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Materials Technology Gaps for Low Cost Grid Storage

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Sandia National Laboratories

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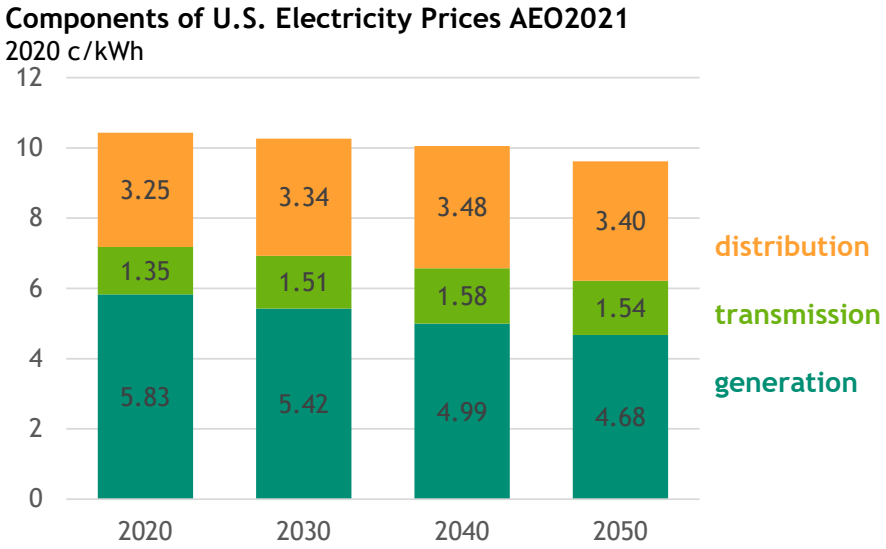
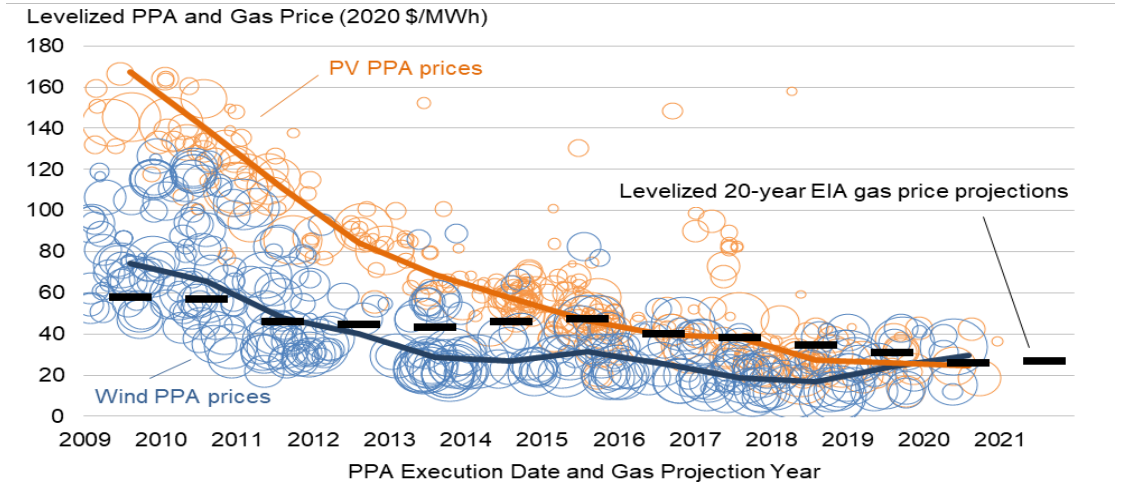
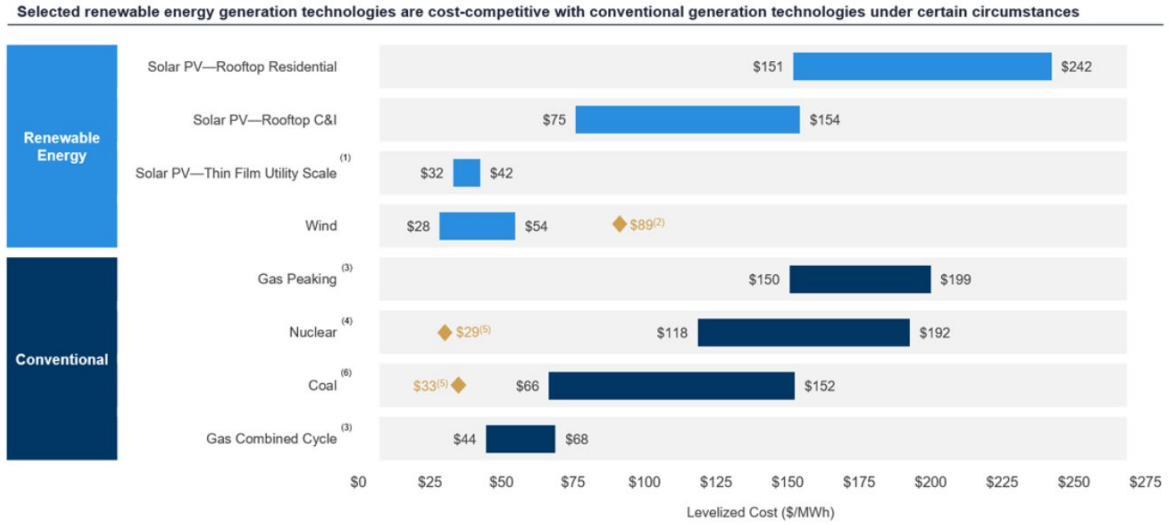
Electricity Costs



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2021 (AEO 2021)* www.eia.gov/aeo



Source: Ryan Wiser, et al, Land-Based Wind Market Report, August 2021, Berkeley Lab, windreport.lbl.gov;
Note: Smallest bubble sizes reflect smallest-volume PPAs (<5 MW), largest reflect largest volume PPAs (>500 MW).

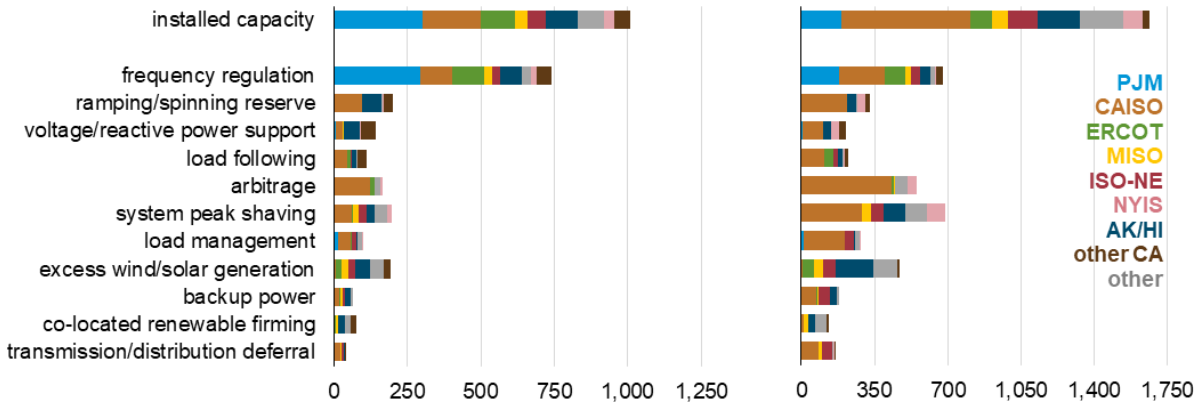


Source: Lazard, 2019: https://www.lazard.com/perspective/lcoe2019

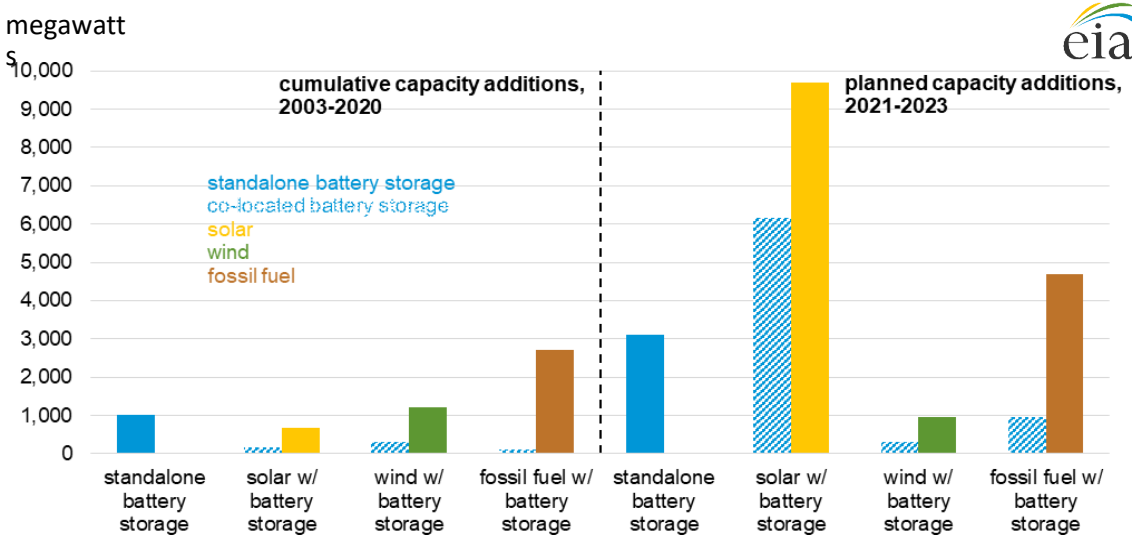
BIG QUESTION

What is the levelized cost on a kWh delivered by a BESS that the industry can accommodate?

Where is BESS Getting Deployed?



Applications served by large-scale battery storage (2019)



U.S. large-scale battery storage power capacity additions, standalone & co-located

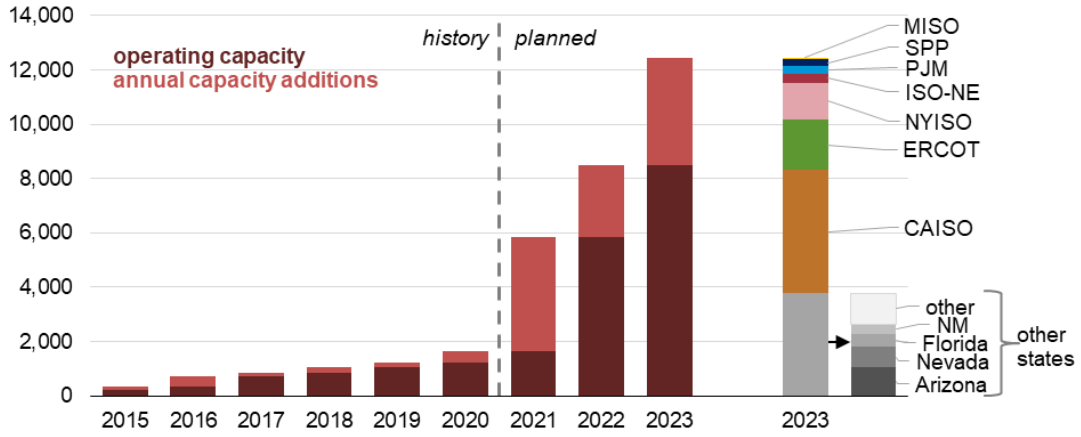
Early deployments are all power applications (expensive)

Planned new capacity in the pipeline is hybrids either with solar, wind or NG in selected markets

Energy markets beginning to open, energy storage is still expensive for many energy applications

Battery energy storage systems are mostly using Li batteries

Source: U.S. Energy Information Administration, Dec 2020 Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*



Large-scale battery storage cumulative power capacity, 2015–2023

Cost and Performance Trajectory of Grid-Connected ES Systems

No uniform cost and performance data

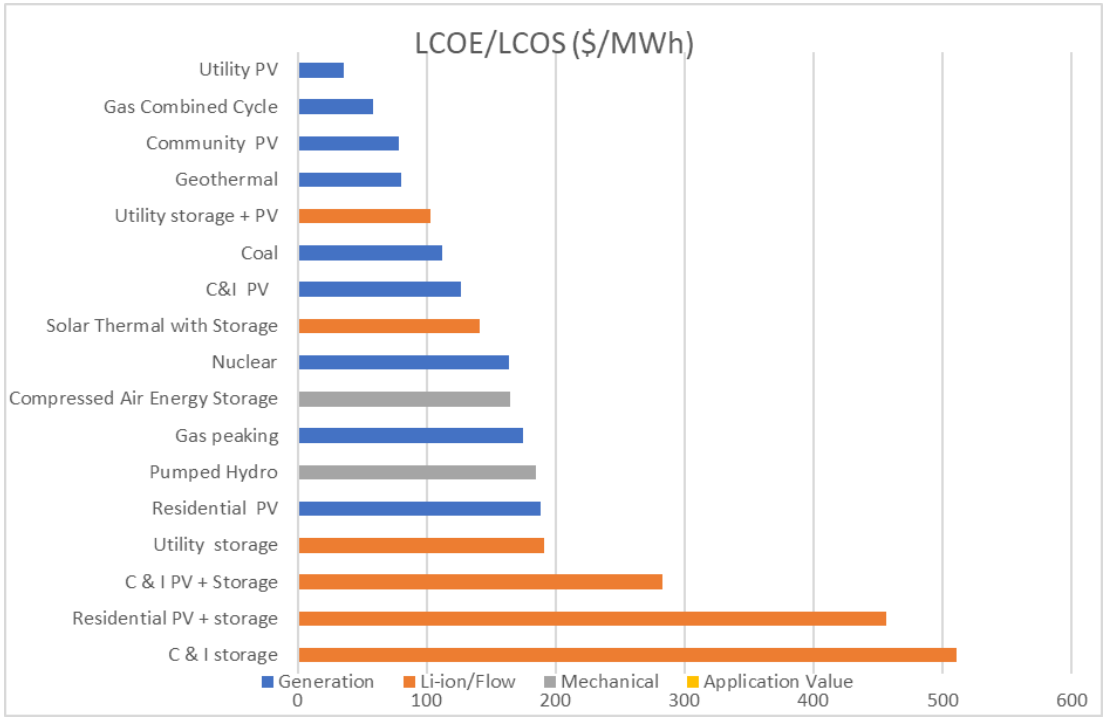
Most cost and performance data is proprietary

Some available public resources:

- Energy Storage Technology and Cost Characterization Report, US DOE Energy Storage Grand Challenge (https://www.energy.gov/energy-storage-grand-challenge/energy-storage-reports-and-data)
- Energy Storage Pricing Survey (ESPS), Sandia National Laboratories (https://www.sandia.gov/ess-ssl/lab-pubs/snl/)
- Cost Projections of Battery-Scale Utility Storage, July 2019, National Renewable Energy Laboratory

Other resources:

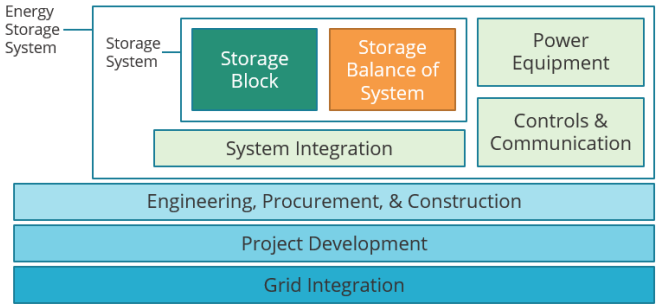
- US Energy Storage Monitor - Wood Mackenzie and ESA
- BNEF Emerging Energy Storage Technologies Report



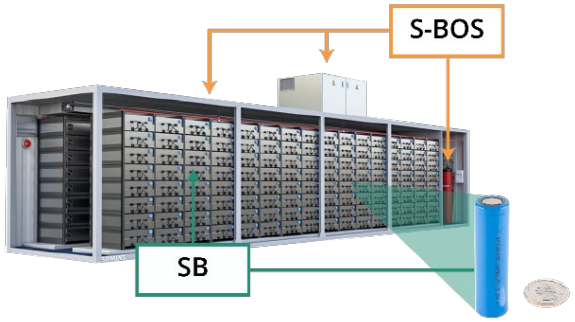
Energy Storage Technology and Cost Characterization Report, US DOE Energy Storage Grand Challenge (https://www.energy.gov/energy-storage-grand-challenge/energy-storage-reports-and-data

Except for PV + Utility Storage(2h), all other applications are not competitive with conventional generation, except in selected markets and load centers

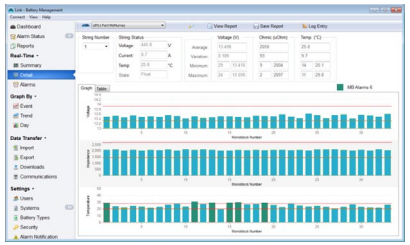
Energy Storage is more than batteries



ESS components



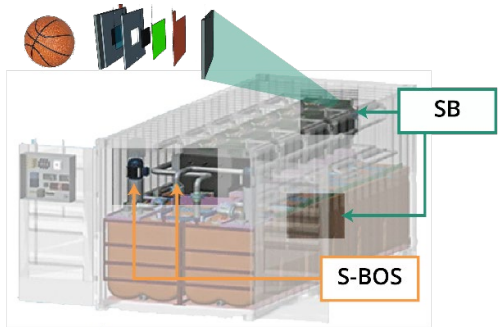
18650 Li-ion ESS



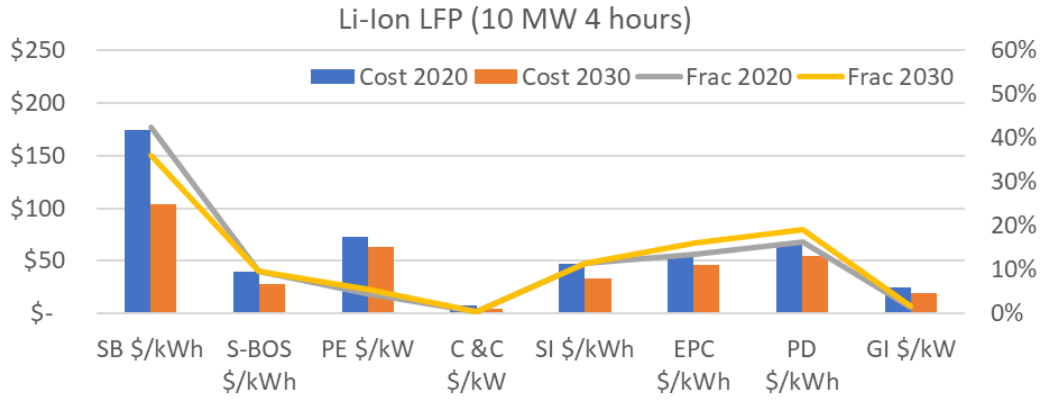
C&C

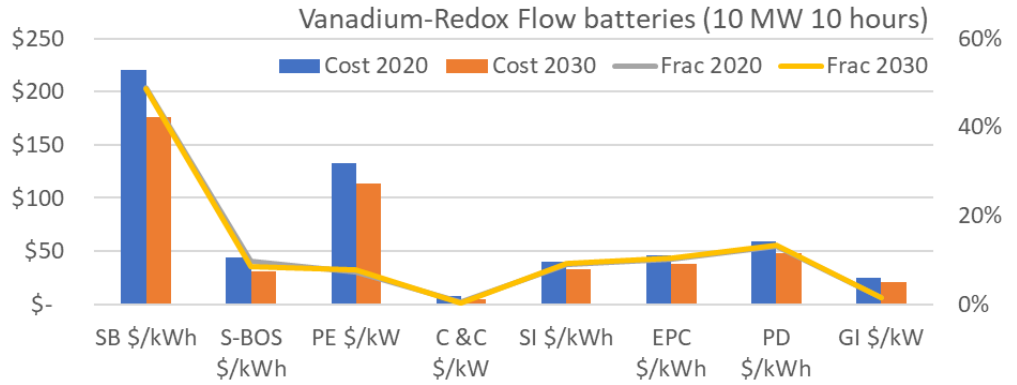
PE

Software and Power Converters



Flow battery





Components making a Battery Energy Storage System

Even if the energy storage component becomes significantly cheaper, BOS costs won't go down as much

Energy Storage Technology and Cost Characterization Report, US DOE Energy Storage Grand Challenge
(https://www.energy.gov/energy-storage-grand-challenge/energy-storage-reports-and-data

Getting to lower LCOS

$$LC = \frac{\sum(C_t + O\&M_t + F_t)(1+r)^{-t}}{\sum E_t (1+r)^{-t}}$$

Major knobs with cell improvements

Cell price – BOM and manufacturing

Technology - performance

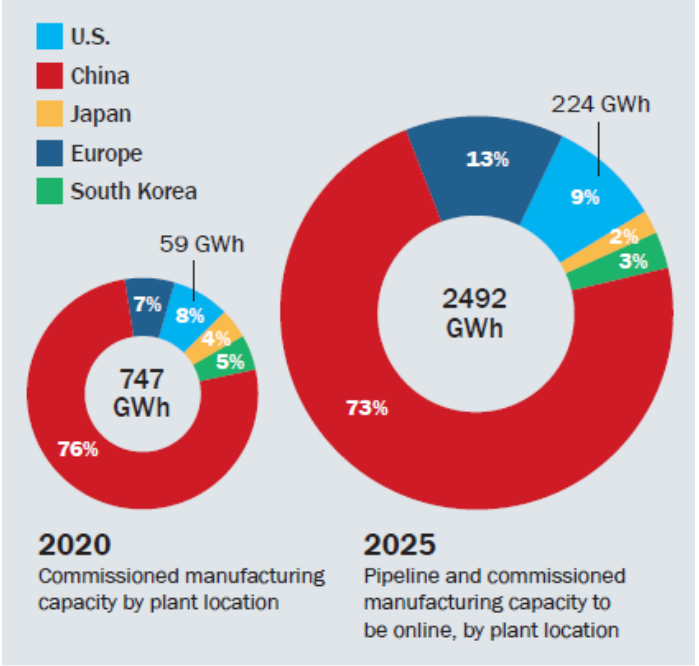
Cycle life – biggest knob to tweak

System level improvements

O&M costs – system degradation, operational safety

Scale and cycles of learning

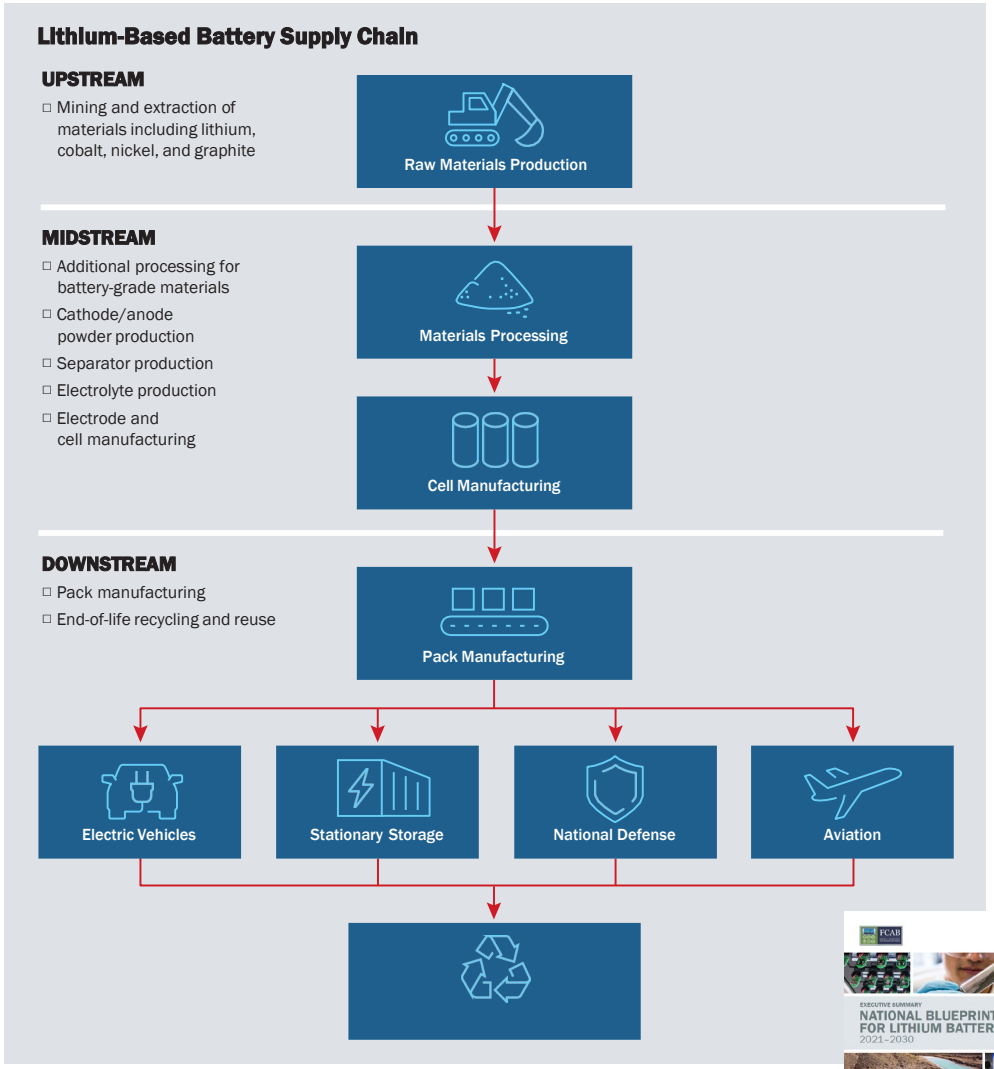
Standardized deployments



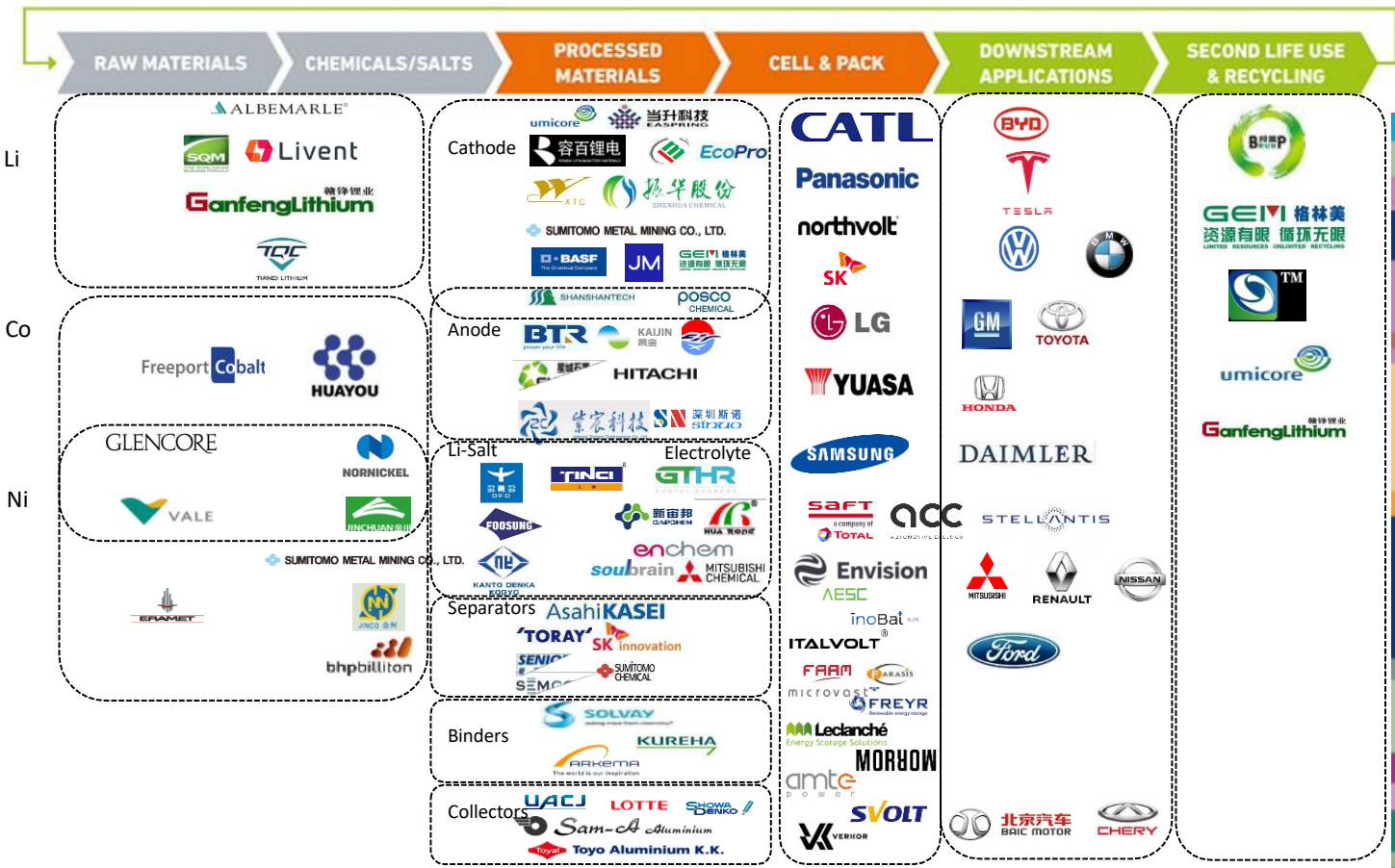
Cell manufacturing capacities by countries and regions (Source: "Lithium-Ion Battery Megafactory Assessment", Benchmark Mineral Intelligence, March 2021).

Li-ion Battery Manufacturing Costs – already efficient and at vast scale in manufacturing. Any future gains are incremental.

Supply chains are global and complex: Lithium supply chain

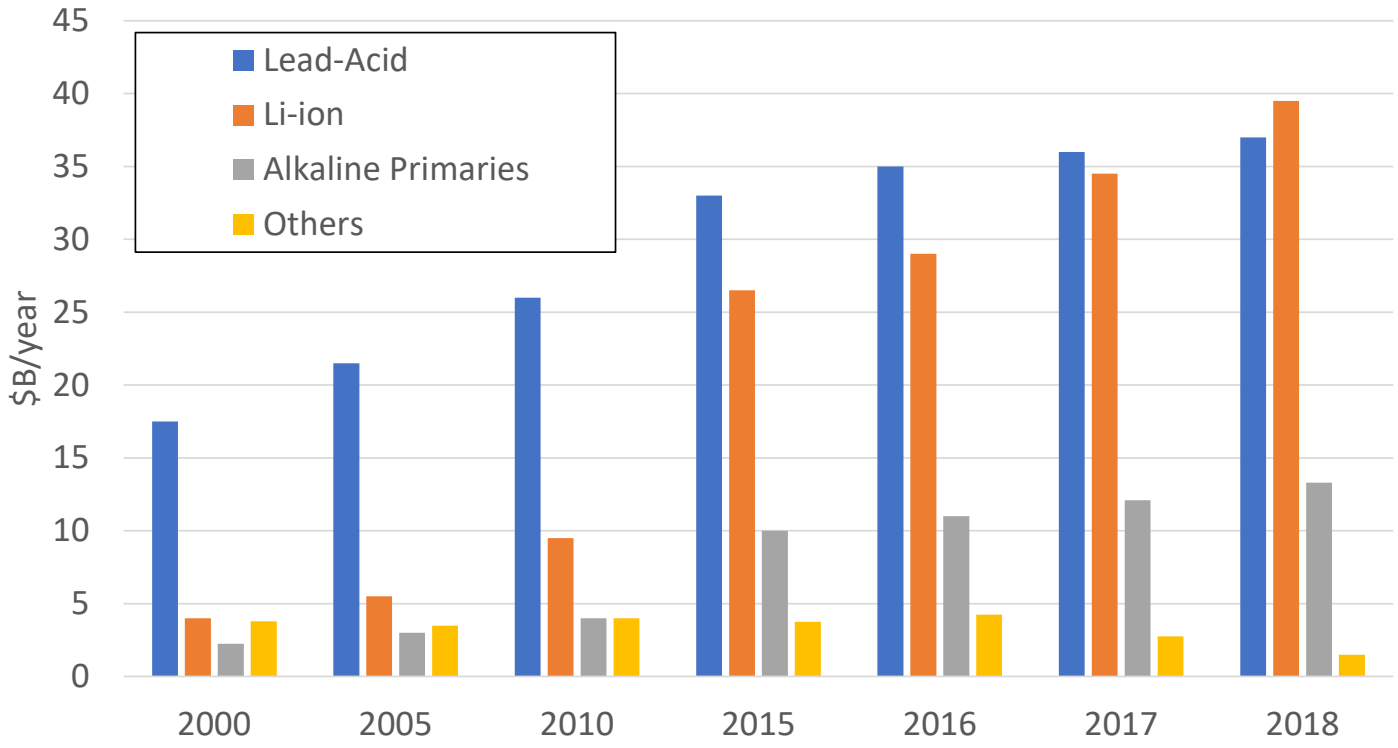


Source: **National Blueprint for Lithium Batteries**, Federal Consortium for Advanced Batteries (FCAB), June 2021. DOE: /www.energy.gov/eere/vehicles/ DOE/EE 2348



Source: C. Pillot, Avicenne Energy, 2020

Other Battery Technologies



Battery manufacturing

- Stable and mature Lead-Acid market
- Growing Li-ion market (EV, Portable), but took 30 years to reach scale

Other battery technologies like Zn-MnO2, NaS, and Flow are at scale

- Need to scale up to maturity levels similar to lead acid and lithium batteries
- Need manufacturing scale to fully realize cost advantages\

Supply chains are slow to build and take time (20 to 30 years)

Acknowledgements

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