Energy Storage in Our Clean Energy Future

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Trends
Energy storage is a tiny portion of our system today

U.S. installed power capacity by technology

Source: Bloomberg NEF
Growth in capacity will be mainly in renewables

U.S. installed power capacity by technology

Source: Bloomberg NEF. Note: Forecast is part of analysis part of New Energy Outlook 2018.
C2.2. In energy systems, modelled global pathways (considered in the literature) limiting global warming to 1.5°C with no or limited overshoot (for more details see Figure SPM.3b), generally meet energy service demand with lower energy use, including through enhanced energy efficiency, and show faster electrification of energy end use compared to 2°C (high confidence). In 1.5°C pathways with no or limited overshoot, low-emission energy sources are projected to have a higher share, compared with 2°C pathways, particularly before 2050 (high confidence). In 1.5°C pathways with no or limited overshoot, renewables are projected to supply 70–85% (interquartile range) of electricity in 2050 (high confidence). In electricity generation, shares of nuclear and fossil fuels with carbon dioxide capture and storage (CCS) are modelled to increase in most 1.5°C pathways with no or limited overshoot. In modelled 1.5°C pathways with limited or no overshoot, the use of CCS would allow the electricity generation share of gas to be approximately 8% (3–11% interquartile range) of global electricity in 2050, while the use of coal shows a steep reduction in all pathways and would be reduced to close to 0% (0–2%) of electricity (high confidence). While acknowledging the challenges, and differences between the options and national circumstances, political, economic, social and technical feasibility of solar energy, wind energy and electricity storage technologies have substantially improved over the past few years (high confidence). These improvements signal a potential system transition in electricity generation (Figure SPM.3b) (2.4.1, 2.4.2, Figure 2.1, Table 2.6, Table 2.7, Cross-Chapter Box 6 in Chapter 3, 4.2.1, 4.3.1, 4.3.3, 4.5.2).
“The 100 Percent Clean Energy Act”

California's Electricity Dreams Still Need Natural Gas

Energy Storage to Play Key Role in Reaching California Target of 100% Zero-Emission Electricity by 2045 and Beyond

Can Calif. Go All Green Without a Western RTO?

California's 100% 'Clean Energy' Law Omits Some Details
Technology
Largest sources of lithium-ion battery demand over time

Lithium-ion battery demand by segment

GWh/year

Source: Bloomberg NEF, Avicenne, Brodd; Buchmann (2003), Takashita (2007)
Largest sources of lithium-ion battery demand over time

Lithium-ion battery demand by segment

GWh/year
1,600
1,400
1,200
1,000
800
600
400
200
0

Source: Bloomberg NEF, Avicenne, Brodd; Buchmann (2003), Takashita (2007)
Largest sources of lithium-ion battery demand over time

Lithium-ion battery demand by segment

GWh/year

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Electric vehicles
Stationary storage

Source: Bloomberg NEF, Avicenne, Brodd; Buchmann (2003), Takashita (2007)
Largest sources of lithium-ion battery demand over time

Source: Bloomberg NEF, Avicenne, Brodd; Buchmann (2003), Takashita (2007)
How much grid lithium-ion required by 2030?

“SCE models showed that in order to reduce its grid-based GHG emissions to 28 million metric tons by 2030, California load-serving entities would need to procure an additional 9,604 MW of energy storage.”

9,604 MW x 5h = 48 GWh (1 Gigafactory)

x $200/kWh = $9.6B

Source: utilitydive.com

Source: Google

Source: BloombergNEF
EVs demand high energy density and low cost

Energy density by battery type

High energy density roadmap depends on lithium metal

Drivers are energy density and cost

Grid storage options are much broader than lithium-ion

But can any compete with declining lithium-ion battery costs?

Lithium-ion battery cathode chemistry mix outlook

**Passenger electric vehicles**

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**Utility-scale energy storage**

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Source: Bloomberg NEF

811 = 8x more Nickel than Manganese & Cobalt

111 = equal parts Nickel Manganese Cobalt
Economics
California challenge: Fading value of solar

Source: California Independent System Operator (CAISO)
How batteries can bolster solar economics

Source: Bloomberg NEF. Note: Shows CAISO SP15 Day-Ahead power prices
How batteries can bolster solar economics

No batteries

Source: Bloomberg NEF. Note: Shows CAISO SP15 Day-Ahead power prices
How batteries can bolster solar economics

No batteries

6GWh of batteries

Source: Bloomberg NEF. Note: Shows CAISO SP15 Day-Ahead power prices
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Battery dispatch

Source: Bloomberg NEF. Note: Shows CAISO SP15 Day-Ahead power prices
### Batteries in wholesale markets deliver value in different timescales

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**Additional use-cases will add complexity and value**
Energy storage system costs are complex

Battery cost forecast ($/kWh)

Source: Bloomberg NEF
Curtailment

Varies over months, not just hours and days

Growing rapidly with increased renewable penetration
Lower capital cost targets for long duration storage

Grid storage spans 3 orders of magnitude in time scale

 Fewer cycles over life requires lower storage capex to be economical on a levelized cost basis

Assumes:
- 20yr life
- 10% discount rate
Lower capital cost targets for long duration storage

Current storage technologies too expensive for long duration storage
Lower capital cost targets for long duration storage

New battery chemistries with <$20/kWh capital cost required for multi-day storage and beyond
What if you could have grid storage at 1/10\textsuperscript{th} the cost of lithium-ion with no materials constraints?

Super abundant materials like sodium, sulfur
Global Storage Potential: Pumped Hydro vs. Aqueous Sulfur

Pumped Hydro Facility: Ludington, Michigan
Volume: 39M m³ of Water
Area: 3.4 km²
Storage: 1.9 GW/15 GWh

Global Pumped Hydro:
~170 GW/2 TWh Installed

Berri Gas Plant Sulfur Pyramid: Al Jubayl, Saudi Arabia
Volume: 1.6M m³ Sulfur (70% of KSA annual production)
Area: 0.171 km²
Storage: 24 GW/1.2 TWh Storage Potential

Global Sulfur Resource:
Annual Production: 69 megatons* - 0.5 GW/25 TWh storage potential

Storage at Giga Scale

Today’s battery technology for transportation

$200/kWh

Tomorrow’s battery technology for grid storage

Looks more like a chemical plant $<20/kWh
Key takeaways

- Grids are becoming increasingly renewable and storage is essential to the clean energy future.
- It will add complexity and value.
- We will need lower-cost, longer-duration storage.
- Multiple technologies will be needed beyond lithium-ion batteries.
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