are Expensive, but Majority Cost Less Than $1B



Synthesis

Lead-acid Innovation Driven by Materials and Components; Li-ion by Deployment and Materials



We're Applying Framework to Broader Set of Technologies as Part of a Report to Congress

- Report will demonstrate composition and impact of portfolio investment approach to reducing energy storage LCOS.
- Will look across Energy Storage Grand Challenge use cases.
- We would appreciate speaking to everyone in the audience with subject matter expertise on these technologies!

Technologies

- Lead-acid
- Li-ion
- Supercapacitors
- Flow batteries
- Pumped storage hydropower
- Compressed air energy storage
- Flywheels
- Sodium-ion
- Thermal
- Hydrogen

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American-Made Challenges

Energy Storage Innovations Prize

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American-Made Challenges

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- The American-Made program is designed to incentivize innovation through prizes, training, teaming, and mentoring.
- Fast-track product development timelines from years to months, speed innovator progress, and create partnerships that connect entrepreneurs to the private sector and national laboratories.
- This program is funded by the U.S. Department of Energy and administered by the National Renewable Energy Laboratory.

Energy Storage Innovations Prize

- Next month: **seeking next-generation technology innovations for grid-scale, long duration energy storage.**
- Innovators with emerging technology innovations can compete for a portion of the **$300,000 cash prize**.
- The Energy Storage Innovations Prize supports Department of Energy goals to foster development of new technologies that meet grid reliability, equity, and decarbonization objectives.

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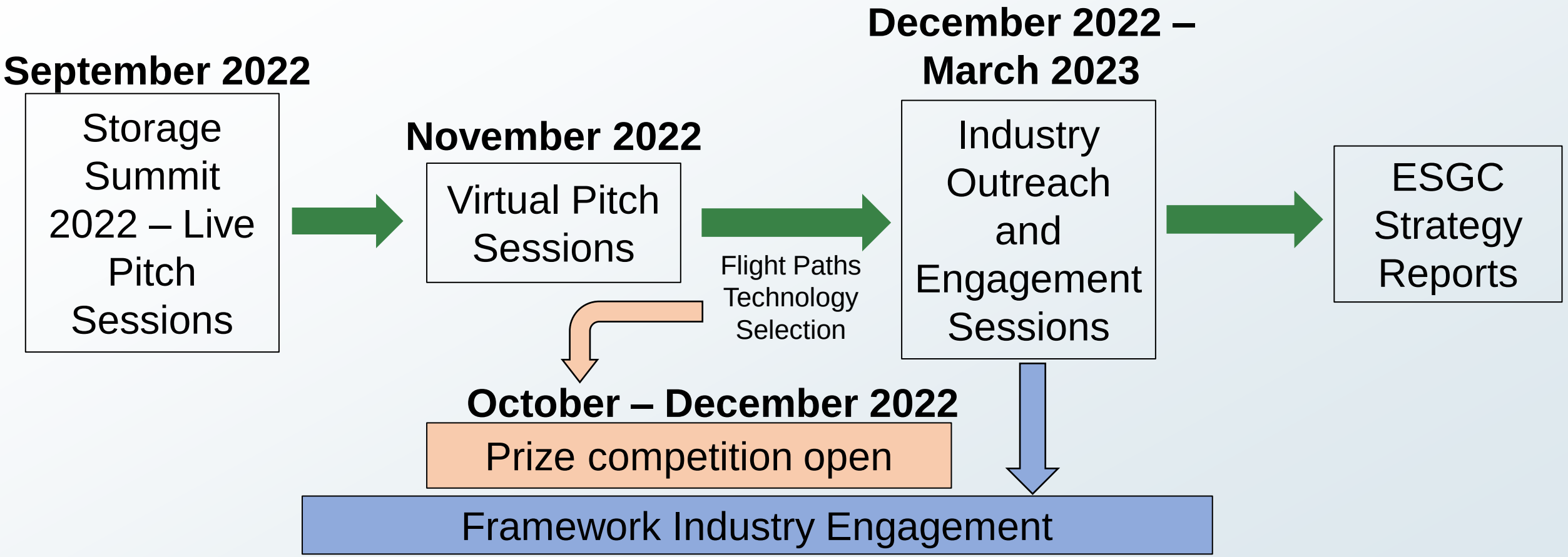
SI – Flight Paths

- Today's pitch sessions will inform which technologies are selected for Flight Paths.
- Subsequent process will seek industry consortia and input.

Flight Paths Output: Which R&D innovations are best suited for collaborations and partnerships?

Flight Paths & SI Timeline



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