ENERGY STORAGE GRAND CHALLENGE
U.S. DEPARTMENT OF ENERGY

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

Patrick Balducci[1], Thomas Mosier[3], Venkat Durvasulu[3], Crystal Ferels[1], Nigel Becknell[2], Ben Shrager[4], Hill Balliet[3]

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[1]Argonne National Laboratory
[2]NanoGraf Corporation
[3]Idaho National Laboratory
[4]U.S. Department of Energy




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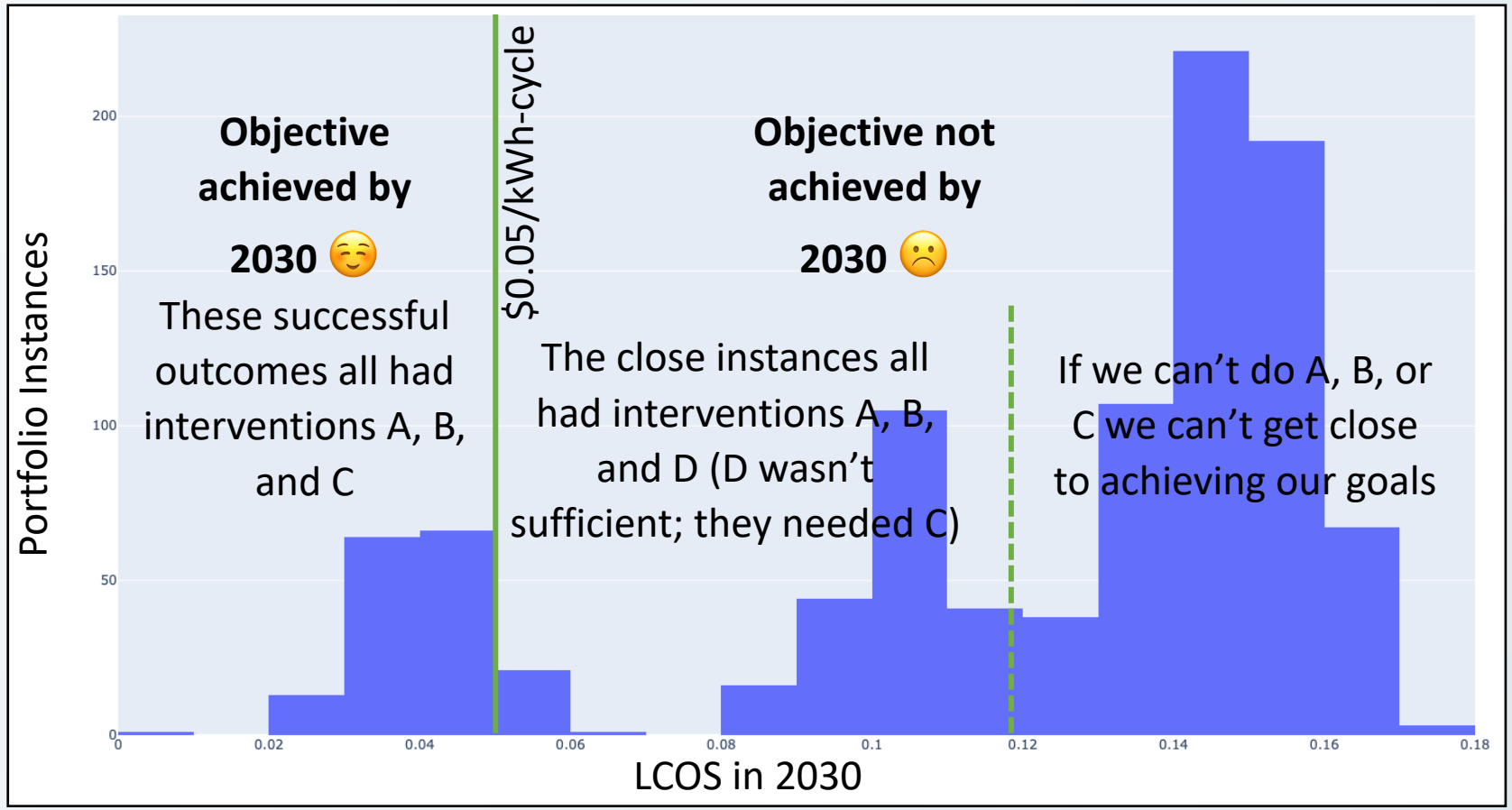
Outline

- 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

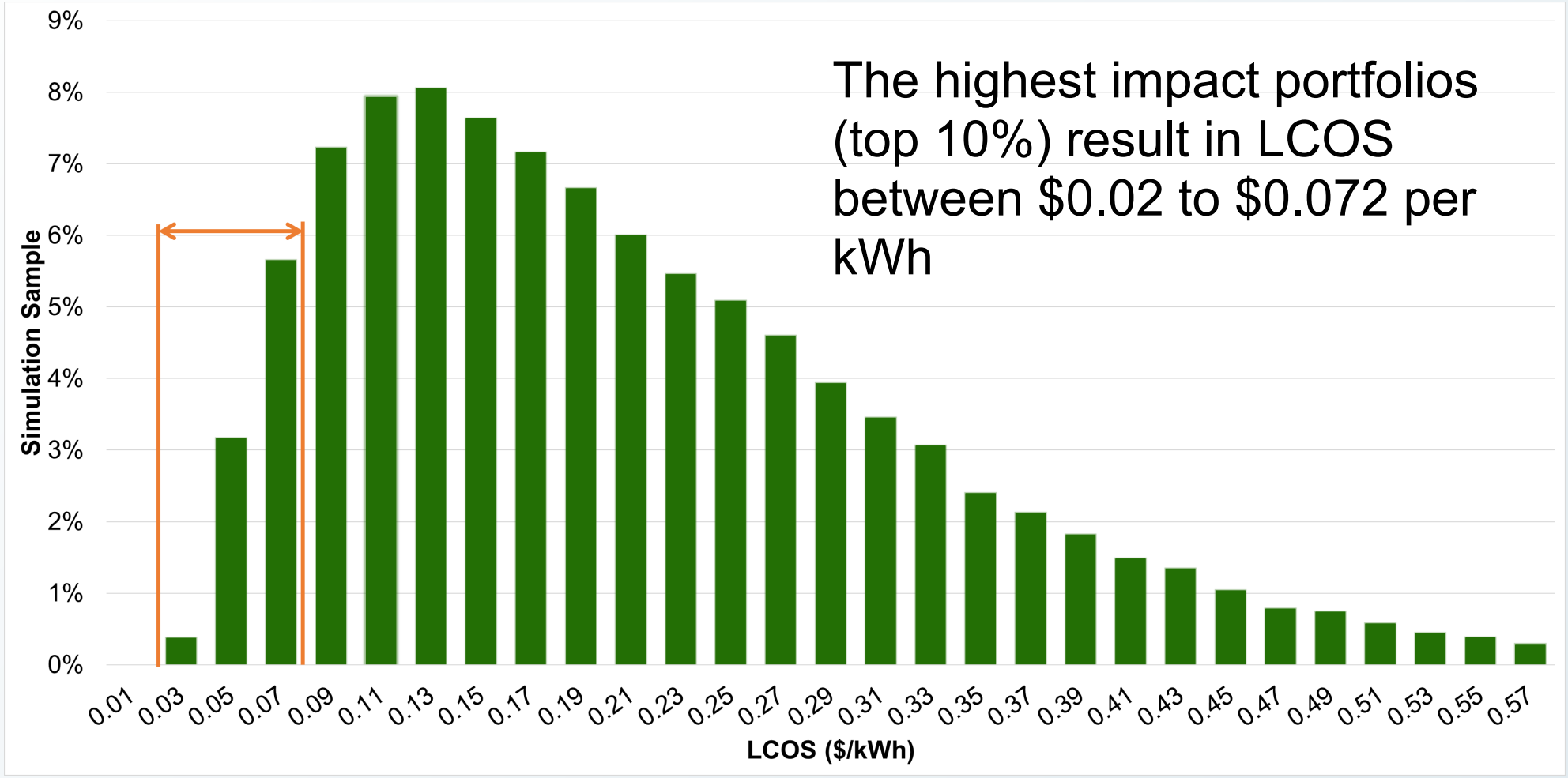
Innovation Category	Innovation
Raw materials sourcing	Mining and metallurgy improvements
	Alloying in lead sources
Supply chain	Supply chain analytics
Advance material development	Novel active material
	Improving paste additives - carbon
	Improving paste additives - expanders or other
	Novel electrolytes
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

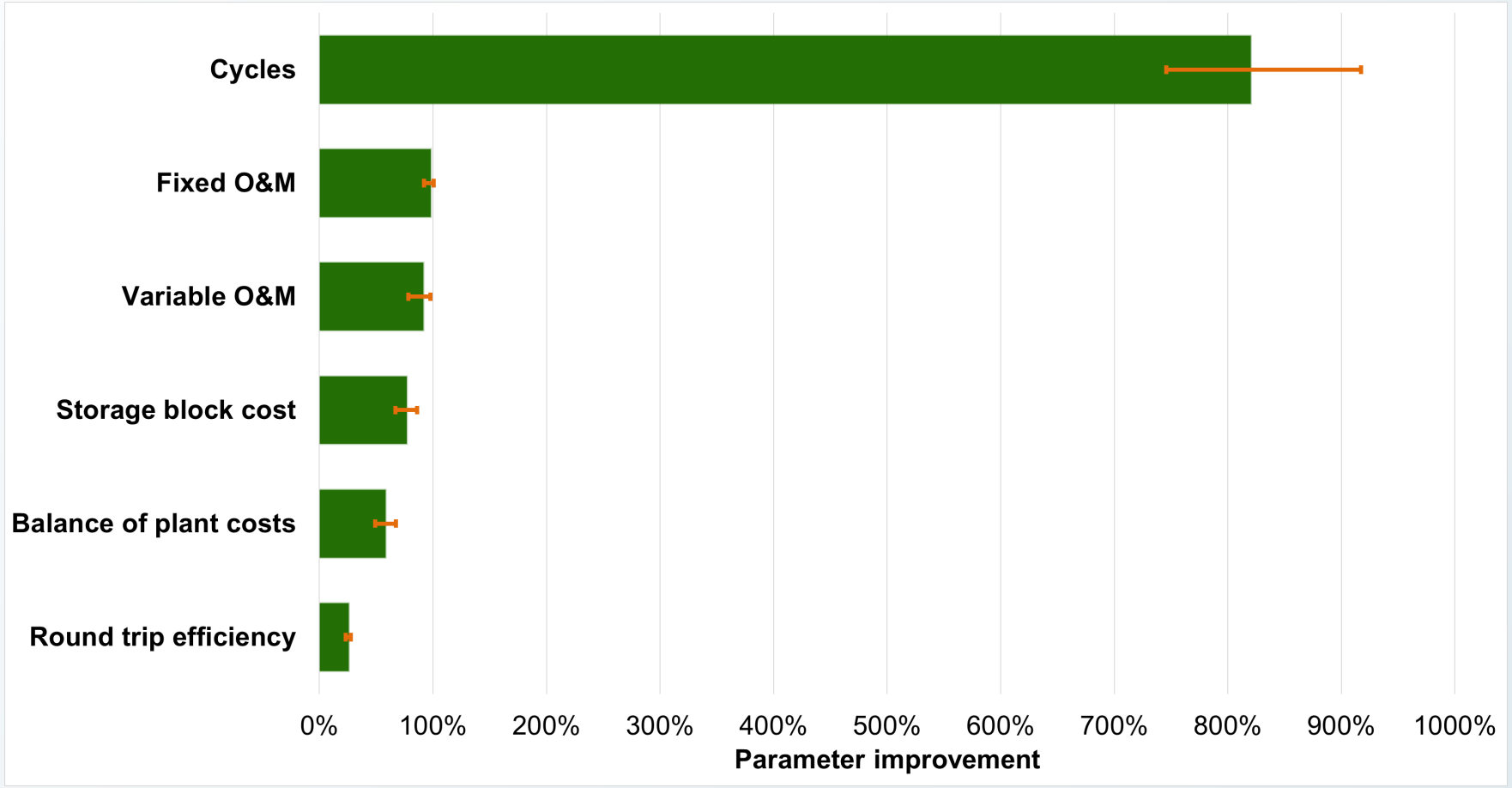
Innovation Category	Innovation
Raw materials sourcing	Cathode material mining
	Domestic sourcing of Lithium
Supply chain	Anode material production
	Mining permitting
	Co-locating manufacturing and mines
Advanced material development	Solid-state electrolyte improvements
	Anode innovations
	Electrode and 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

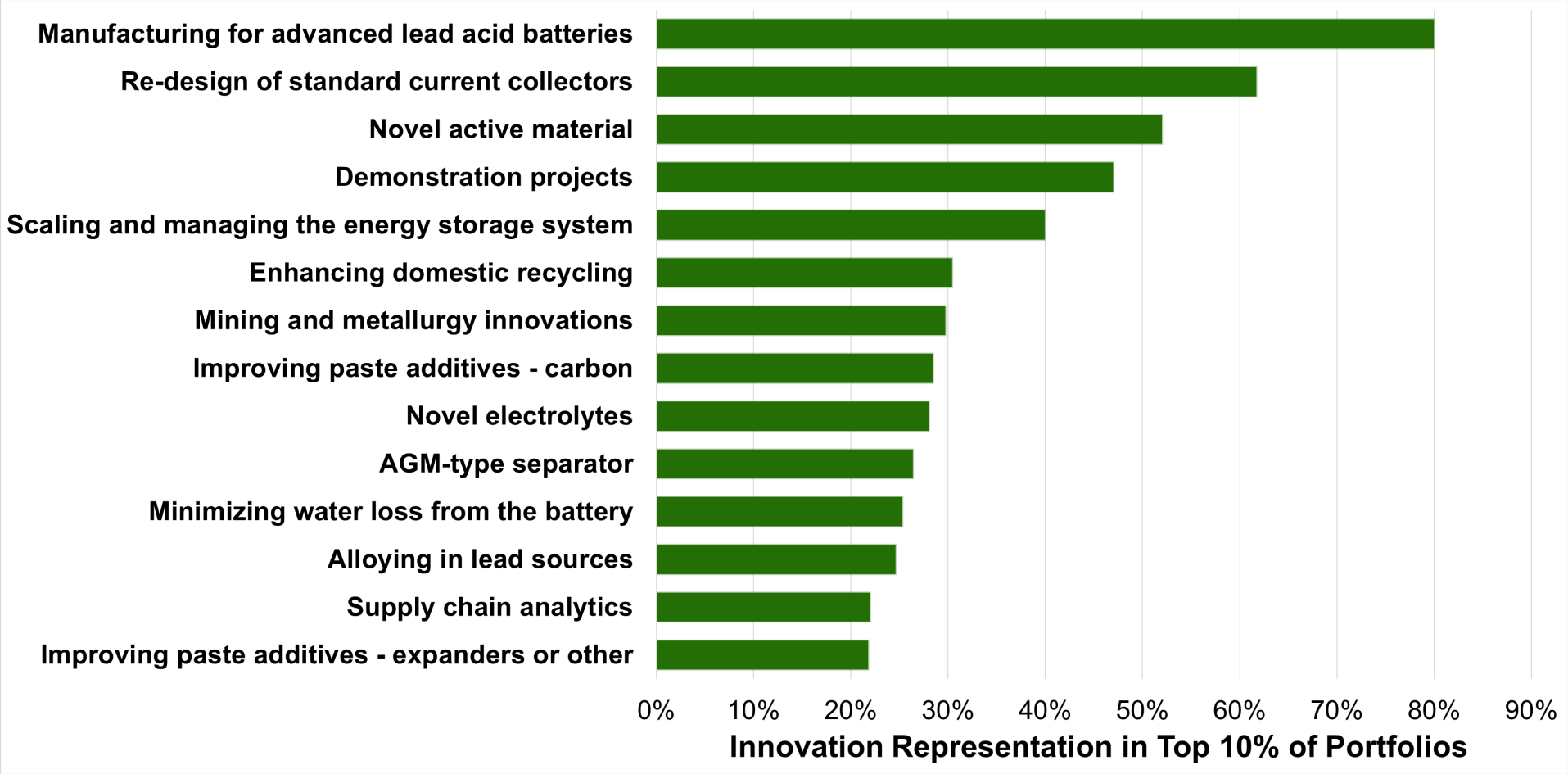
Some Innovation Portfolios Substantially Reduce LCOS



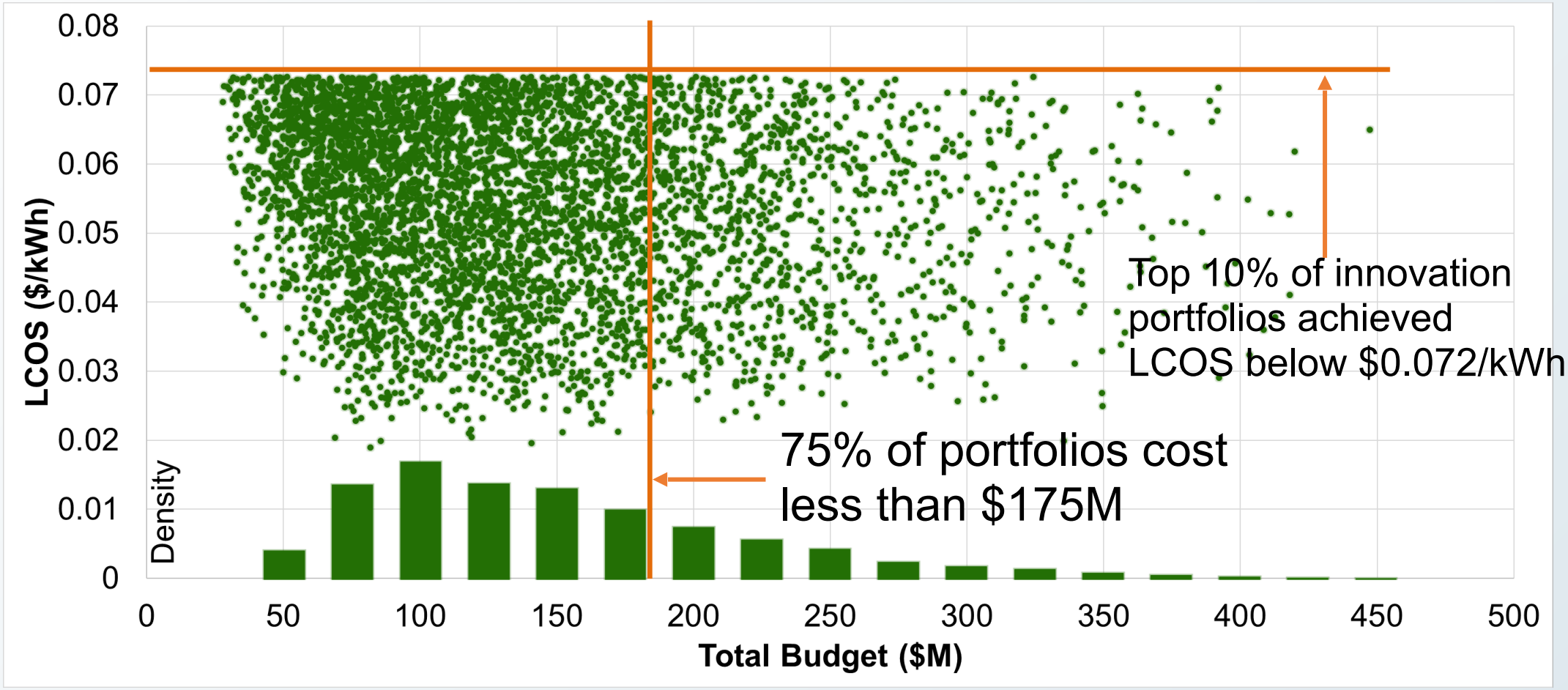
Achieving This Dramatic LCOS Reduction Would Require a Dramatic Improvement to Cycles



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

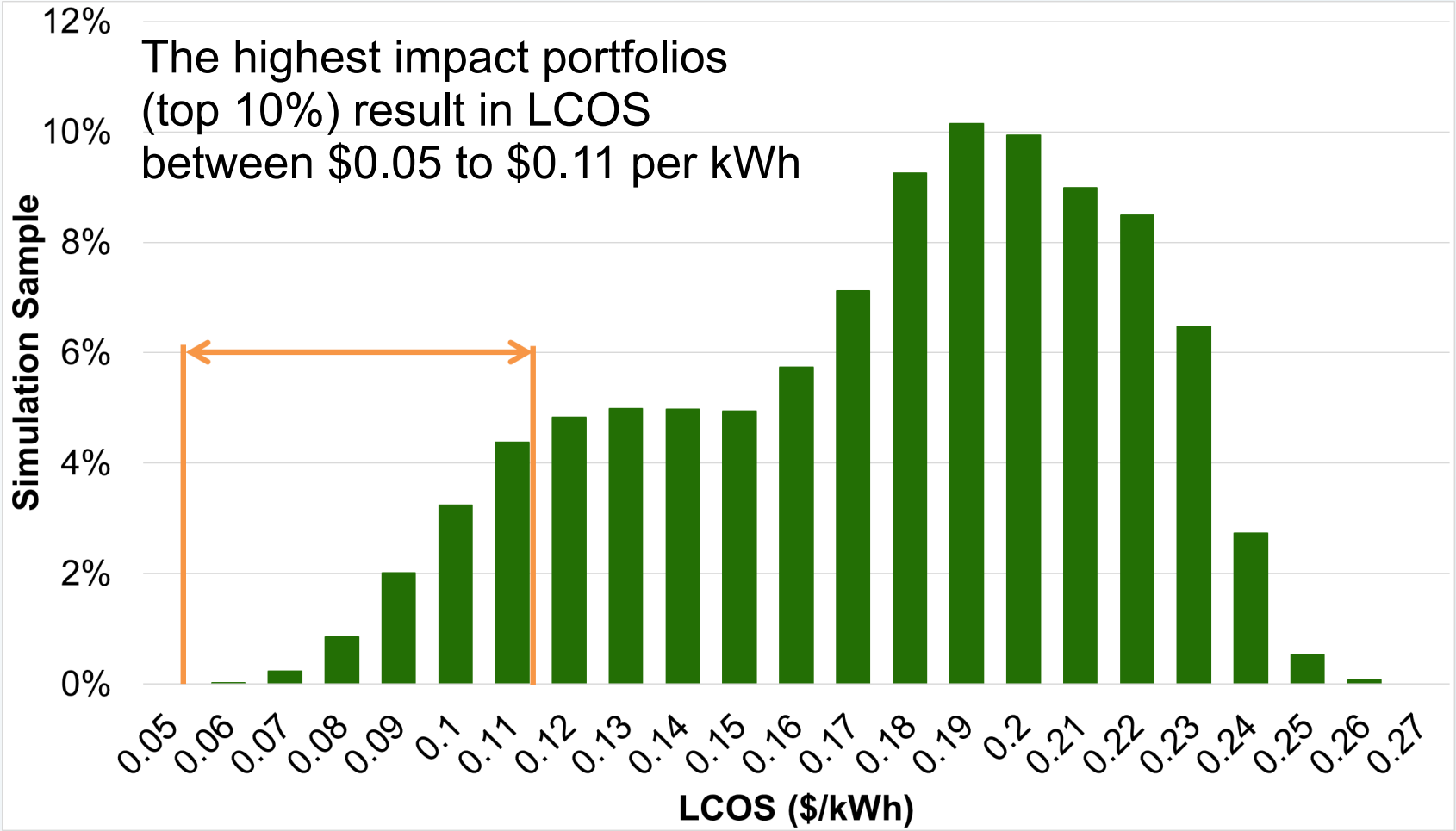


Significant Number of High Impact Portfolios Cost Less than $150M

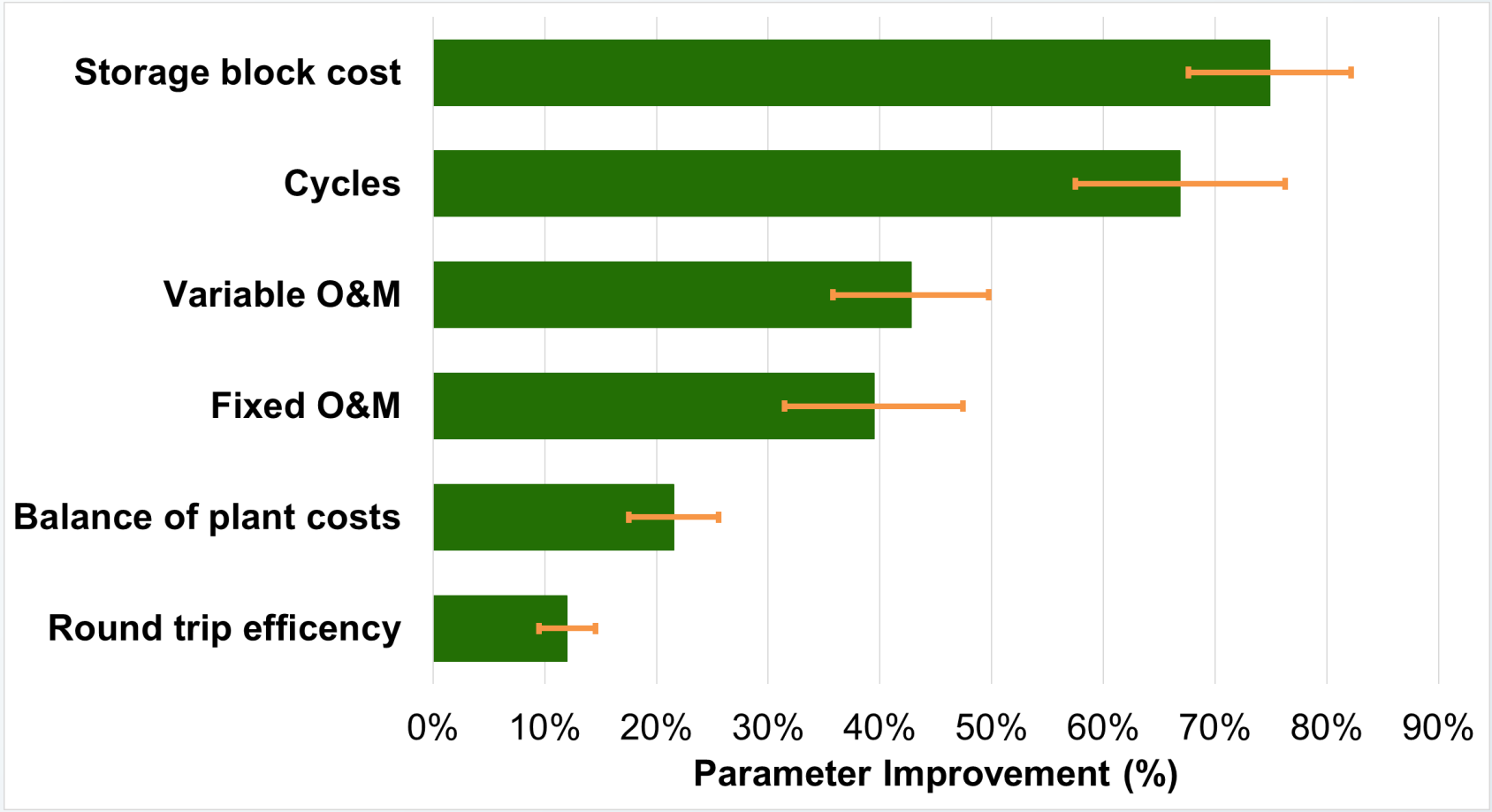


Lithium-ion Battery Results

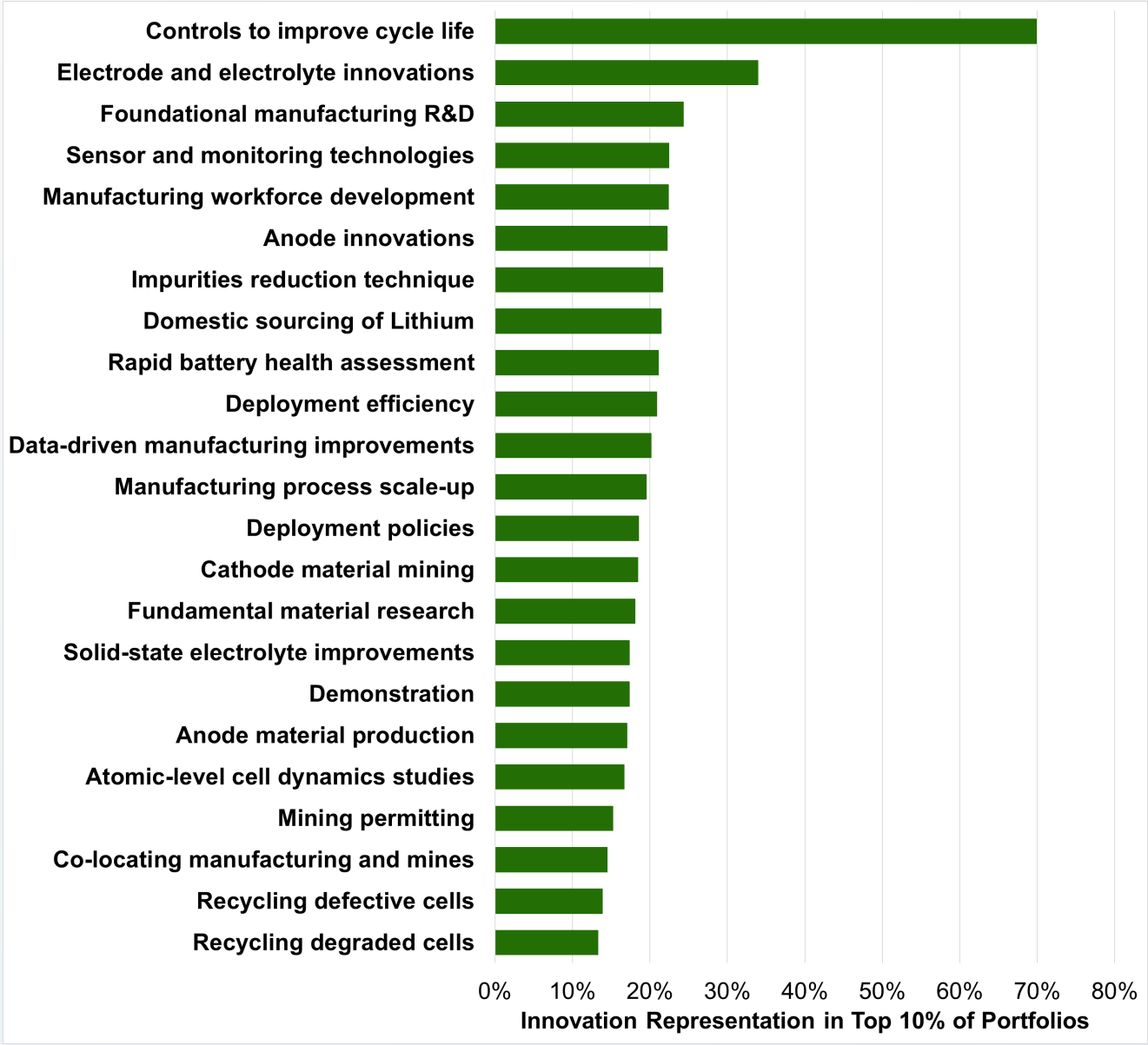
Deepest LCOS Reductions Require Significant Intentionality



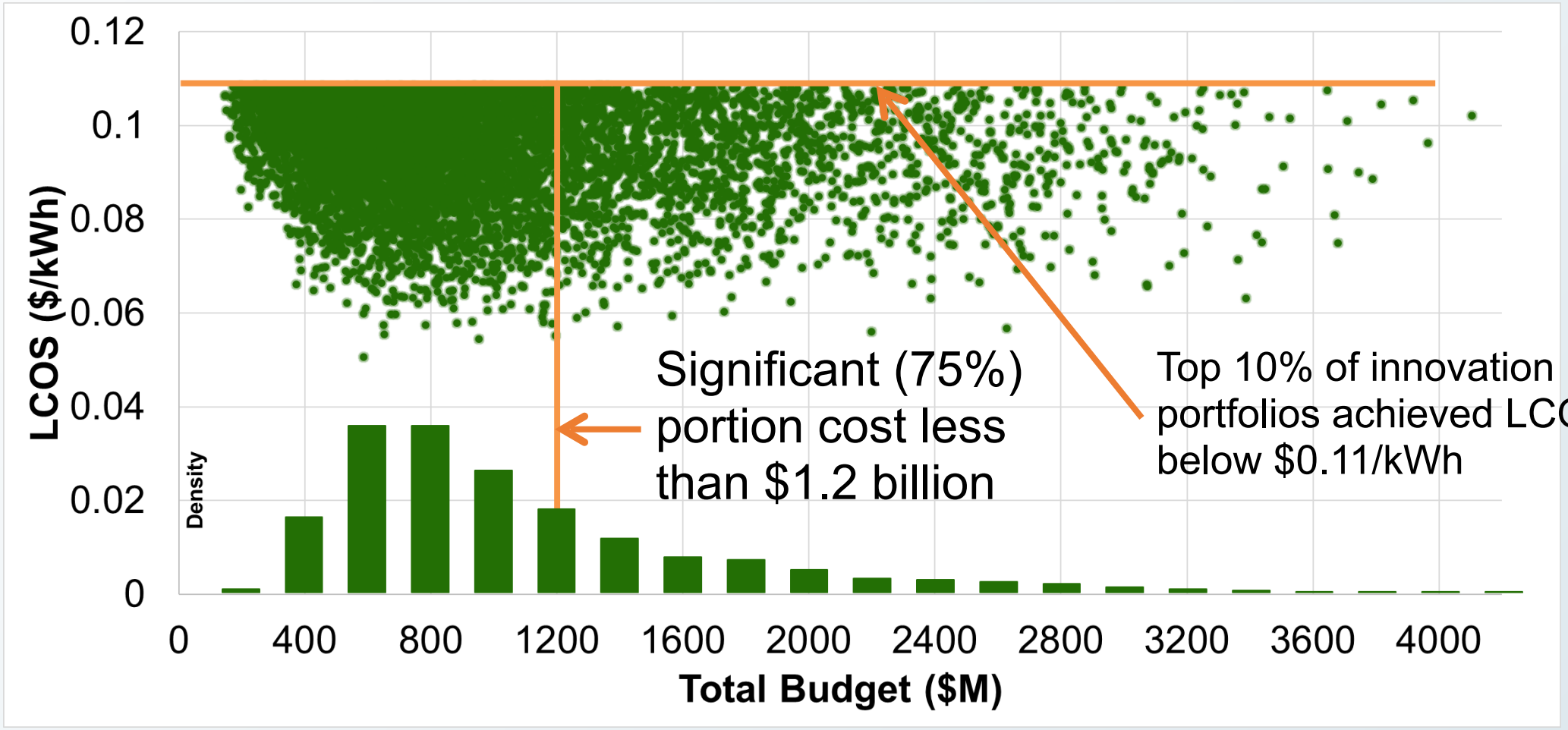
Storage Block and Cycles Key to Achieving Deepest LCOS Reductions



Deployment and Advanced Materials Are Key to Highest Impact Portfolios

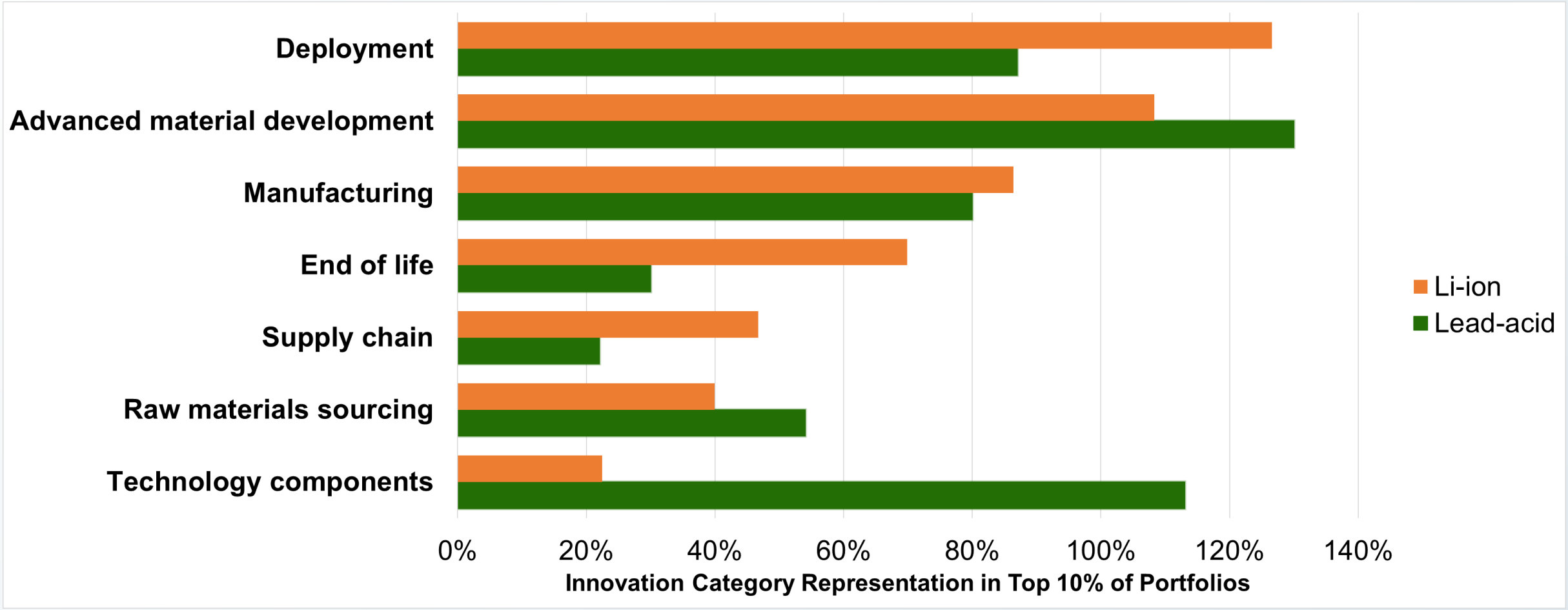


Li-ion Innovation Portfolios Are Expensive, but Majority Cost Less Than $1B



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

Contact information

Patrick Balducci

Backup Slides

Motivation

ESGC Technology Development Activity 2

*Identify a portfolio of energy storage technologies that have an **R&D pathway** to achieve significant progress towards **ESGC cost targets by 2030**. Develop standardized metrics that facilitate technology-agnostic cost and performance evaluations.*

ESGC Roadmap Figure 3

Lead-acid Battery Innovations (1-4)

Innovation Category	Innovation	Description
Raw Material Sourcing	Mining and metallurgy innovations	• Ex. hydrometallurgical processes and extracting Pb as a byproduct of other mining processes • Innovations that would extend the lifetime and extraction efficiency of current, domestic Pb mines
	Alloying in lead sources	• Related to the impurity or alloy composition of primary or secondary Pb • Remove harmful impurities from Pb sources or make those impurities less impactful on the battery performance
Supply chain	Supply chain analytics	• Reduce risk in the supply of critical lead-acid battery materials (lead, plastics, additives, etc.) • Ex. lowering the fraction of valuable EOL lead-acid batteries that are exported or reducing the rising costs and lead times of critical materials
Technology components	Re-design of standard current collectors	• Fundamentally altering the popular grid architecture of standard lead-acid battery current collectors, such as changing: ▪ Aspect ratios/current collector thickness ▪ Design/placement of current collector tabs ▪ Current collector materials (Pb alloys or non-Pb based) • Different designs such as bipolar or tubular gel construction and electrode materials necessary to improve those designs

Lead-acid Battery Innovations (5-9)

Innovation Category	Innovation	Description
Technology components	AGM-type separator	• Ex. novel materials, coatings, and fabrication methods • Minimize stratification, aid diffusion, facilitate gas transfer, maintain stack compression • Tailoring to high-performance on both the positive and negative side of the battery
	Minimizing water loss from the battery	• Minimizing the detrimental effects of water loss or the need to add water by controlling: ▪ Positive electrode corrosion and overcharging ▪ Water diffusion through the cell casing ▪ Water loss through the venting system ▪ Catalysts for improving oxygen recombination
Manufacturing	Advanced manufacturing for lead-acid batteries	• Developing a manufacturing process that deviates from historically prominent methods • Ex. manufacturing bipolar batteries, a Li-ion-like manufacturing process, or other processes to make lead-acid manufacturing greener
Advance material development	Novel active material	• Using a different lead-based material than what is currently mixed into pastes during lead-acid battery manufacturing
	Improving paste additives - carbon	• Using high surface area carbons to improve battery performance

Lead-acid Battery Innovations (10-14)

Innovation Category	Innovation	Description
Advance material development	Improving paste additives - expanders or other	• Improving the performance of expanders added to the paste • Developing novel synthetic additives that improve paste performance • Ex. naturally occurring expanders (lignosulfonates), synthetic molecules, or inorganic materials
	Novel electrolytes	• Non-aqueous or other novel electrolyte compositions • Fundamentally altering the electrochemical processes in the lead battery and attempt to avoid sulfation
Deployment	Scaling and managing the energy storage system	• Integrating and managing a large number of low-voltage batteries in a stationary energy storage system • Operating a grid-connected system while improving performance and extending cycle life
	Demonstration projects	• Combining innovations into a demonstration project for a specific deployment • Likely conducted through a consortium of companies or utility, with DOE and private entities both contributing to the project • Analytic support could be supplied by national laboratories
End of life	Enhancing domestic recycling	• Enhancing recycling automation and domestic capacity and reducing its environmental impact • Ex. hydrometallurgy for secondary lead production, recycling electrolyte, and recovering byproducts to improve the value proposition for recycling • Planning for recycling of the battery during the design and manufacturing stages