Opportunities for LDES technologies

Keynote presentation

Los Angeles

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THE NATIONAL CONSORTIUM FOR THE ADVANCEMENT OF LONG DURATION ENERGY STORAGE TECHNOLOGIES

Roland Berger

Your presenter today

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We have a dedicated team of international energy storage experts supporting clients along the entire value chain on strategic topics

Introduction to Roland Berger's global "Battery Team"

Our experience

Unmatched experience of 150+ projects with key players along storage value chain

- **Materials**: BASF, JM, AsahiKASEI, 24M, Shanshan, Merck, Group14, Mosaic, Syrah Resources
- **Cell mfg.**: LG Energy Solution, CATL, Samsung SDI, Panasonic, SK on, Verkor, northvolt, SVOLT, Gotion, ACC, PowerCo, BAK
- **Auto OEMs**: gm, Volkswagen, Hyundai, Porsche, SAIC Motor, NIO, Ford, Audi, Lucid, VinFast, BMW, Rivian, Daimler
- **ESS players**: Enervenue, Ameren, cerberus, EQT, Augwind, Goldman Sachs, Energy Vault, LDES, BlackRock, ViZn Energy, Sumitomo Electric, Hydrostor, Cumulus, conEdison
- **Recycling**: Li-Cycle, Cirba Solutions, Managem, Solvay, Aurubis, Hyundai Motor Group, Retriev Technologies, Ascend Elements, Volkswagen

Our offerings

Investor Support
- Commercial & Technical Due Diligence
- Red flag assessment
- Other financial advisory (M&A target search, investment thesis development, Independent Engineering Review)

Strategic Advisory
- Growth strategy (product, market entry, go to market)
- Participation model (value chain/vertical integration strategy)
- Supply chain securitization
- Partner search/JV negotiation support

Operational Support
- Product cost reduction incl. should cost analysis & benchmark
- Gigafactory planning & execution support
- Footprint & site selection

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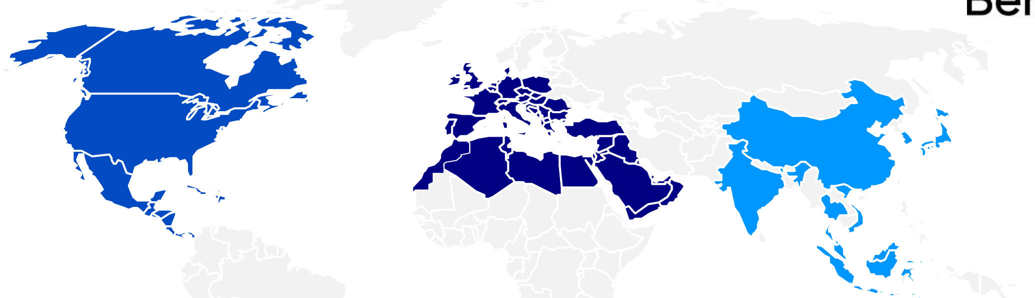
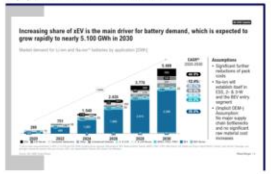
Our team



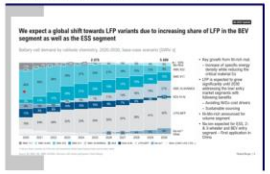
Global team of 50+ battery technology and market experts with hubs in North America, Europe and Asia

Our tools & models

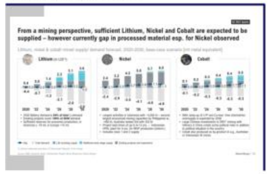
LiB & NaB demand forecast per application & market



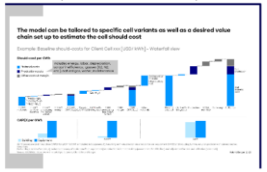
Battery technology roadmaps and market share forecast



Battery materials supply vs. demand forecast



Integrated cell should cost model (PCAM/CAM/Cell)



Set of proprietary tools & databases that can be leveraged during projects

As US energy systems transition to cleaner technologies, LDES will play an increasingly larger role – Challenges must be overcome to enable adoption

Executive summary

Policymakers identified **11 key challenges** to be addressed to **drive US LDES adoption**. They focus on **improving technology and cost**, **creating market support mechanisms**, and **increasing stakeholder awareness**

Of the 11 key challenges, **five directly address reducing the lifetime cost of ownership** of these technologies as measured on a levelized cost basis

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Compressed air energy systems (CAES) and **sodium-ion batteries** appear to already **be at cost parity** with LiBs, however, improvements are needed to **solidify tech. competitiveness**

Lowering install. costs, improving operating costs, and **strengthening TRL** would position LDES favorably against LiBs, especially as there are limitations to LiBs for grid applications

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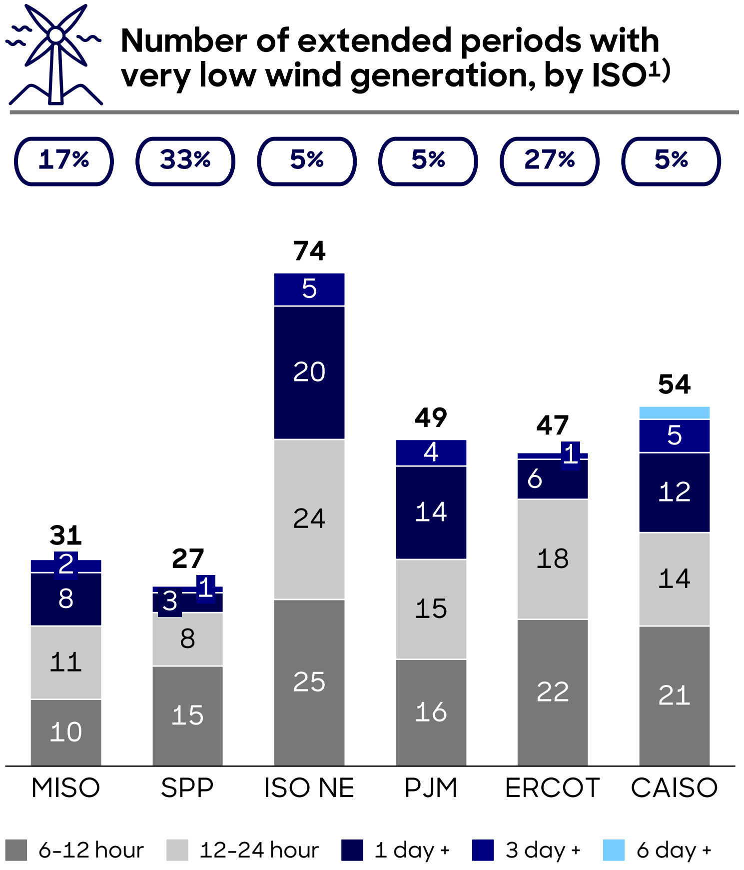
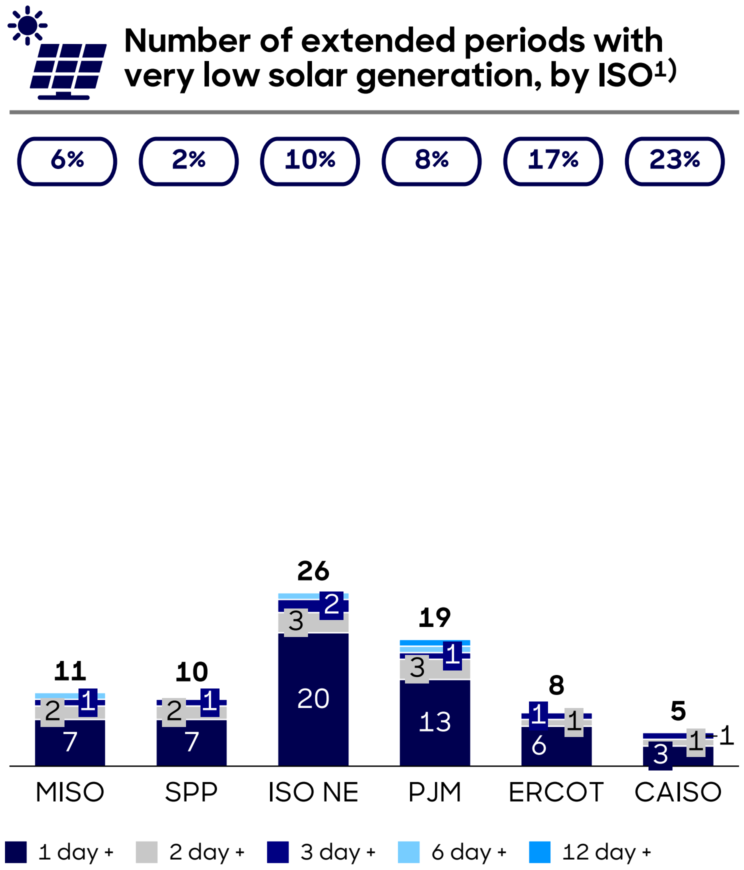
LDES will play an important role for the grid as more renewables are integrated to meet climate targets – **subsidies, such as the IRA's ITC, can help drive this further.** For projects to come online and receive the credit in time, **demonstration projects must progress today**

The shift to longer duration storage technologies is partly driven by extended renewable outages, underscoring the need for LDES in 'firming' supply

Prevalence of wind and solar intermittency in the US, by ISO





Increasing intermittency poses firming and reliability challenges:

- Wind and solar generation can experience **long periods of underperformance**
- Each year, wind generation experiences **numerous "shortfalls" that are up to 24 hours** long and a **handful of "shortfalls" that are multiday** periods of sustained lack of wind generation
- As countries enforce **increasingly aggressive renewable targets**, larger shares of renewables will **create more frequent generation shortfalls**

There is a **rising need** for **longer-duration capacity resources:**

- At **higher renewable penetration levels**, firming renewables will require **longer duration resources** such as **LDES**, esp. for **resilience use cases**:
  - **Redundancy of power supply** and a hedge **against interruptions** for use cases where down-time is costly or sensitive (e.g., data centers, military bases)
  - **Remote communities** which could be **early adopters**, as they are on the edge of the grid, with outages that can last for days/weeks in areas prone to natural disasters[2)]

1) Annual average count by event duration, Jan '19 – March '23; 2) The Grid Deployment Office launched the Puerto Rico Energy Resilience Fund to support Puerto Rico's grid resilience efforts, with USD 450 m in funding

Source: S&P Capital IQ, EIA 930

Lithium-ion has multiple shortcomings when used as a stationary energy storage technology

LiB technology limitations

Safety	Lithium has a lower **thermal stability** than other technologies. High temperatures during charging/discharging cycles may result in **overheating,** especially if not cooled properly
Scale	There are **no scaling effects** for utility-scale LiB systems. Doubling the capacity by stacking two LiB systems means **doubling the CapEx and size** of the overall system
Degradation	**LiB experiences system degradation** through charging/discharging cycles which requires **upsizing** with initial system design and periodic **augmentation,** resulting in **additional costs**
Scarcity	Lithium is a **scarce material** with **limited resources** and is currently subject to increasing and volatile commodity prices, making forecasting the system price difficult
Duration	**LiB discharge duration** is **limited by lithium's chemical characteristics**. A 4-hour LiB system can be increased by adding more Li electrolyte, however, this will **reduce the battery's lifetime**
ESG	Lithium is a **scarce element**, in which companies with stringent ESG targets may have limitations to its use. Also, frequent replacements of LiB lead to the accumulation of **toxic waste products**

ESG - Environmental, social and governance

Source: Desk research, DOE Global Energy Storage Database

DOE's *Pathways to Commercial Liftoff* report highlighted 11 challenges facing LDES today – Five, if addressed, have direct implications on its levelized cost

Improve LDES tech. and decrease cost

- Decrease in system costs by 2030
- Increase policymaking for LDES
- Assessment of supply chain improvements
- Improvement in roundtrip efficiency by 7-15%
- Define workforce training and skills required

Create LDES market

- Develop uniform resource adequacy approach
- Introduce market support mechanisms
- Required market changes at wholesale level

Increase LDES knowledge and awareness

- Include LDES in utility grid firming plans
- Resources to evaluate grid exp. to accommodate LDES
- Develop public info. on LDES vs. primary comp. factors

Focus for today

Roland Berger's levelized cost analysis utilizes capital, operating and financing costs to estimate total cost of ownership across standardized use cases

Levelized lifetime technology cost model methodology

Inputs

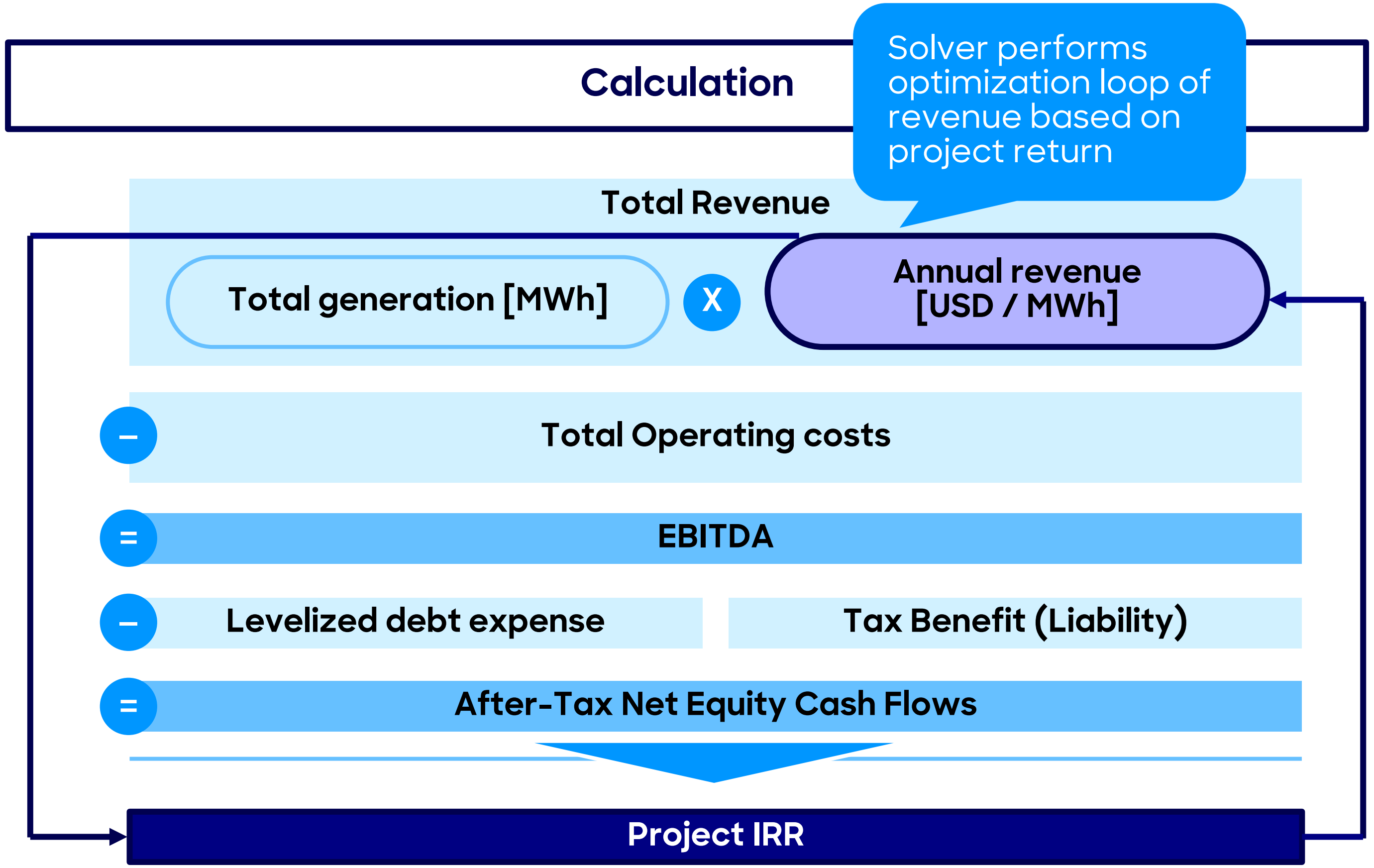
Operating parameters:
Aligned use-cases

Operating costs:
Input cost data

System capital costs:
Input cost data

Financial assumptions:
Technology-specific WACCs, Taxes

Calculation



Result: Levelized Cost

Levelized Cost Interpretation:

Required annual revenue – as a function of system output – to achieve the input investor return, given inputs

Source: Roland Berger

The five challenges can be mapped to specific components of the levelized cost analysis

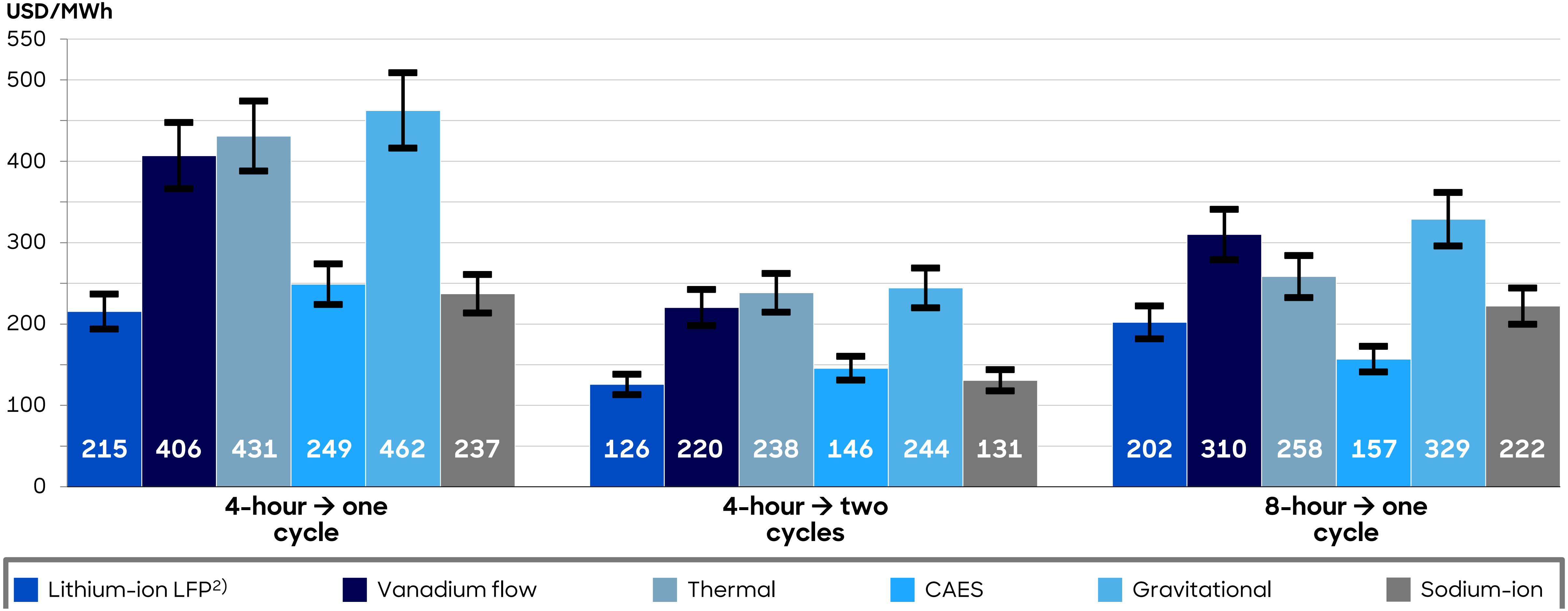
Overview of applicable LCOS drivers

LDES Consortium challenge	Capital costs	Operating costs	Financing costs
Decrease in system costs by 2030	✓	✓	
Improvement in roundtrip efficiency by 7-15%		✓	✓
Define workforce training and skills required	✓		
Assessment of supply chain improvements	✓		
Increase policymaking for LDES	✓	*Could enable through funding technologies to scale* →	✓

✓ Applicable LCOS component that LDES Consortium challenge has direct implications for

CAES has a lower TCO compared to lithium and other technologies at eight-hour durations

Unsubsidized 2023 levelized cost 100 MW [USD/MWh]; Cost of equity premium included1)



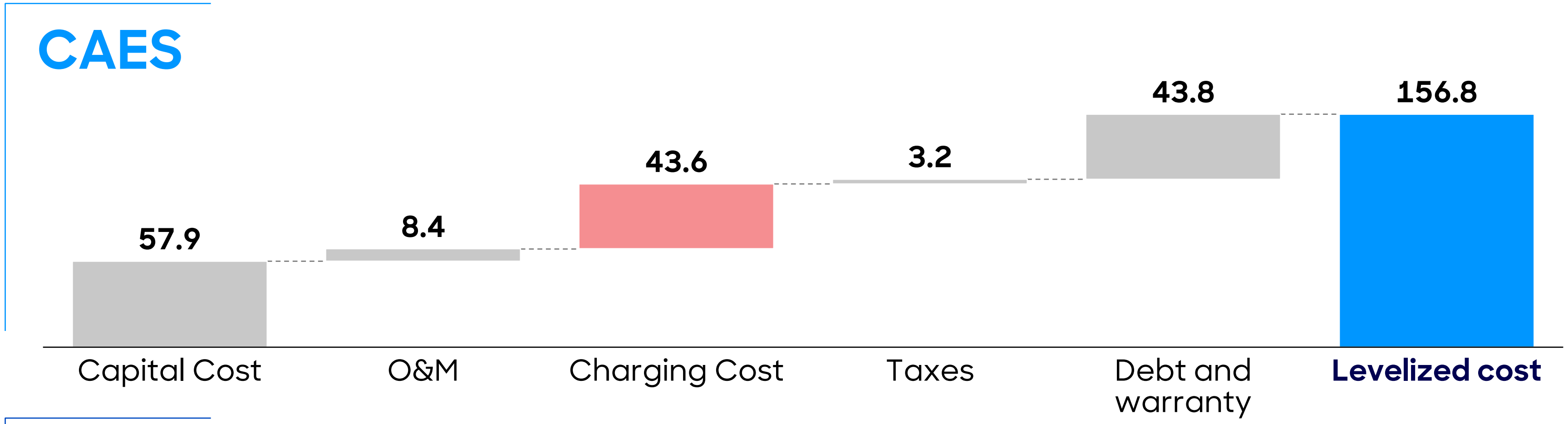
1) Cost of equity premium is 17% to take a newer technology's 'risk' into account in these eyes of an investor. All technologies assumed a cost of equity premium other than LFP; 2) RTE assumed to be 90% for all three use cases. 1-cycle use cases assume 2.1% degradation while 2-cycle use case assumes a degradation of 4.2%

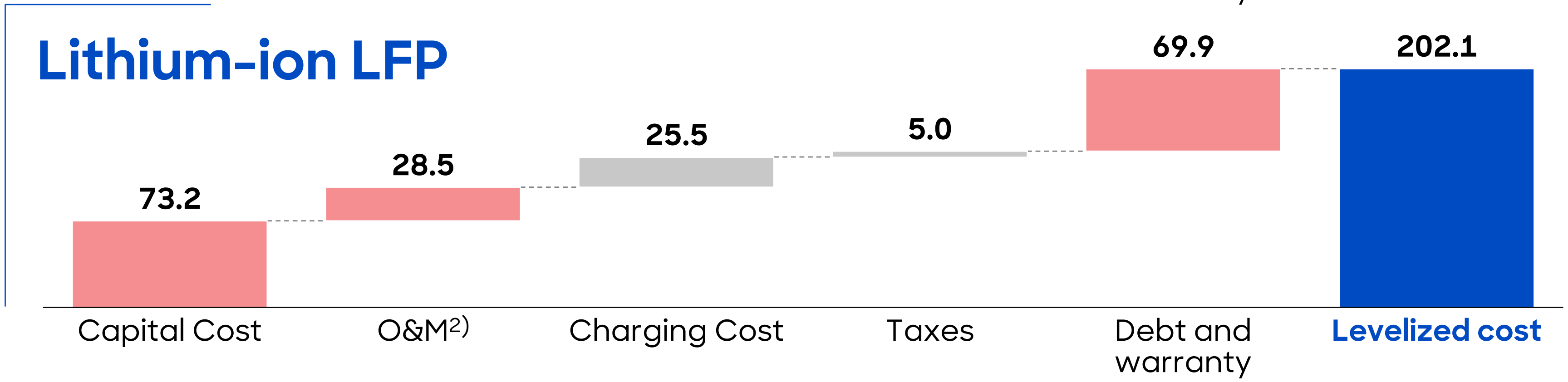
Source: Roland Berger, PNNL, Industry interviews

Indicative

CAES benefits from its economy of scale and durability as balance of system, augmentation of LiB and other costs make its TCO higher at eight-hour duration

2023 levelized cost breakdown [USD/MWh]: CAES vs. LFP – 100 MW 8-hour, 1 cycle; ROE premium *included*[1)]





Significant cost difference vs other technology

Comments

- **CapEx is the largest cost component**, representing 37% of the total levelized cost for the CAES system
- CAES has lower O&M costs, driven by lack of augmentation needed
- **List of key differing assumptions:**
  - CAES CAPEX: USD 165.87 per kWh
    - LFP CAPEX: *USD 332.00 per kWh*
  - CAES O&M: USD 2.00 per kWh
    - LFP O&M: *USD 5.25 per kWh*

1) Prices are unsubsidized; 2) Augmentation is >60% of LFP O&M cost and degradation is assumed to be 4.2%

Source: Roland Berger

In addition to improved tech. performance, if the 5 challenges are addressed, LCOS savings will also be realized via a stronger supply chain and workforce

Overview of addressed challenges' implications on levelized cost components

Challenges addressed:

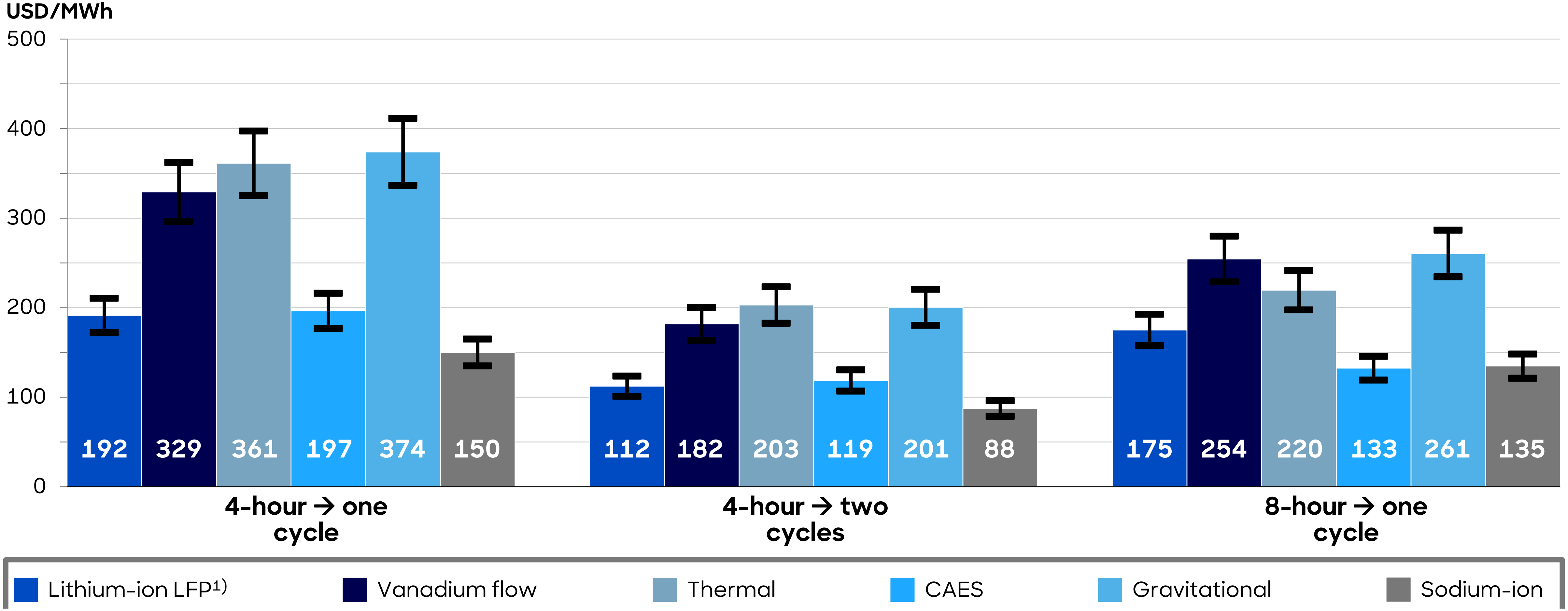
- Decrease in system costs by 2030
- Increase policymaking for LDES
- Assessment of supply chain improvements
- Improvement in roundtrip efficiency by 7-15%
- Define workforce training and skills required

Implications:

- ✓ Lower installation costs through improved tech. and increased know-how
- ✓ Improved charging and augmentation costs via further advanced technologies
- ✓ Robust supply chain with shorter lead times
- ✓ Decrease cost of equity risk premium in financing due to higher TRLs

The forecasted price decline for Na cells creates competitive pressure on LDES technologies in 2030 – CAES is still the most competitive while others trail behind

Unsubsidized 2030 levelized cost 100 MW [USD/MWh]; Cost of equity premium excluded



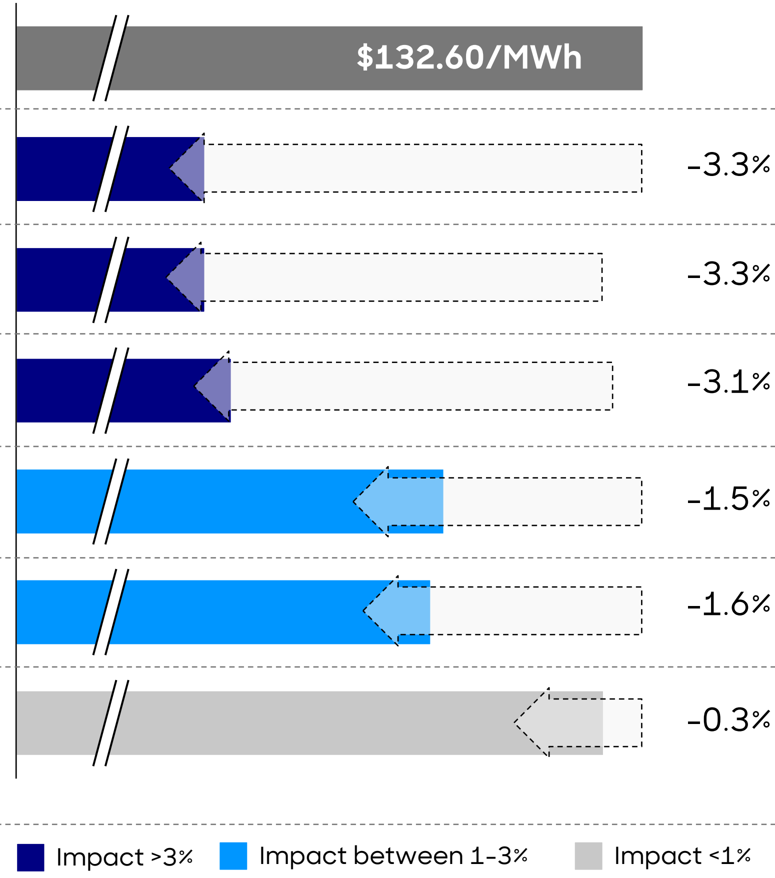
1) RTE assumed to be 90% for all three use cases. 1-cycle use cases assume 2.1% degradation while 2-cycle use case assumes a degradation of 4.2%

Source: Roland Berger, PNNL, Industry interviews

Without considering regional cost disparities, improving operational parameters such as depth of discharge can decrease LDES LCOS the most

LCOS sensitivity to key project parameters, holding all else equal [100 MW, 8-hour 2030 CAES]

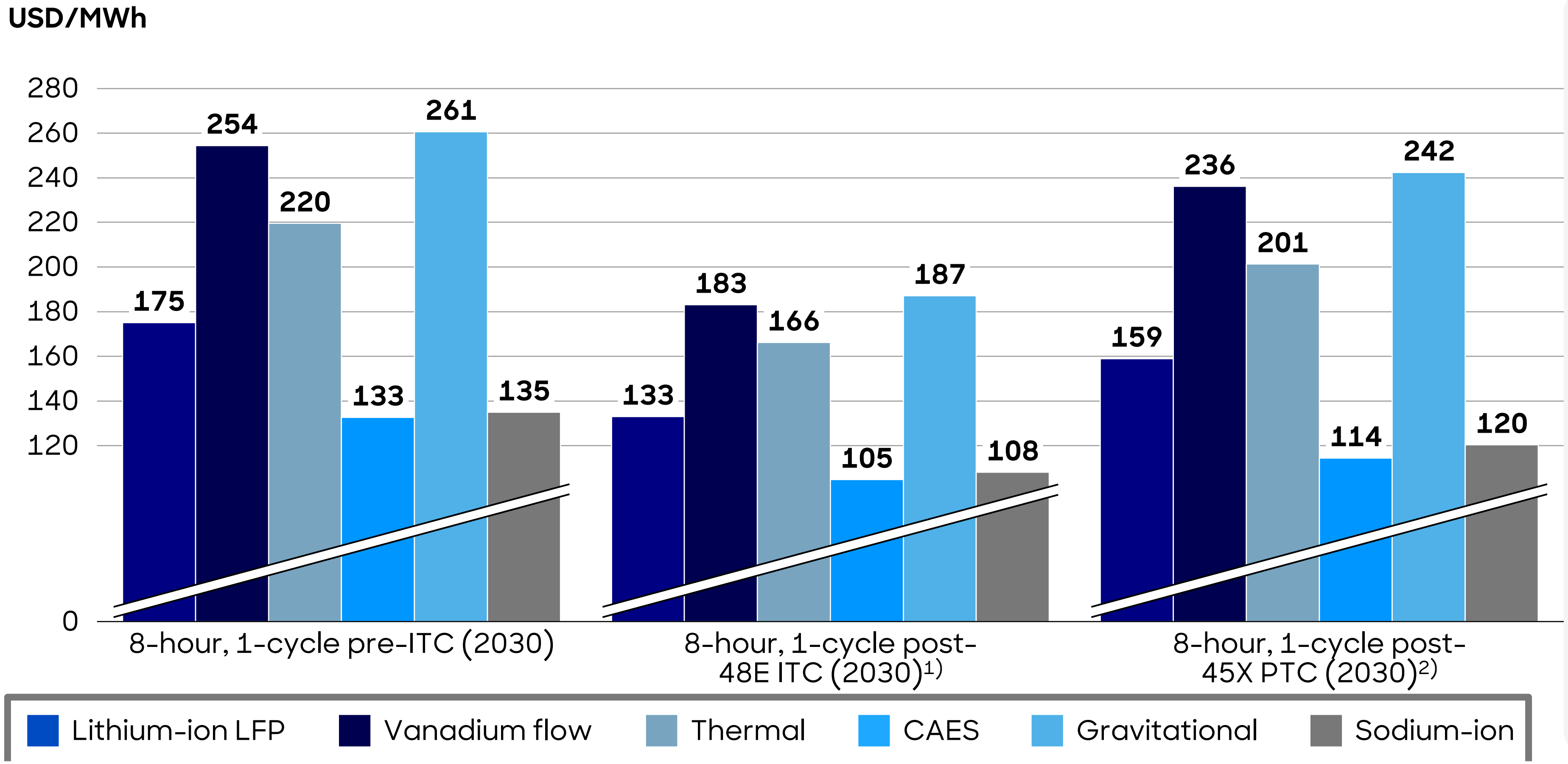
Parameters	Levers	Variation	LCOS	Impact
Base LCOS	**N.a.**	**(Base)**	**$132.60/MWh**	
Depth of Discharge	• Operational decisions and efficiencies	5% increase		-3.3%
Cycles per year	• Operational decisions and efficiencies	5% increase		-3.3%
System costs	• Module cost reduction	5% decrease		-3.1%
Roundtrip efficiency	• Parasitic load reduction • Operational efficiency	5% increase		-1.5%
Charging costs	• Charging optimization (incl. using software)	5% decrease		-1.6%
O&M costs	• Operational efficiency	5% decrease		-0.3%



Source: Industry survey on storage costs, Roland Berger

LDES LCOS can be further decreased by ~10-30% via the ITC or manufacturing PTC from the Inflation Reduction Act

Overview of 48E ITC and 45X PTC impact on 2030 LCOS for LDES technologies [100 MW 8-hour, 1-cycle]



Comments

- To receive 48E, projects **must begin construction** before 2032 or when US GHG emissions from electricity are 25% or lower of 2022 emissions
- It will be important for projects early on (mid to late 2020s) **to capture the ITC and lower costs** as the technologies scale
- 45X manufacturing PTC assumed to be passed onto end customer of battery system, lowering capital costs

1) Figures assume prevailing wage requirement is met for 30% of CAPEX. Figures do not include domestic content (+10%) or energy community (+10%) adders. As the 45X credit begins to phase-out in 2030, 75% of credit is assumed - $33.75 per kWh instead of $45 per kWh

Source: Roland Berger, PNNL, Industry interviews

To drive LDES adoption, the liftoff challenges must be addressed to enable these technologies to scale

Key takeaways

- ESS durations are becoming **longer**, driven by renewable saturation and additions of shorter duration energy storage, **creating a large opportunity for non-lithium chemistries** in the stationary storage market
- The 11 key challenges highlighted by policymakers are could **increase LDES adoption in the US**. Specifically, five of the 11 could directly **impact the technologies' levelized cost**, bridging the cost gap with LiBs
- **Lowering installation costs, improving charging & augmentation costs**, and **strengthening the technologies' readiness level** would position LDES favorably against LiBs as well as other zero carbon baseload technologies
- Non-lithium players will need significant and patient capital to **scale manufacturing in order to achieve targeted economies of scale.** Governments so far are attempting to bridge the gap for non-lithium chemistries, but it is not enough on its own to scale the industry

Roland Berger