Grid of the Future: Lifetime Costs of Energy Storage Technologies

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Lux Research | The Deciding Factor

Agenda

1 **The role of energy storage**

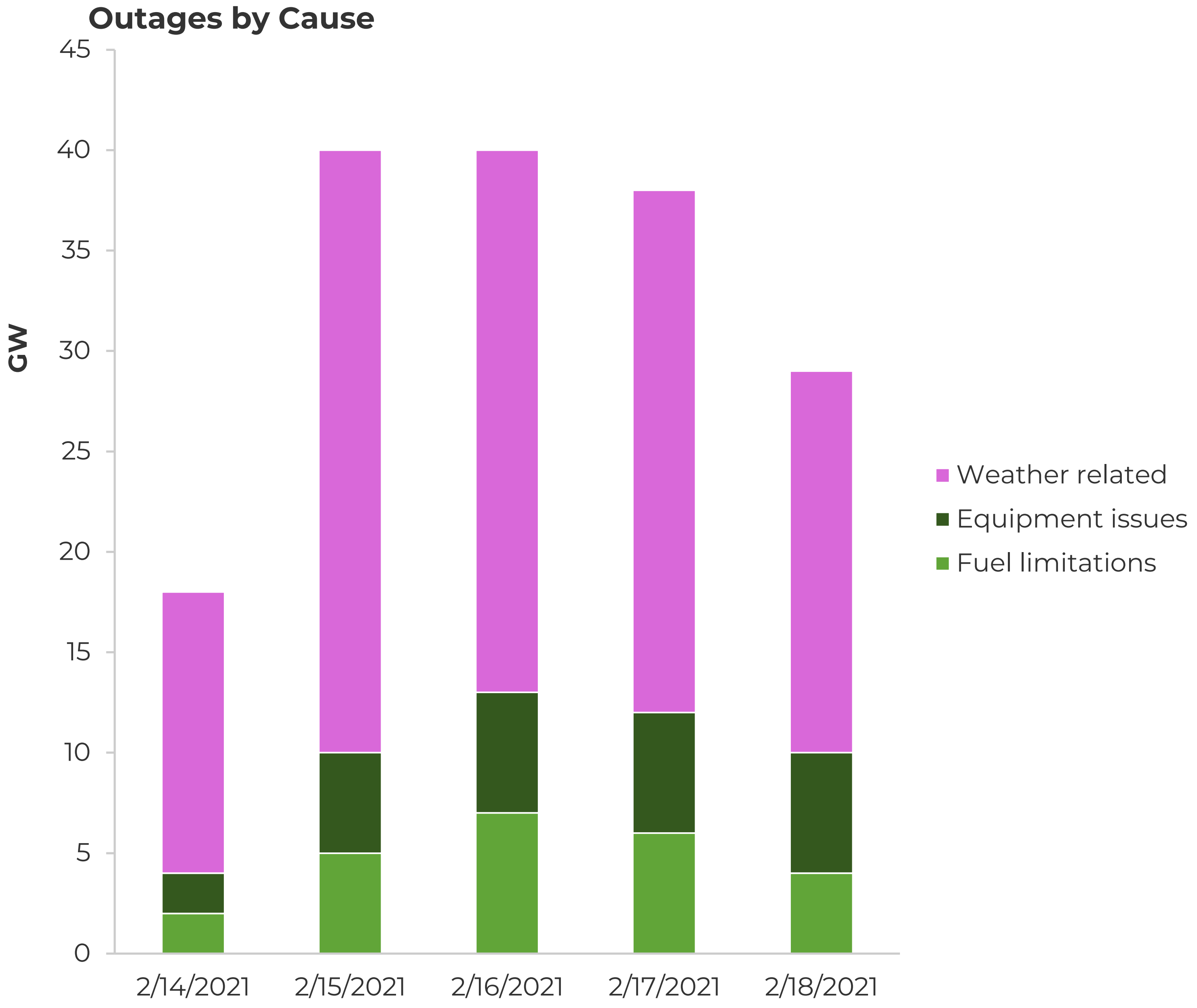
2 Levelized cost of storage

3 Energy storage strategies

In February 2021, winter storm Uri caused up to 70% of residents in Texas to lose power.

Power outages cost ERCOT billions — outdated infrastructure and centralized generation caused multiple blackouts statewide.

Energy storage would have significantly improved reliability of the grid.

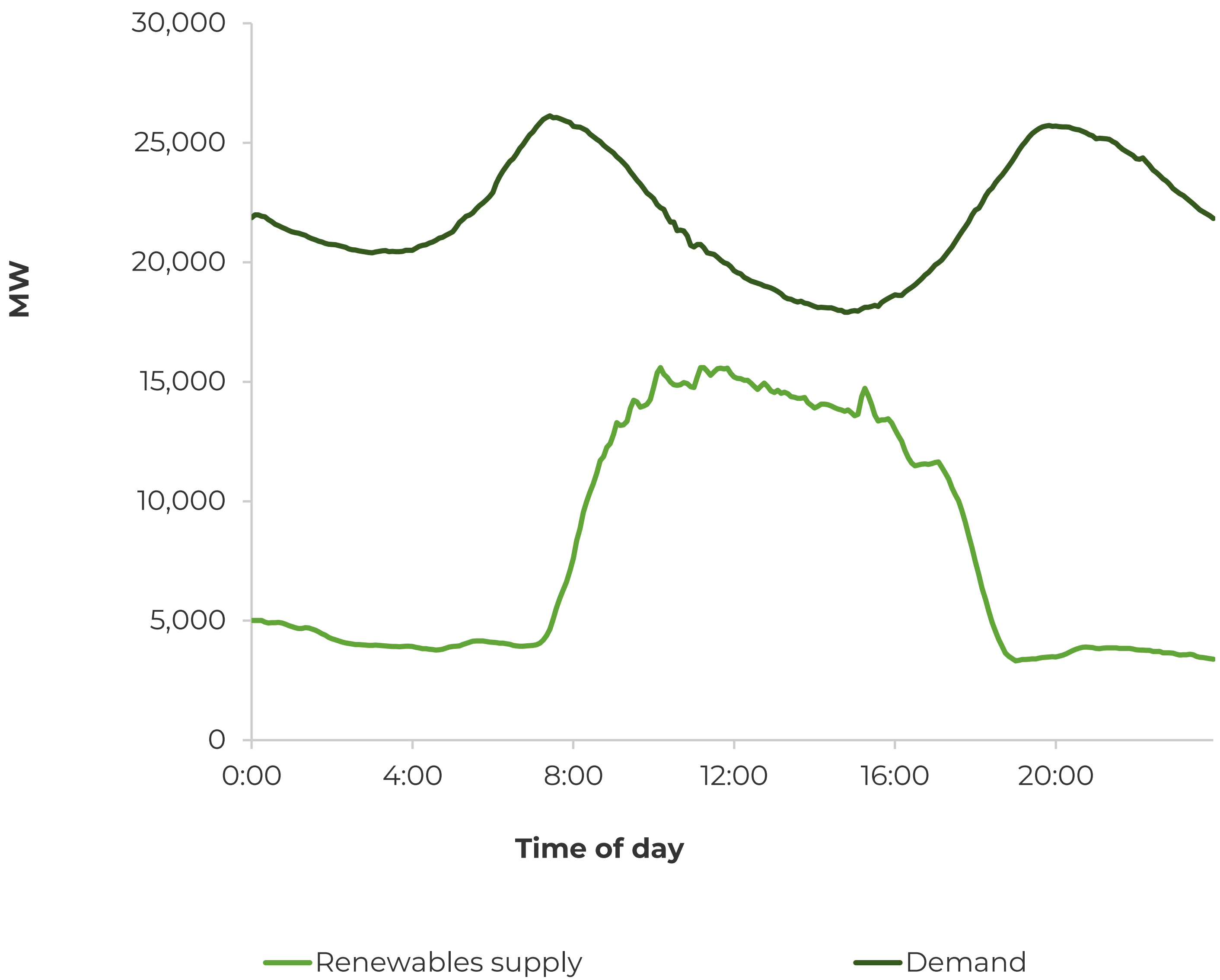


Source: ERCOT

Renewables challenge everyday reliability

Ancillary services like voltage regulation and frequency control require quick response and high efficiency.

CAISO Data for March 2023

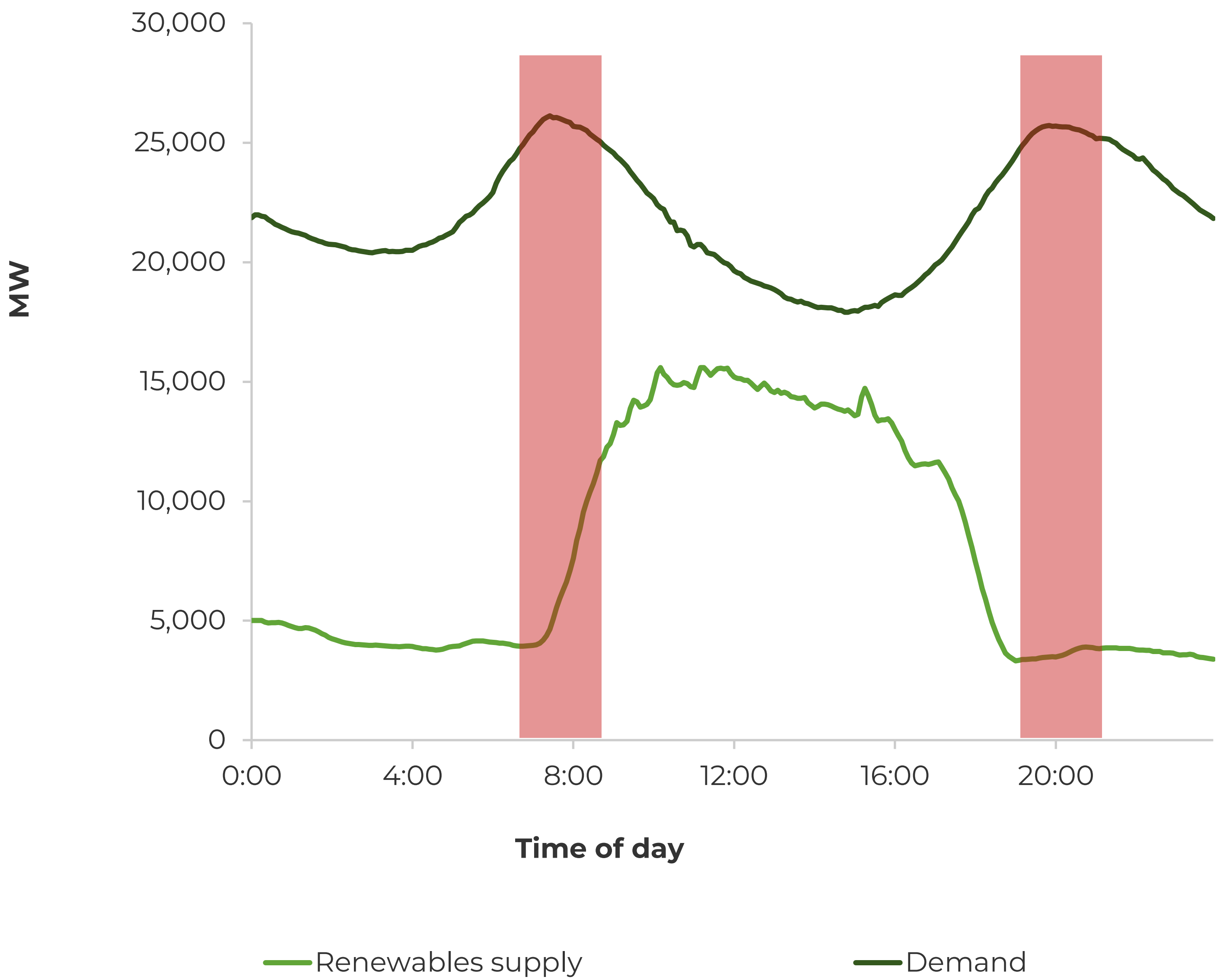


Source: CAISO

Renewables challenge everyday reliability

Peaking capacity applications need large-scale reserves of power.

CAISO Data for March 2023

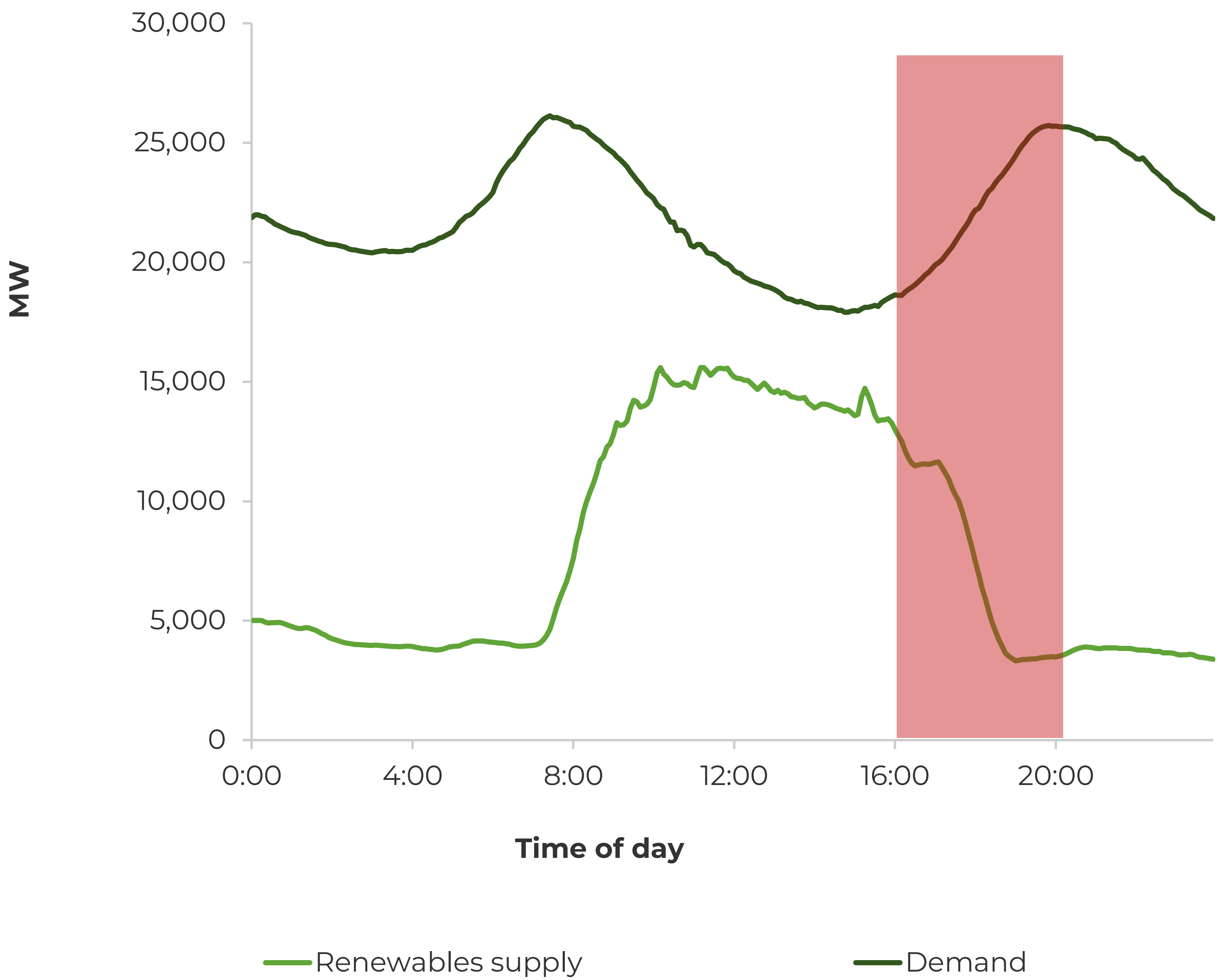


Source: CAISO

Renewables challenge everyday reliability

Renewables integration and backup address both short-term intermittency and multiday power shortages.

CAISO Data for March 2023



Source: CAISO

Energy storage technologies are varied, but most innovations fall into 5 categories

- **Closed electrochemical**
- **Redox flow**
- **Metal-air**
- **Compressed or liquefied air**
- **Pumped hydro**

High efficiencies and compact design allow modularity

Limited by cycle life and operating environment

Technologies include Li-ion, Na-ion, high-temperature NaS, and Zn-ion

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- Closed electrochemical
- **Redox flow**
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- Pumped hydro

Most technologies allow users to decouple power and energy

Potentially low-cost electrolytes, though hampered by low-energy densities

Major chemistries include vanadium, iron, zinc-bromine, and organic molecules

Energy storage technologies are varied, but most innovations fall into 5 categories

- Closed electrochemical
- Redox flow
- **Metal-air**
- Compressed or liquefied air
- Pumped hydro

Low-cost materials are single biggest driver for technology adoption

Limited cycle life and low efficiencies limit uses

Iron-air and zinc-air are best fit for energy storage applications

Energy storage technologies are varied, but most innovations fall into 5 categories

- Closed electrochemical
- Redox flow
- Metal-air
- **Compressed or liquefied air**
- Pumped hydro

Long lifetime of systems with deep discharges

Slow response rate due to system inertia

Technologies include compressed air, cryogenic liquefied air, and liquefied CO_2

Energy storage technologies are varied, but most innovations fall into 5 categories

- Closed electrochemical
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- **Pumped hydro**

Geographically limited and far from load

Economic at large scales with high efficiency

Most-deployed energy storage technology

Energy storage project developers are tasked with choosing a technology based on best technical and economic fit

Technology

- Technology maturity
- Deployment history
- Application fit

Economics

- **Levelized cost of storage (LCOS)**
- Upfront costs
- Revenue potential

LCOS provides a more holistic view of lifetime energy storage costs

Energy Storage Project Inputs

- System inputs
  - Discharge power (MW)
  - Discharge duration (h)
- Operational inputs
  - Cycles per year (#)
  - Project lifetime (y)
- Financial inputs
  - Discount factor (%)
  - Charging cost (USD)

Technology Inputs

- System inputs
  - Capital cost (USD)
  - Efficiency (%)
- Operational inputs
  - O&M cost (USD)
  - Replacement cost (USD)

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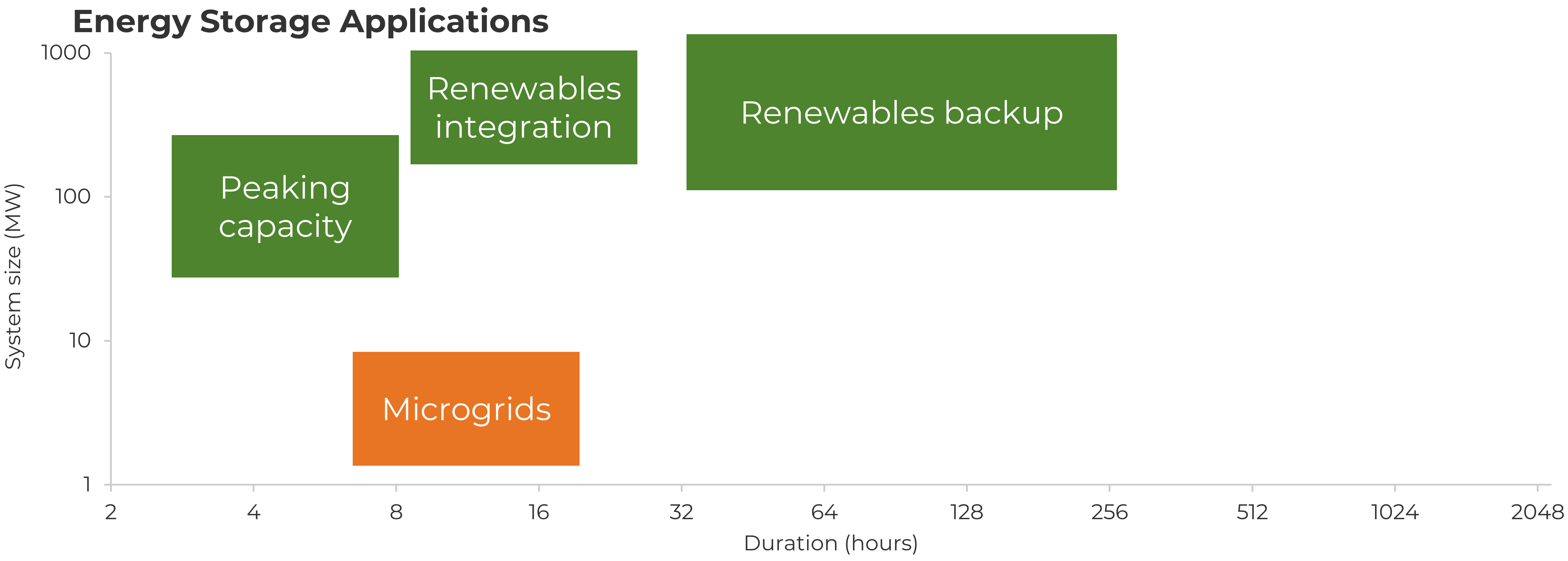
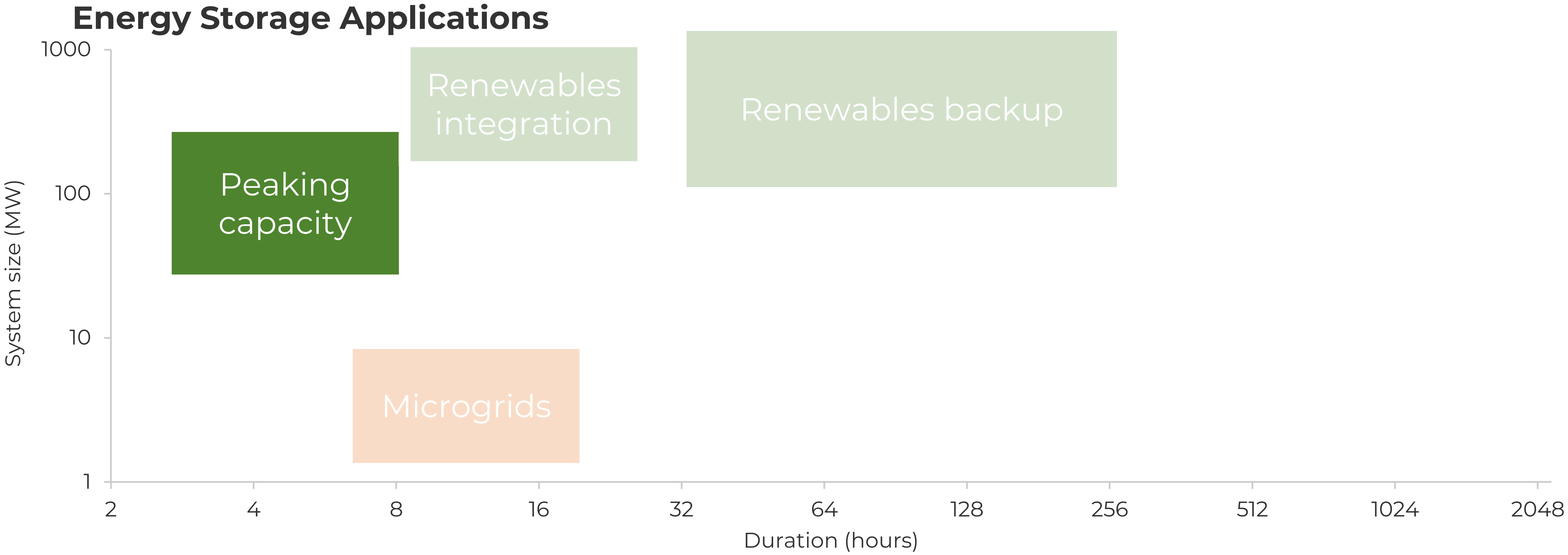
The largest opportunity for growth in energy storage corresponds to the rise of intermittent renewables

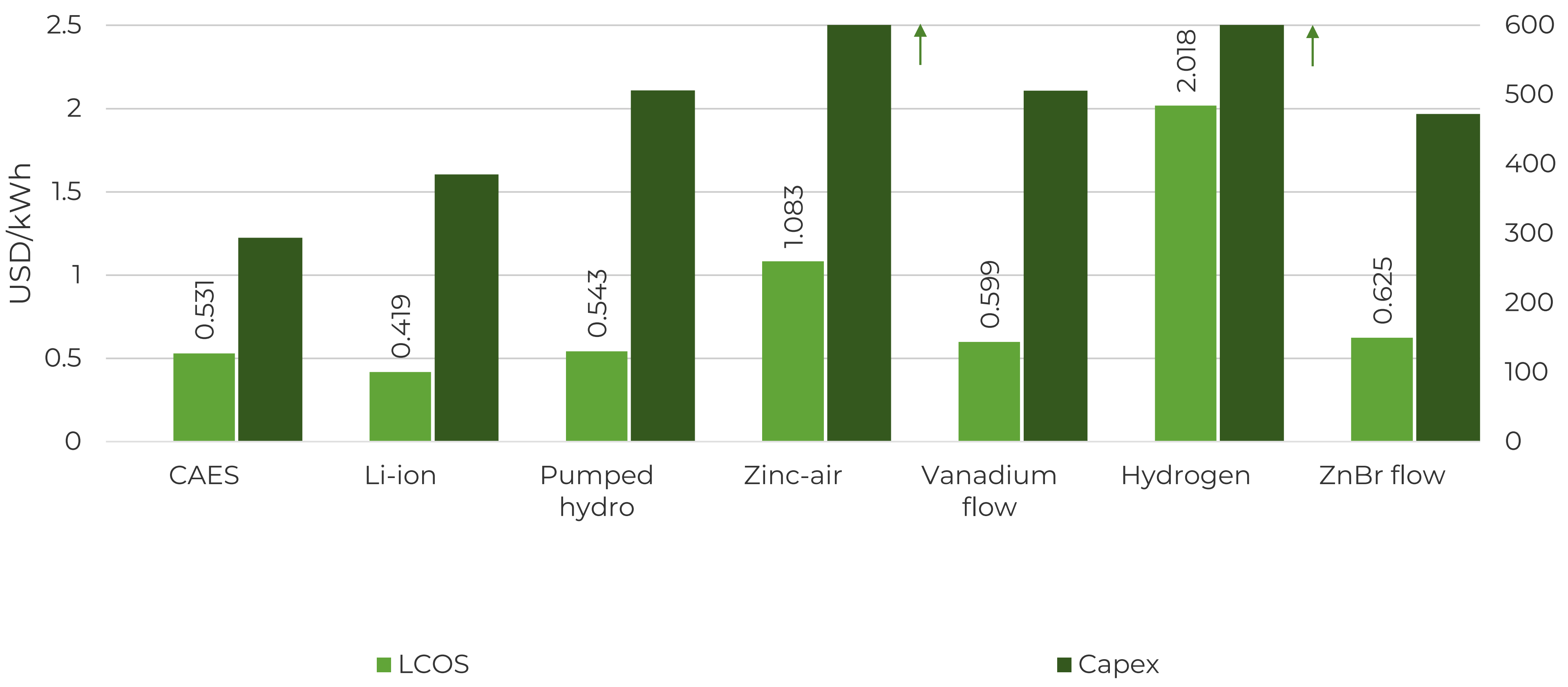


Peaking capacity plays a key role in managing unexpected demand

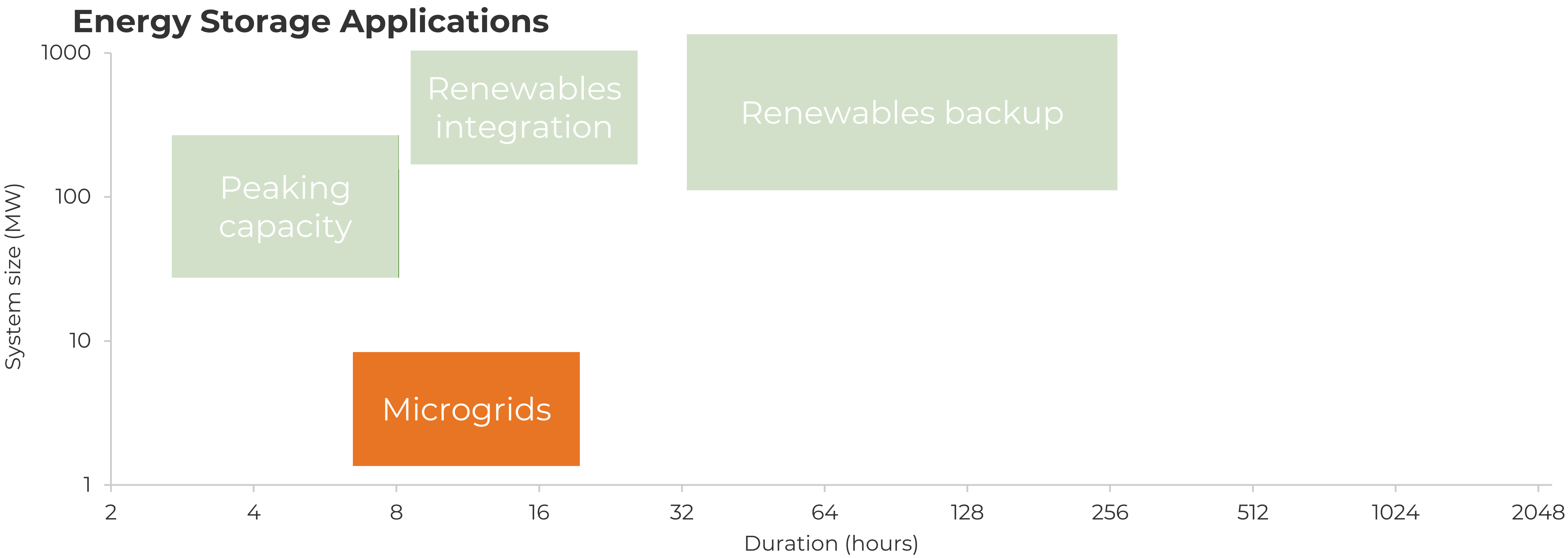


Even at large scale and low utilization, Li-ion batteries beat out mechanical energy storage

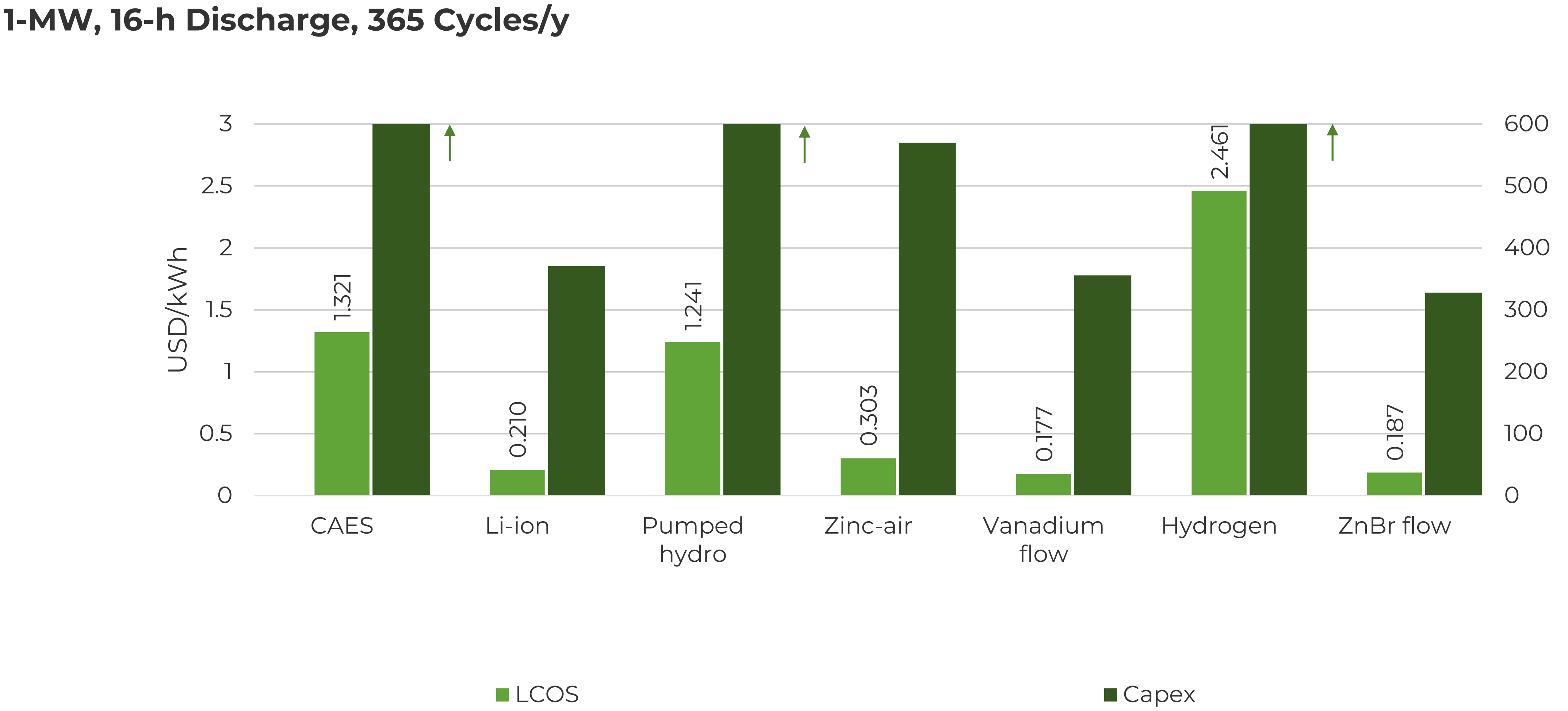
100-MW, 4-h Discharge, 120 Cycles/y



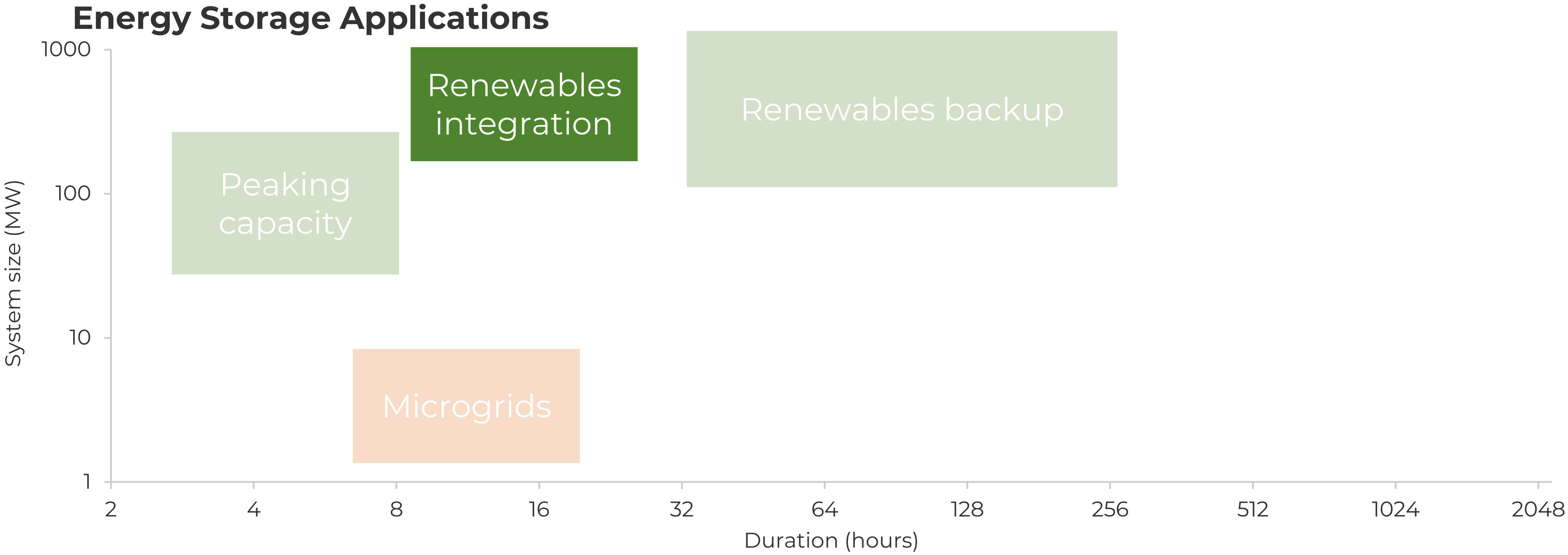
Microgrids will grow as utilities build more resilient grids



Flow batteries best suited for small microgrids rely on renewables

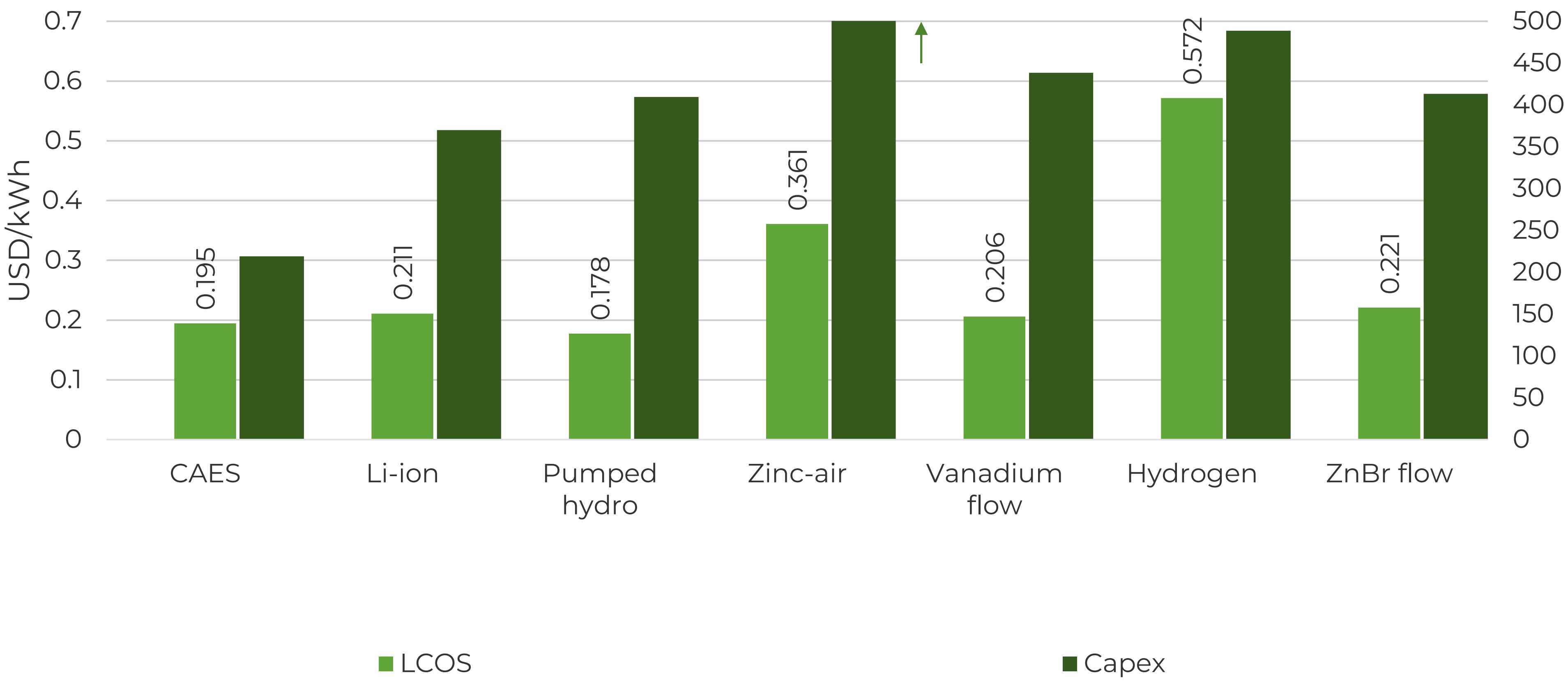


Renewables integration maintains steady output despite variability in renewable power generation

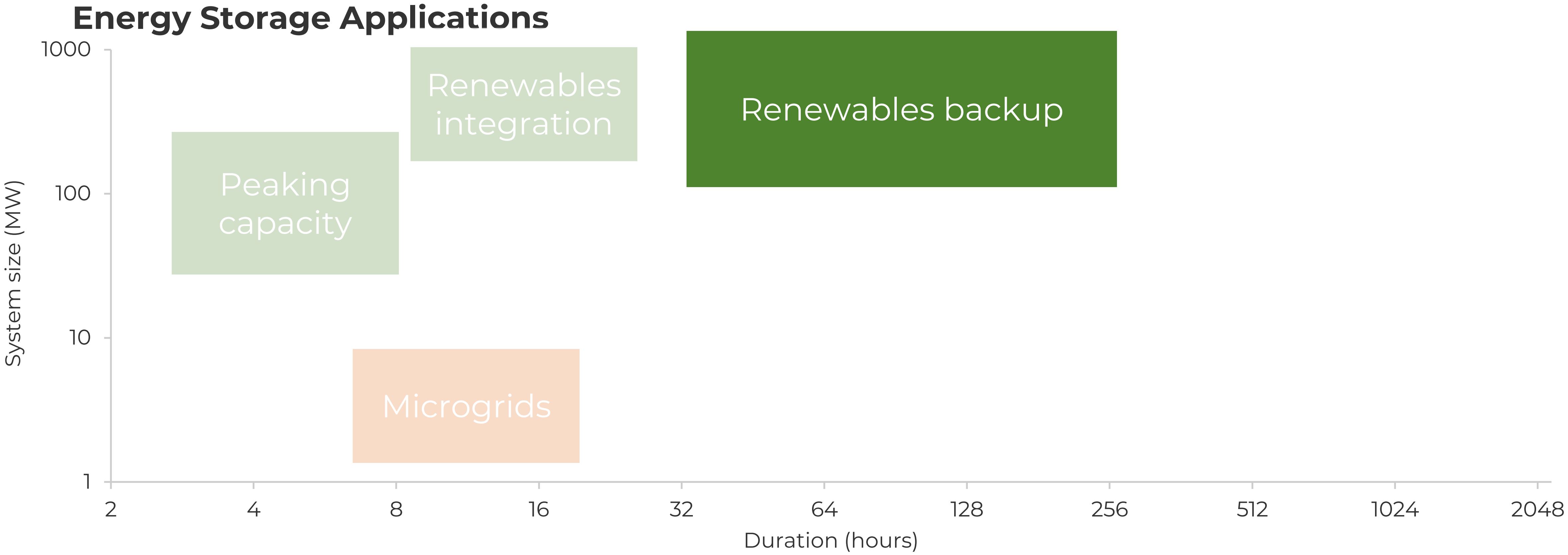


Technology choice for daily renewables integration will vary by project needs

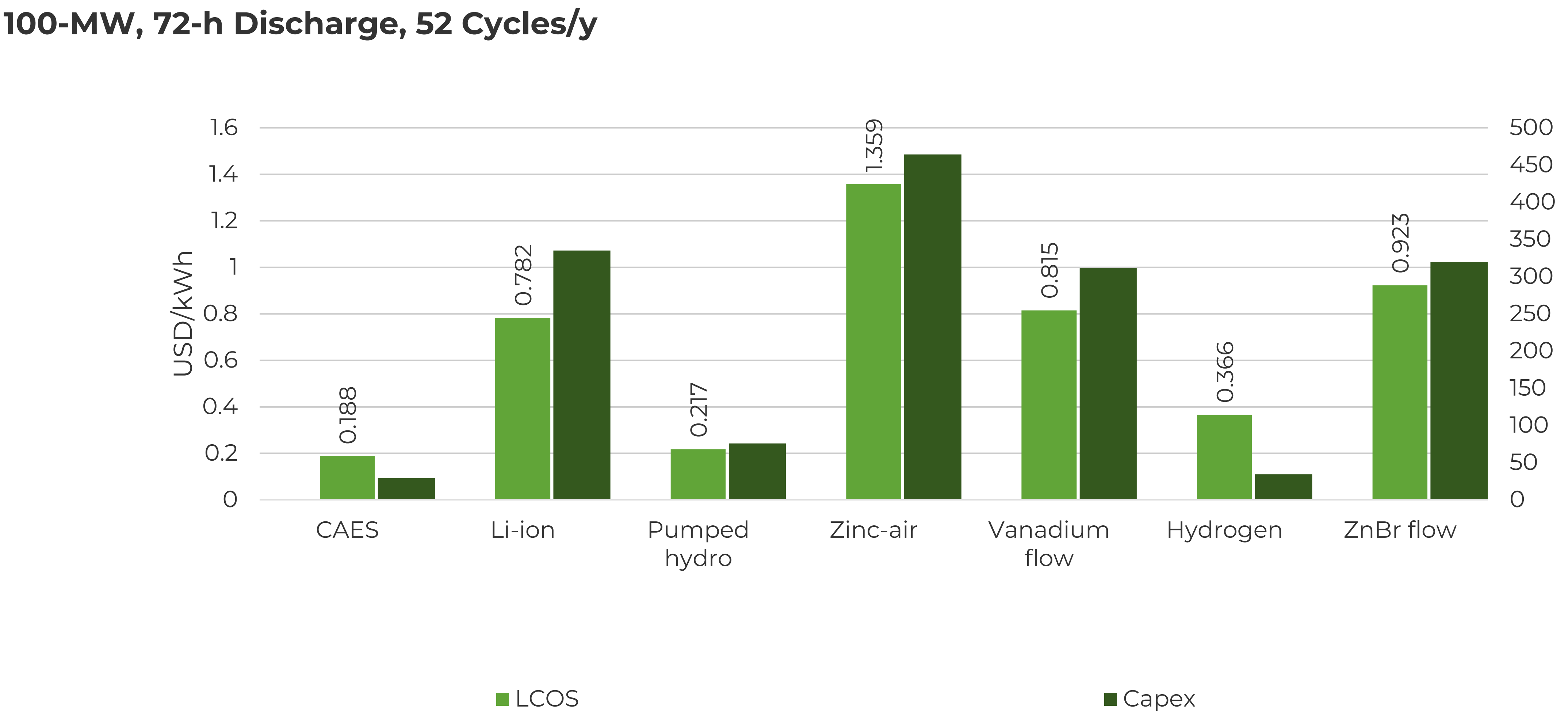
100-MW, 6-h Discharge, 365 Cycles/y



Renewables backup becomes critical as intermittent renewables make up a majority of power generation



Renewables backup works well for large-scale storage like CAES and pumped hydro



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As applications grow more diverse, project developers face a greater challenge of technology choice

Technology

- Technology maturity
- Deployment history
- Application fit

Economics

- LCOS
- Upfront costs
- Revenue potential

LCOS analysis reveals 3 key technologies in the long-duration landscape

Closed electrochemical

Redox flow

Compressed or liquefied air

Texas will need to find significant peaking capacity as demand increases

Image source: ERCOT

Energy storage is booming in Texas

In 2024, 7.5 GW of storage is to be added.

Image source: Hydrostor

Grid needs will evolve based on local energy requirements

Each grid will utilize energy storage differently, with renewables and peaking capacity dependent on environmental factors and power use.

Rapid growth in energy storage will be tied to certain applications.

Image source: CMBlu

Energy storage opportunities will depend on each player's strengths

Utilize government funding and commercial behind-the-meter deployments to act as pilot cases.

Equipment and materials suppliers can enable pathways to lower-cost novel technologies.

Image source: Enervenue

Key Takeaways:

1 **LCOS dominates technology choice, but other factors will remain important.**

Environment, applications, and technology maturity influence adoption and can be a critical tipping point between two competitive technologies.

2 **Energy storage choices are less diverse but require innovation.**

Costs are the determining factor in technology selection, driven up by technology challenges. Developments in this space that improve efficiency, energy density, and engineering flexibility are most important.

3 **Long-duration energy storage pilots are critical in the next few years.**

Grids with high output of intermittent renewables will require six or more hours of energy storage, and pilots will help novel technologies prove a competitive LCOS.

Thank you

A link of the webinar recording will be emailed within 24–48 hours.

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