Energy Storage in Our Clean Energy Future

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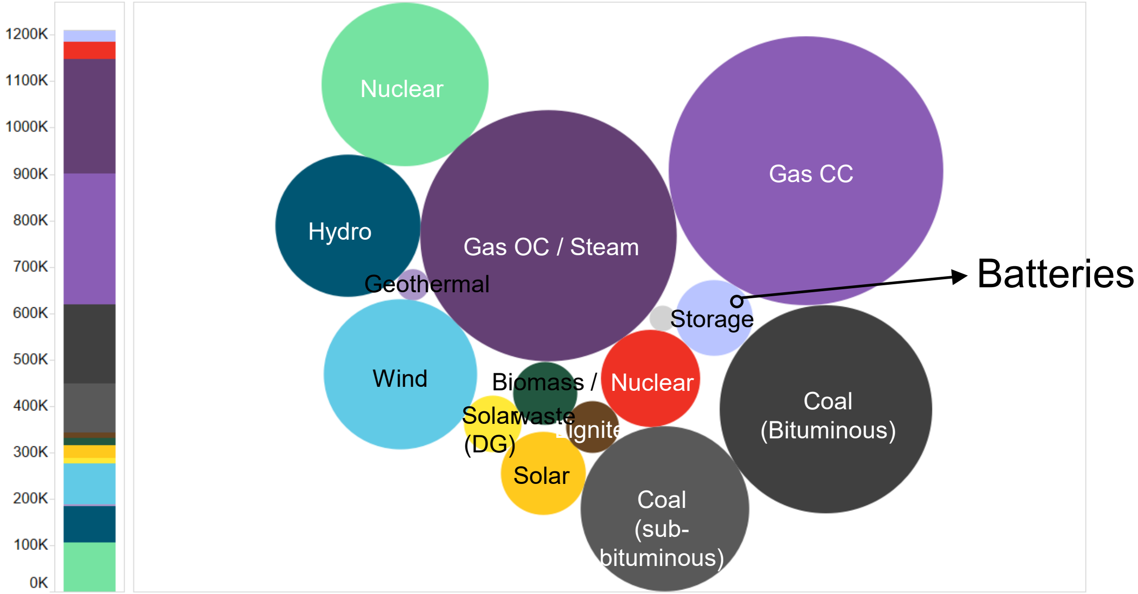
October 17, 2018

BloombergNEF

Trends

Energy storage is a tiny portion of our system today

U.S. installed power capacity by technology



Source: Bloomberg NEF

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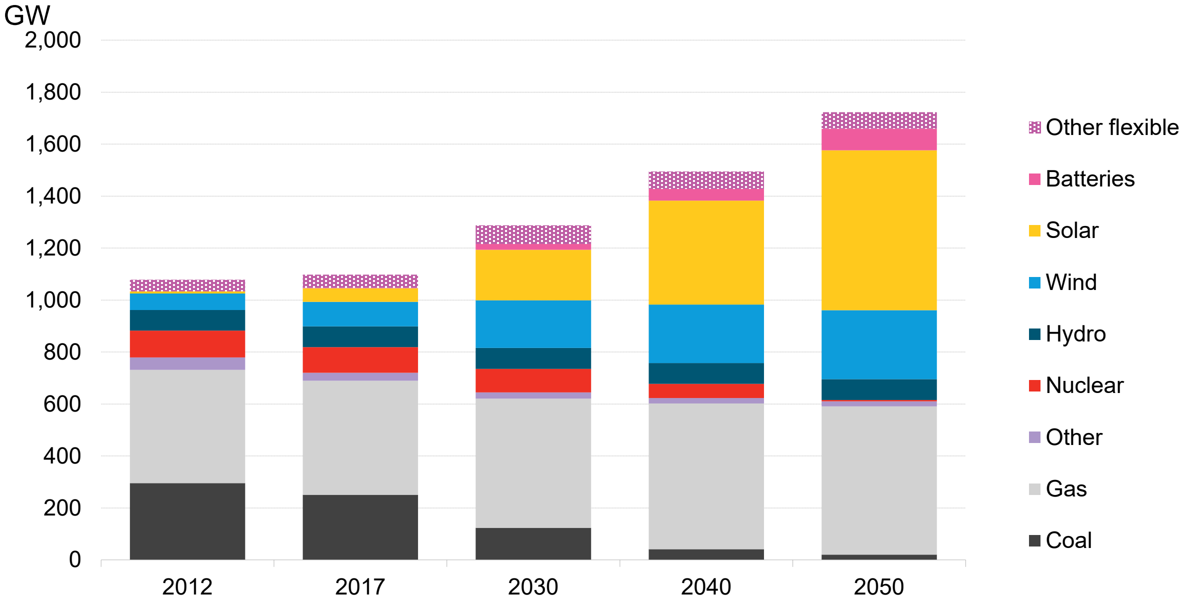
Growth in capacity will be mainly in renewables

U.S. installed power capacity by technology



Source: Bloomberg NEF. Note: Forecast is part of analysis part of New Energy Outlook 2018.

Limiting global warming to 1.5°C

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"

Forbes Sep 14, 2018, 09:02am

California's Electricity Dreams Still Need Natural Gas

ENERGY® STORAGE NORTH AMERICA

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

RTO Insider

Can Calif. Go All Green Without a Western RTO?

October 7, 2018

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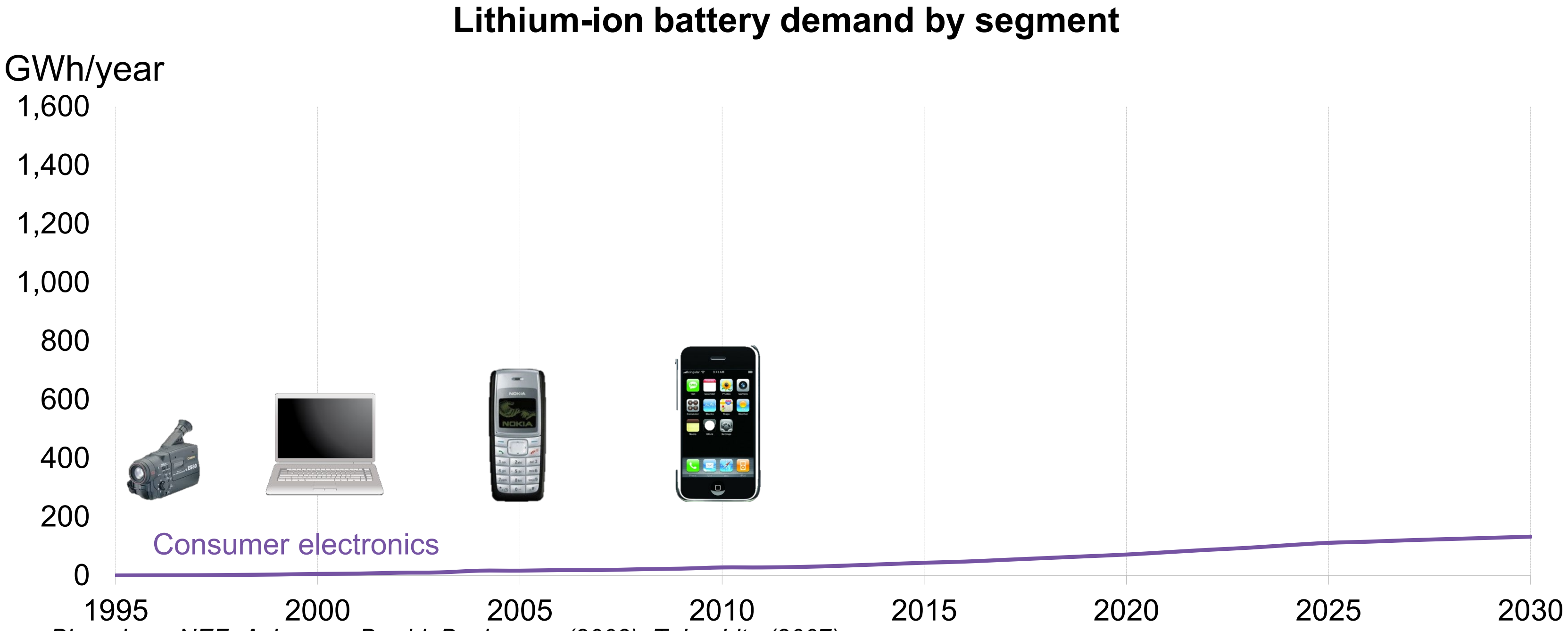
California's 100% 'Clean Energy' Law Omits Some Details

by Stephen Munro / 13 Sep 2018

Technology

Largest sources of lithium-ion battery demand over time



Source: Bloomberg NEF, Avicenne, Brodd; Buchmann (2003), Takashita (2007)

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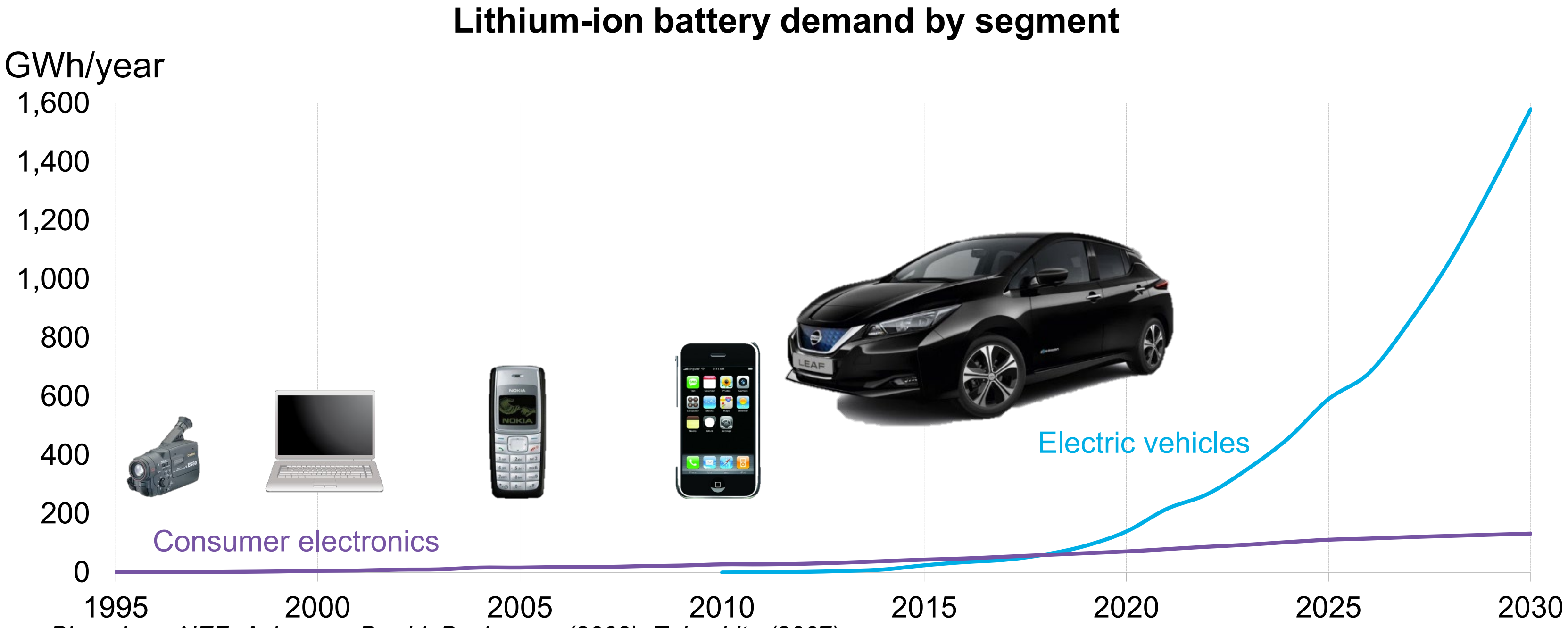
Largest sources of lithium-ion battery demand over time



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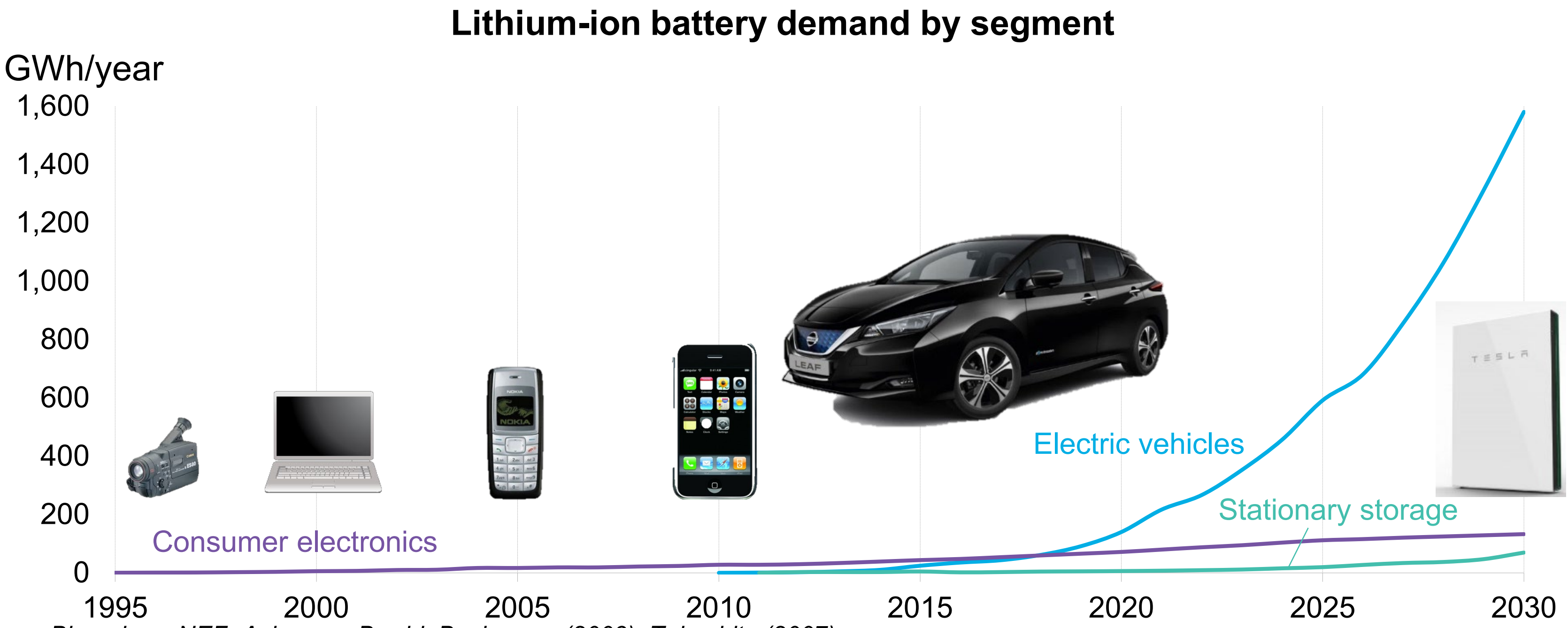
Largest sources of lithium-ion battery demand over time



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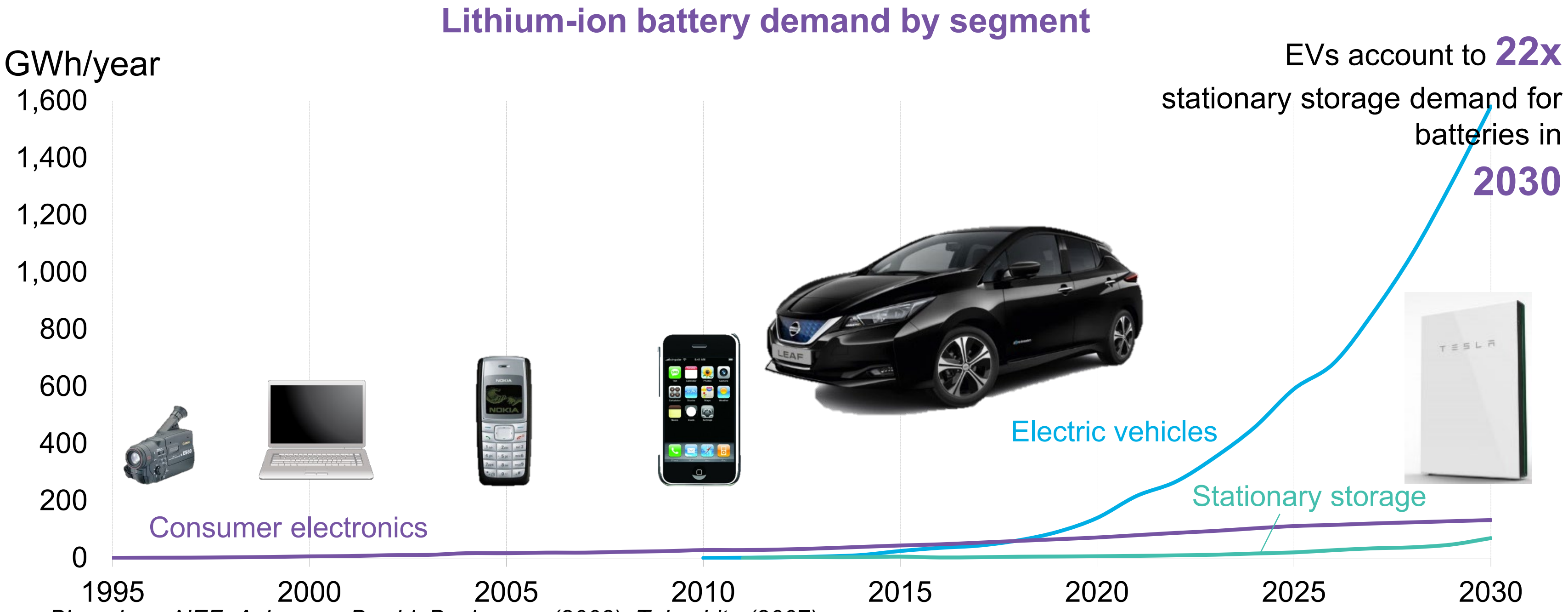
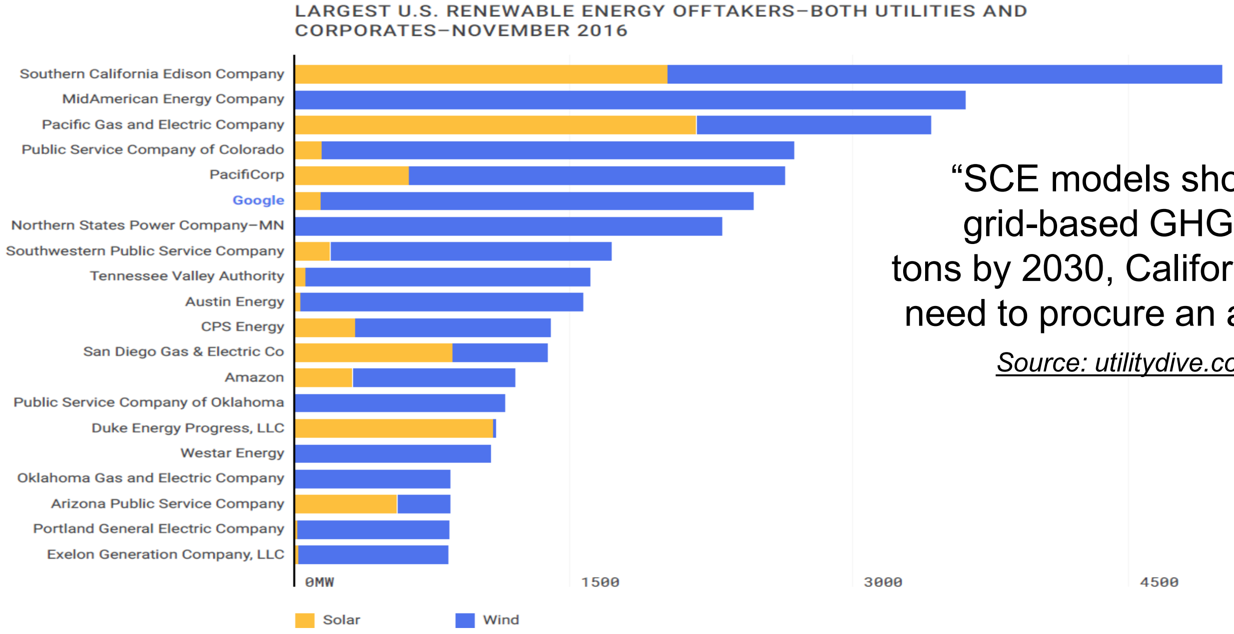
Largest sources of lithium-ion battery demand over time



Source: Bloomberg NEF, Avicenne, Brodd; Buchmann (2003), Takashita (2007)

How much grid lithium-ion required by 2030?



Source: Google

"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."

Source: utilitydive.com

9,604 MW x 5h =

48 GWh (1 Gigafactory)

x $200/kWh =

$9.6B

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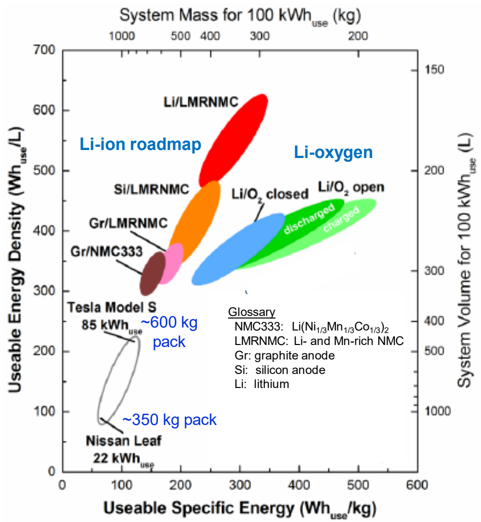
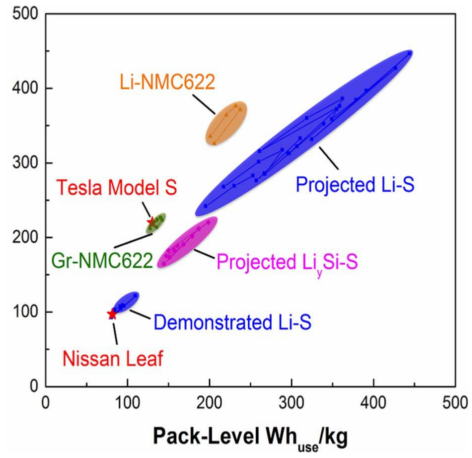
EVs demand high energy density and low cost

Energy density by battery type





High energy density roadmap depends on lithium metal

Drivers are energy density and cost

Source: K.G. Gallagher et al, Energy Environ. Sci, 7, 1555 (2014), D. Eroglu et al., J. Electrochem. Soc., 162, A982 (2015)

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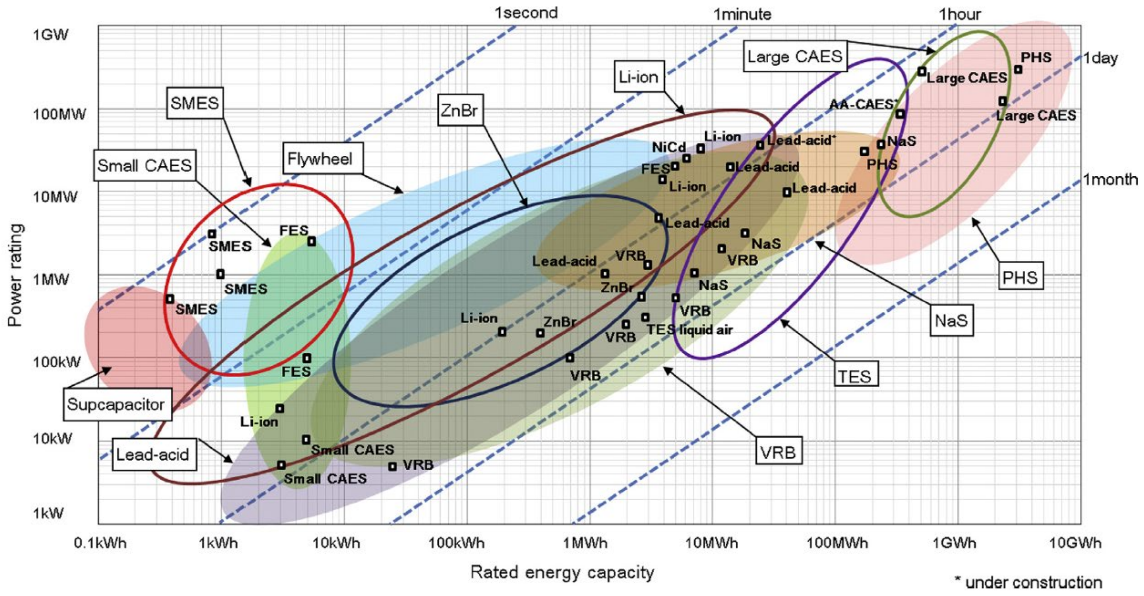
Grid storage options are much broader than lithium-ion

Battery technology energy and power ratings



Source: Applied Energy 137 (2015) 511–536.

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

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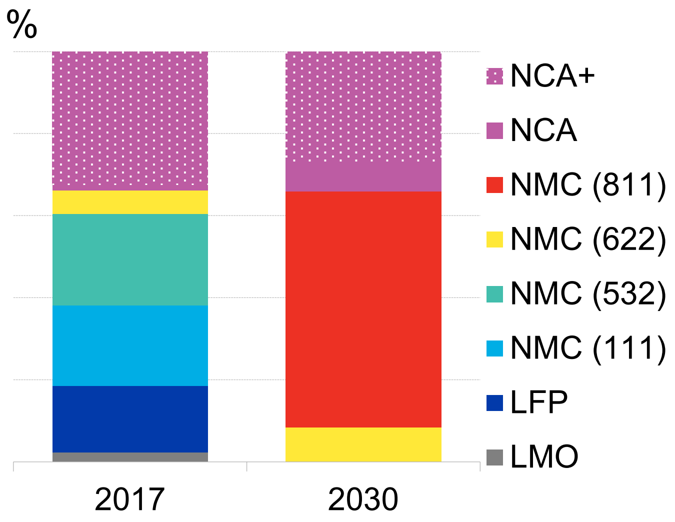
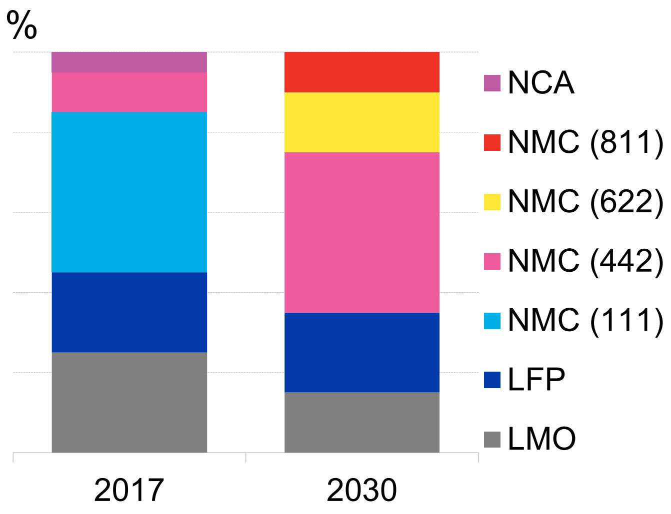
Lithium-ion battery cathode chemistry mix outlook

Passenger electric vehicles



Source: Bloomberg NEF

Utility-scale energy storage



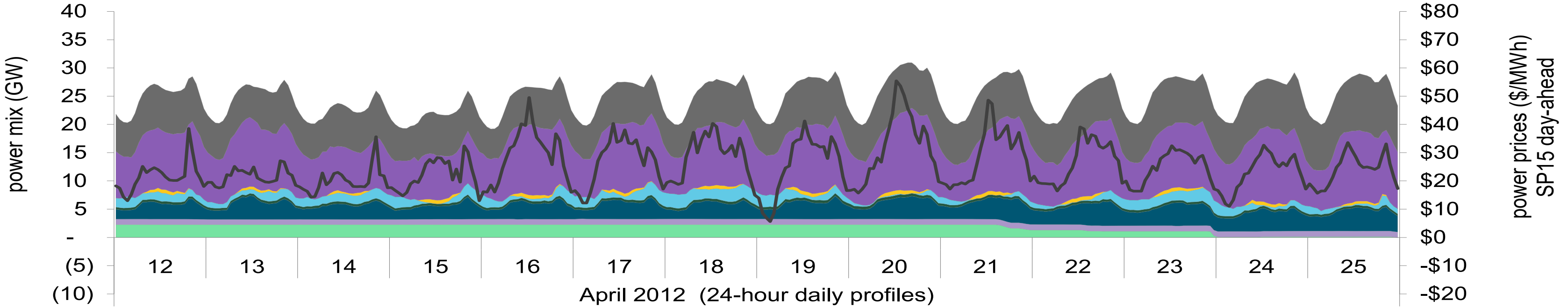
Source: Bloomberg NEF

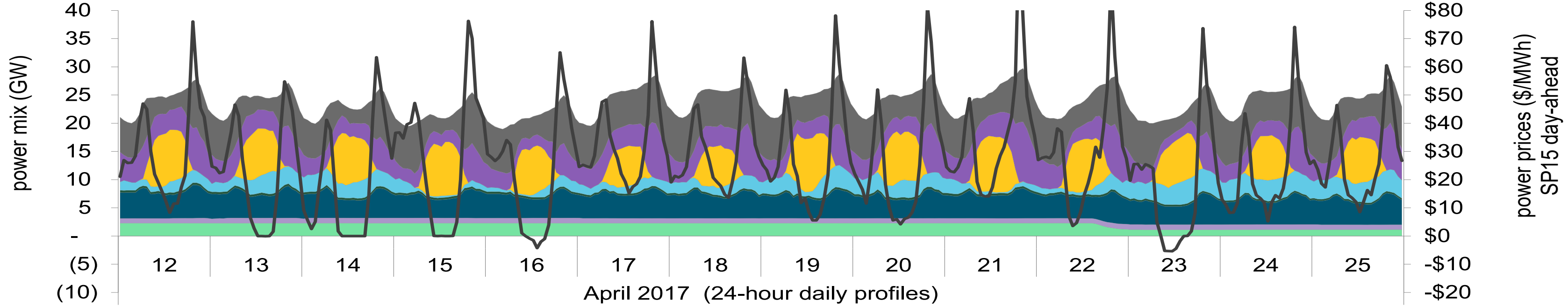
811 = 8x more **N**ickel than **M**anganese & **C**obalt

111 = equal parts **N**ickel **M**anganese **C**obalt

Economics

California challenge: Fading value of solar





Source: California Independent System Operator (CAISO)

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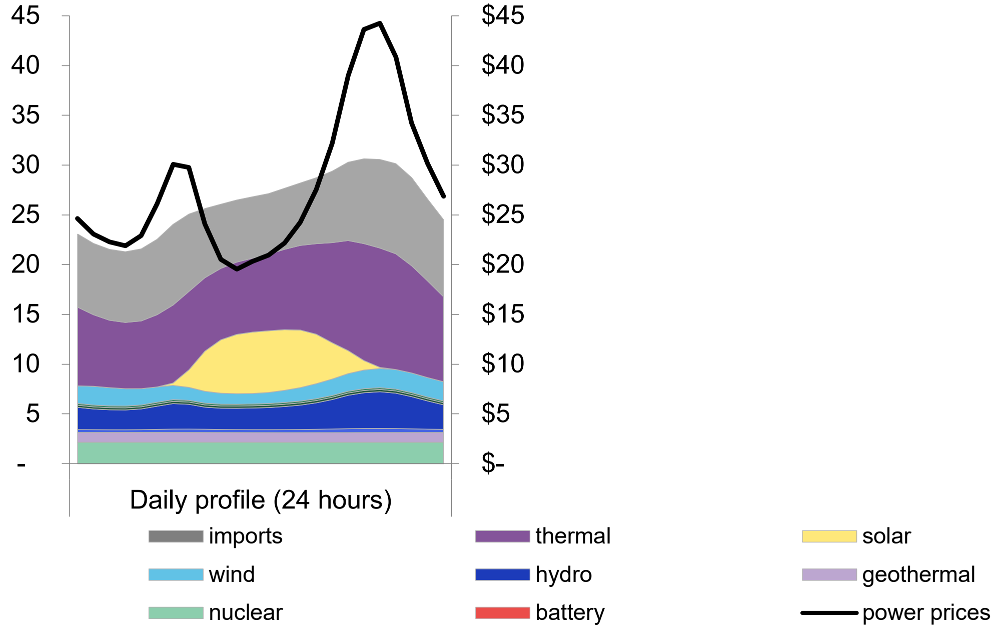
How batteries can bolster solar economics

No batteries



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

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How batteries can bolster solar economics

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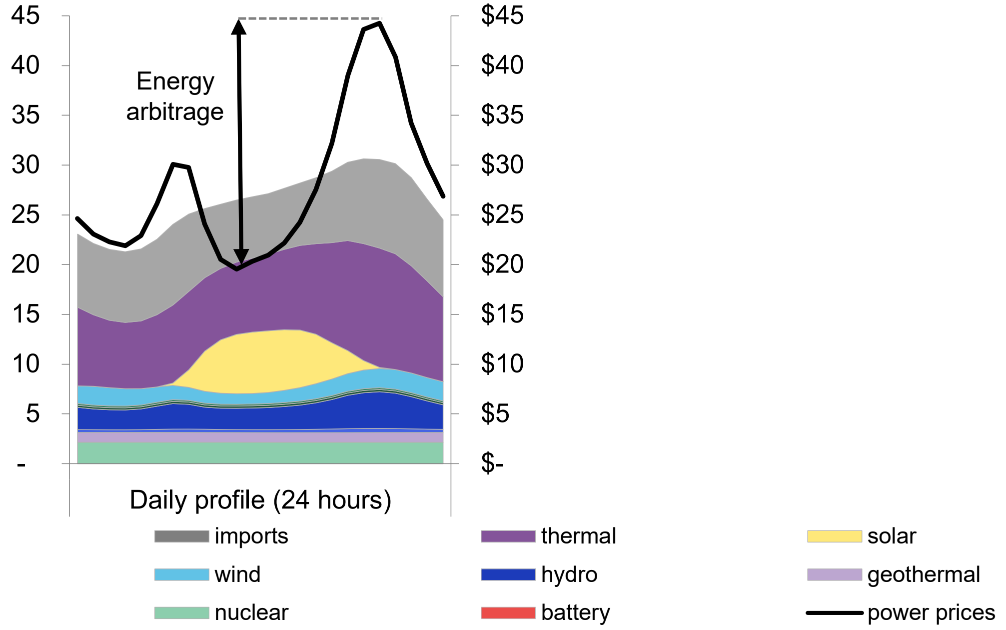

Source: Bloomberg NEF. Note: Shows CAISO SP15 Day-Ahead power prices

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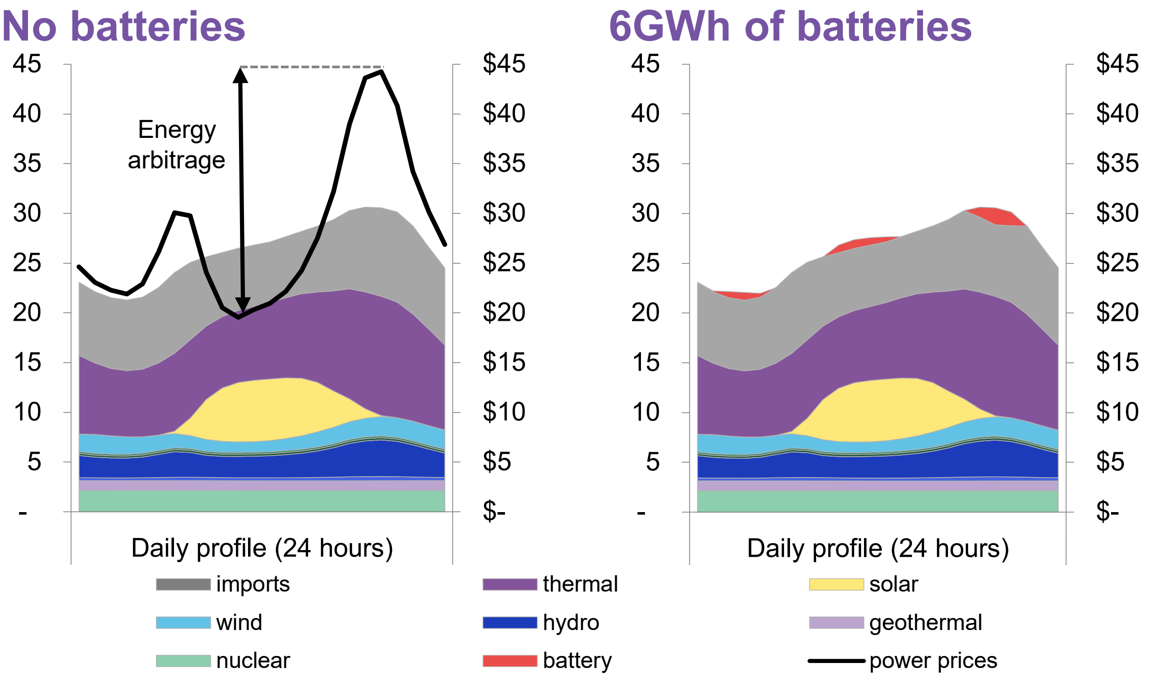
How batteries can bolster solar economics

No batteries / 6GWh of batteries

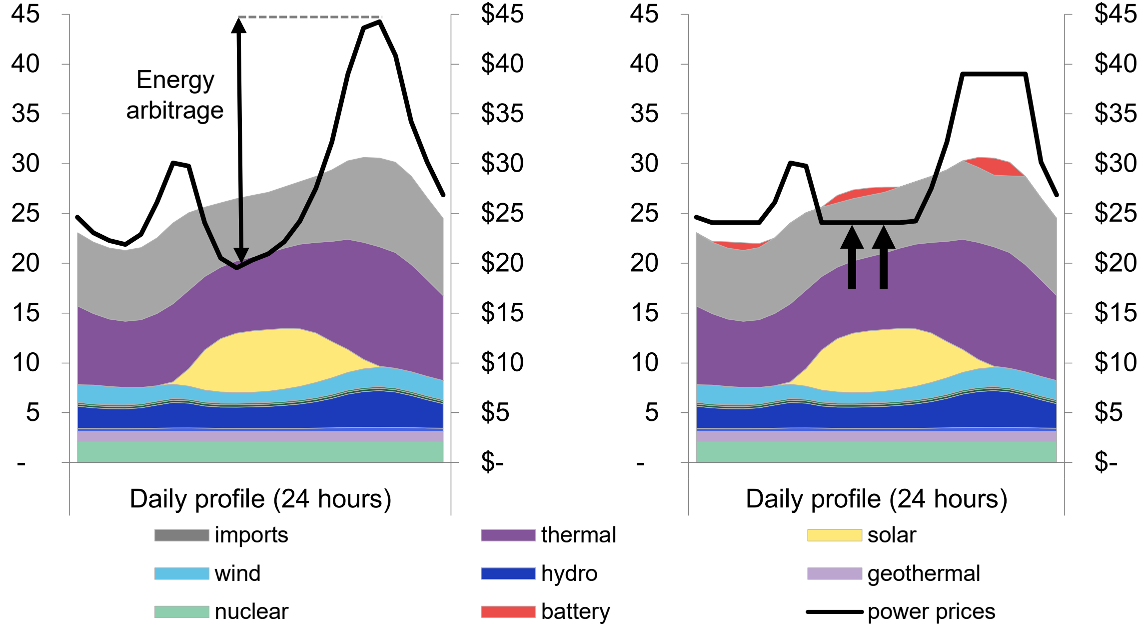


Source: Bloomberg NEF. Note: Shows CAISO SP15 Day-Ahead power prices

How batteries can bolster solar economics

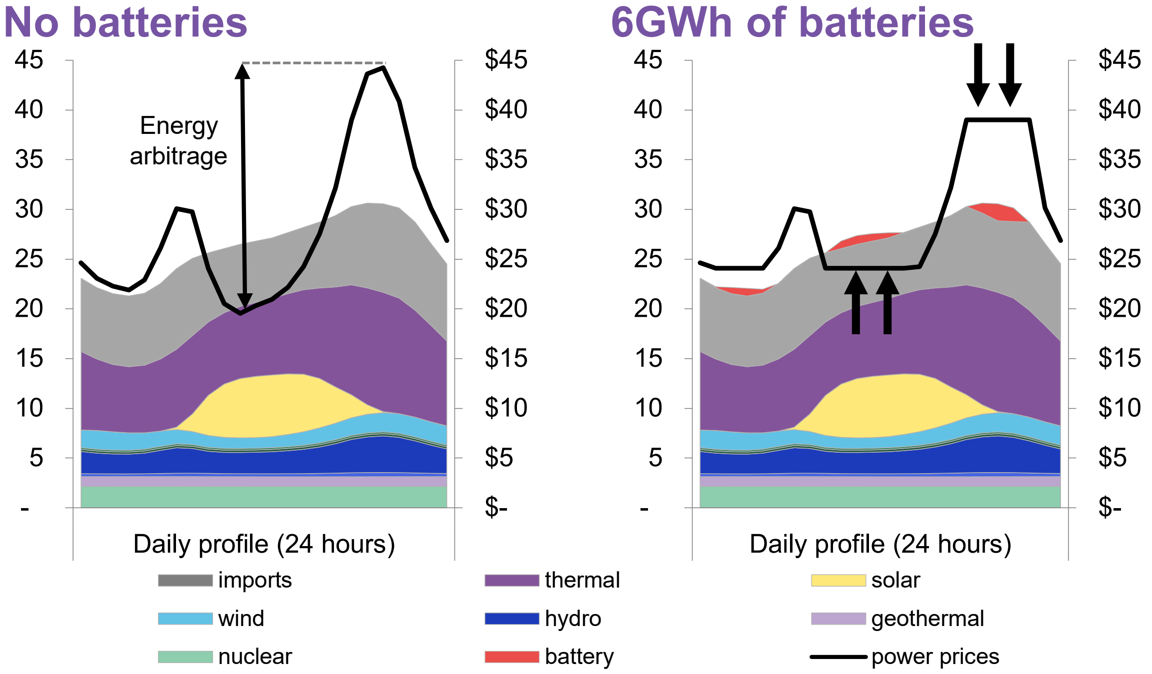
No batteries

6GWh of batteries



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

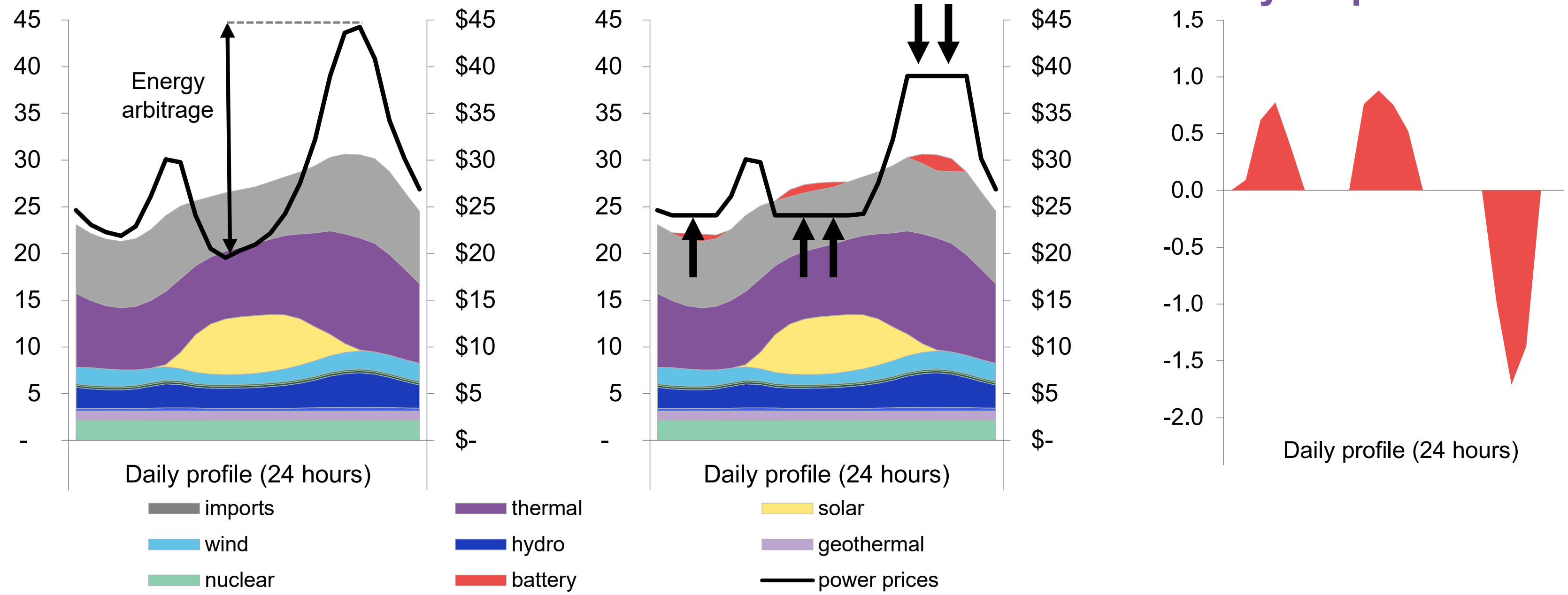
How batteries can bolster solar economics



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

How batteries can bolster solar economics

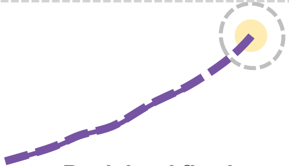
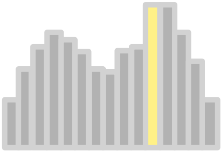
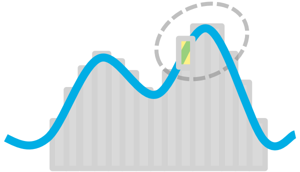
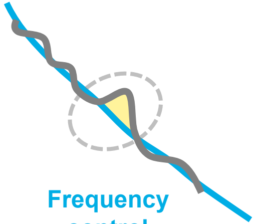
No batteries | 6GWh of batteries | Battery dispatch



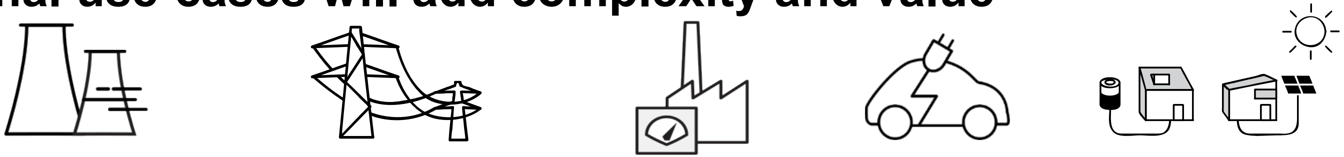
Source: Bloomberg NEF. Note: Shows CAISO SP15 Day-Ahead power prices

Batteries in wholesale markets deliver value in different timescales

Market	Resource Adequacy Capacity markets	Energy (Day-Ahead)	Energy (Real-Time)	Ancillary Services
Delivery window	Years	Hours	Minutes	Seconds
	Peak load firming	Daily dispatch	Intra-hourly adjustments	Frequency control
	Passive market	Active markets		

Additional use-cases will add complexity and value



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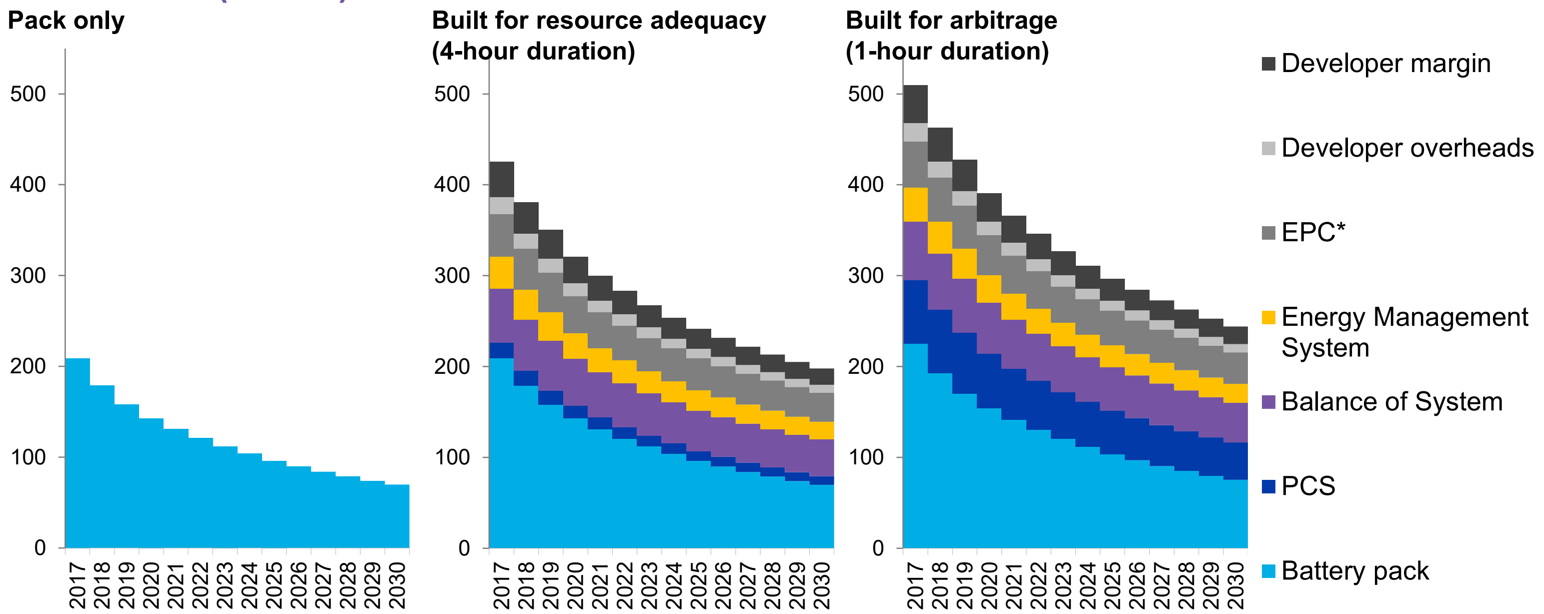
Energy storage system costs are complex

Battery cost forecast ($/kWh)



Source: Bloomberg NEF

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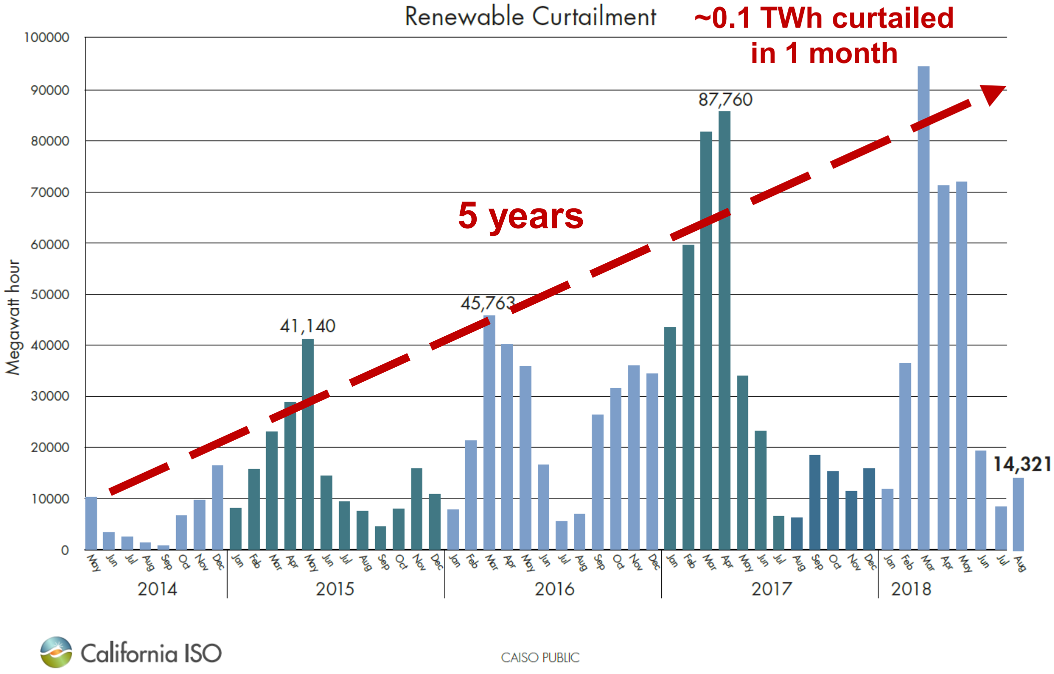
Curtailment

Varies over months, not just hours and days

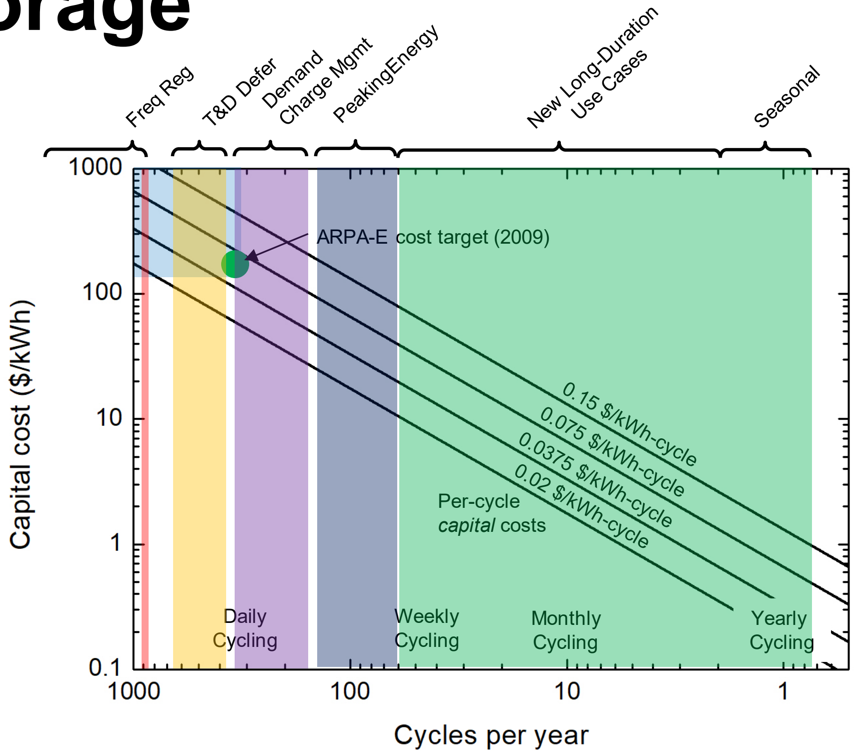
Growing rapidly with increased renewable penetration



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

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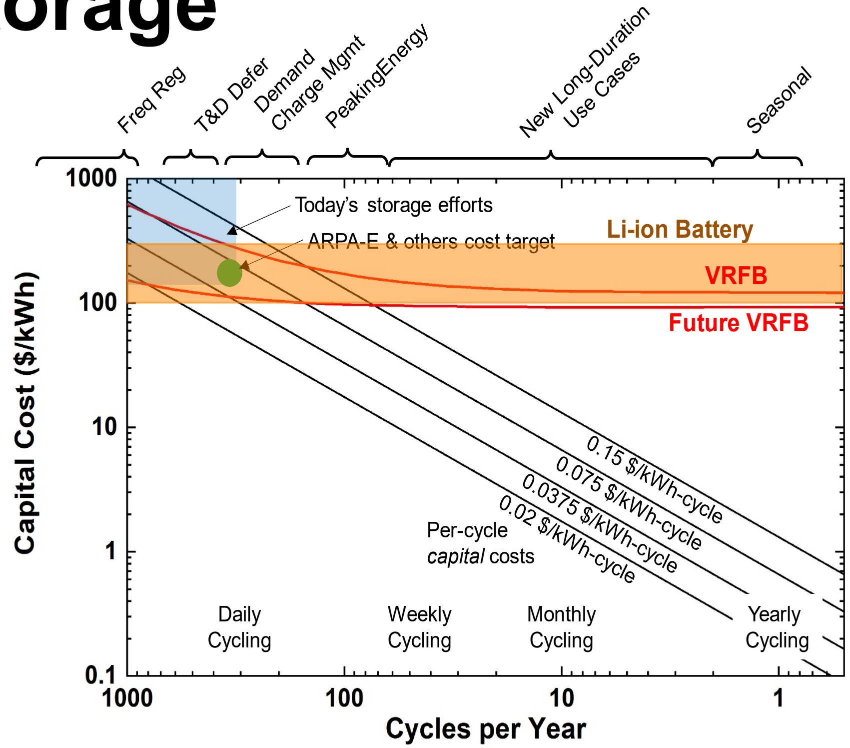
Lower capital cost targets for long duration storage

Current storage technologies too expensive for long duration storage



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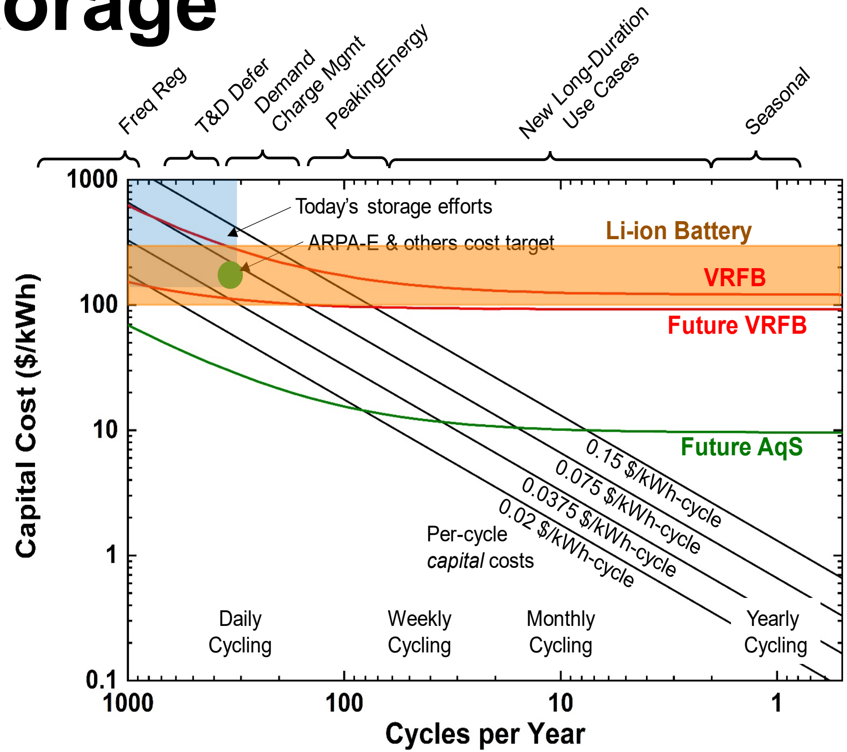
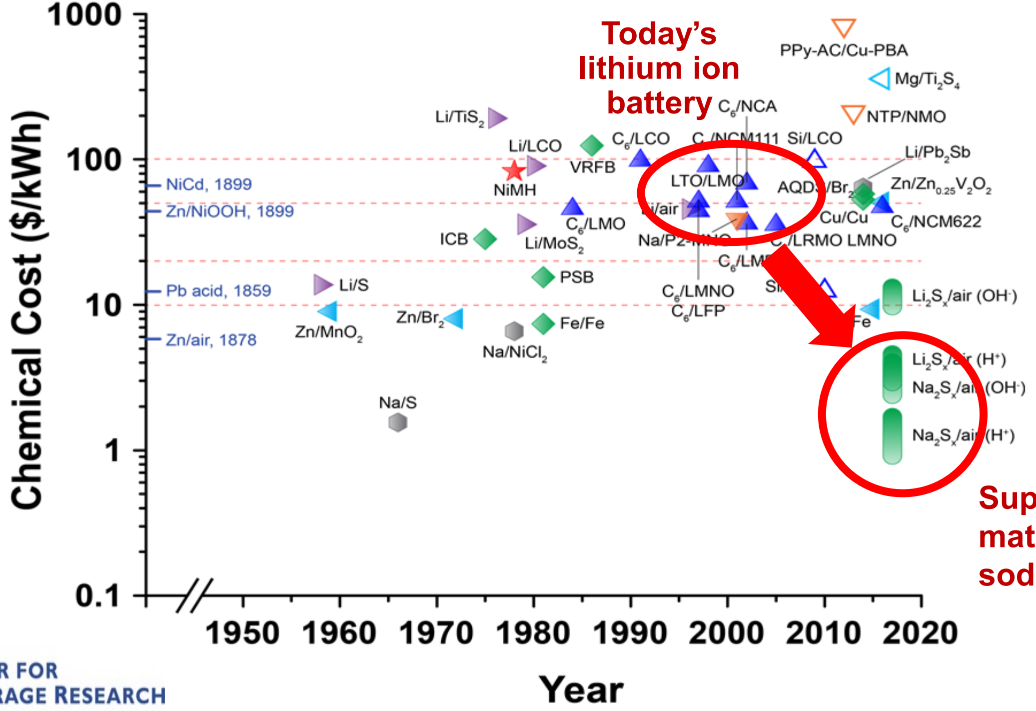
Lower capital cost targets for long duration storage

New battery chemistries with <$20/kWh capital cost required for multi-day storage and beyond



What if you could have grid storage at 1/10th the cost of lithium-ion with no materials constraints?



Super abundant materials like sodium, sulfur

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form energy

Global Storage Potential:
Pumped Hydro vs. Aqueous Sulfur

Pumped Hydro Facility: Ludington, Michigan
Volume: 39M m^3 of Water
Area: 3.4 km^2
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 m^3 Sulfur (70% of KSA annual production)
Area: 0.171 km^2
Storage: ***24 GW/1.2 TWh Storage Potential***

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

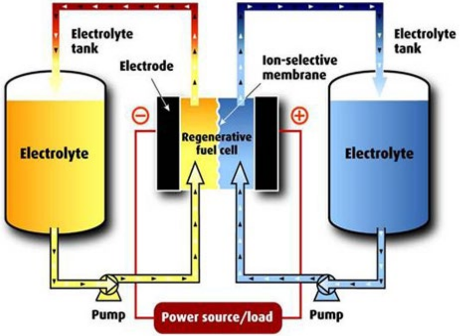
*https://minerals.usgs.gov/minerals/pubs/commodity/sulfur/mcs-2017-sulfu.pdf

Storage at Giga Scale

Today's battery technology for transportation

Tesla

$ 200/kWh



Tomorrow's battery technology for grid storage

San Diego G&E

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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