SAND2021-13004C

Non-Li technologies and solar integration

2021 Southern Africa Energy Storage Systems

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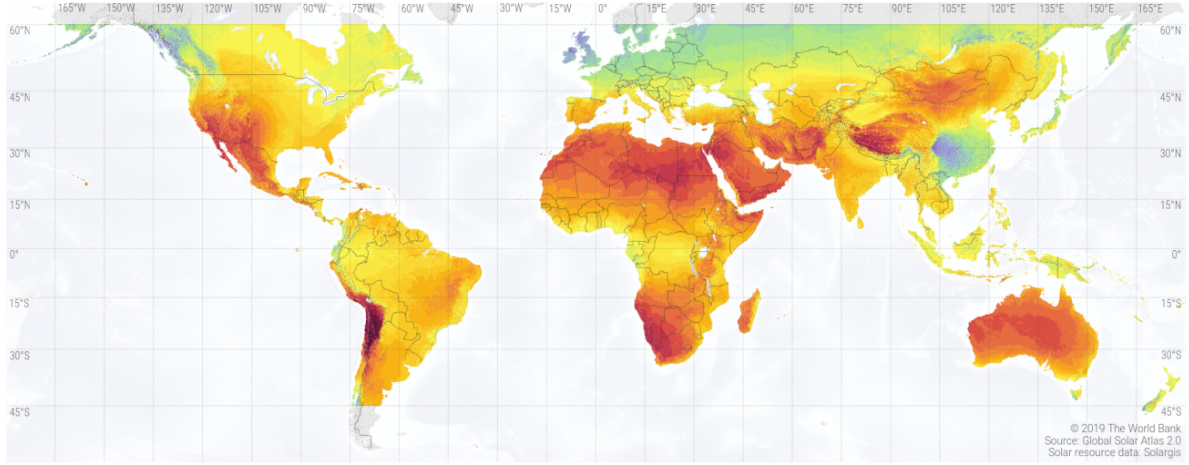
Solar energy is available and inexpensive

Potential solar power

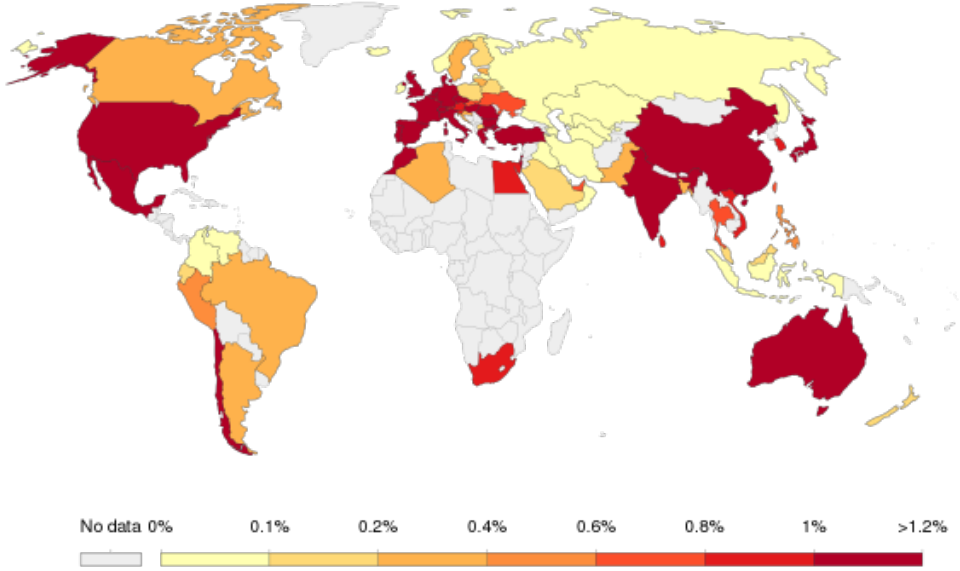


Long-term average of photovolaic power potential (PVOUT)

Daily totals:	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4
												kWh/kWp
Yearly totals:	730	876	1022	1168	1314	1461	1607	1753	1899	2045	2191	2337

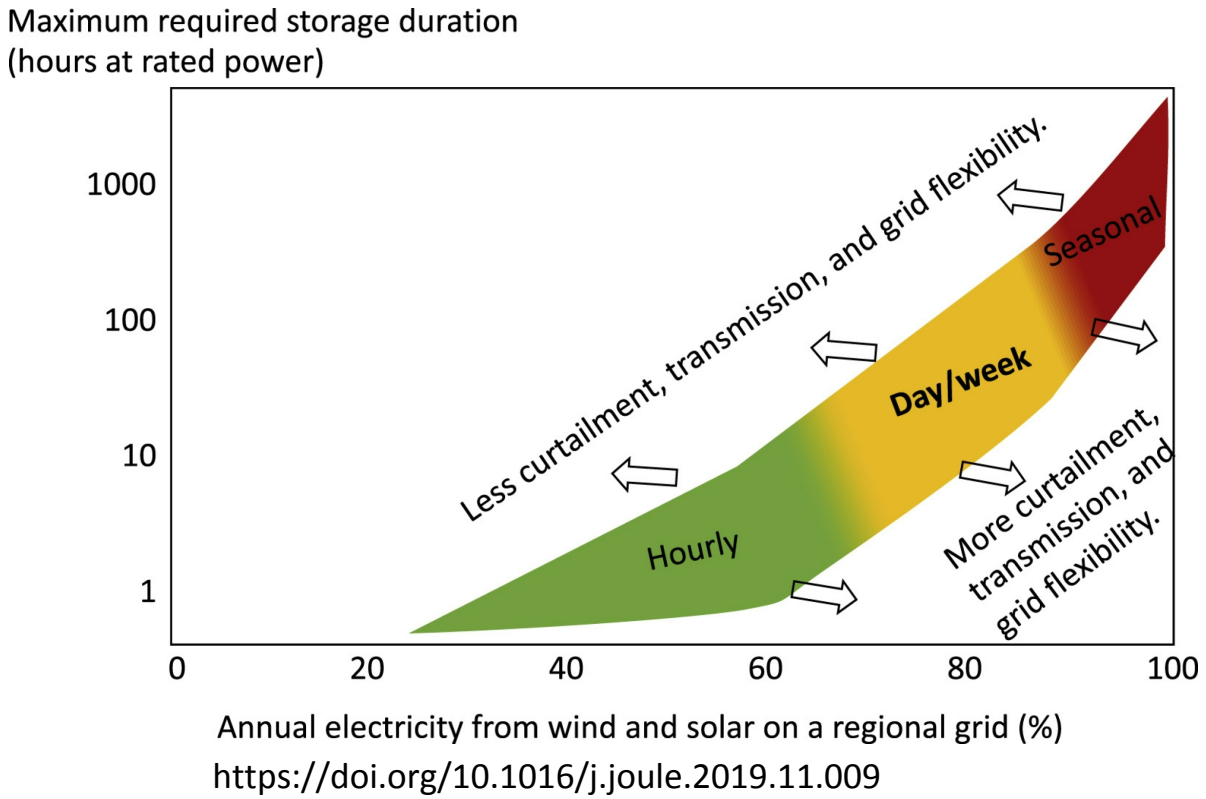
This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit http://globalsolaratlas.info.

% of solar generation in each country

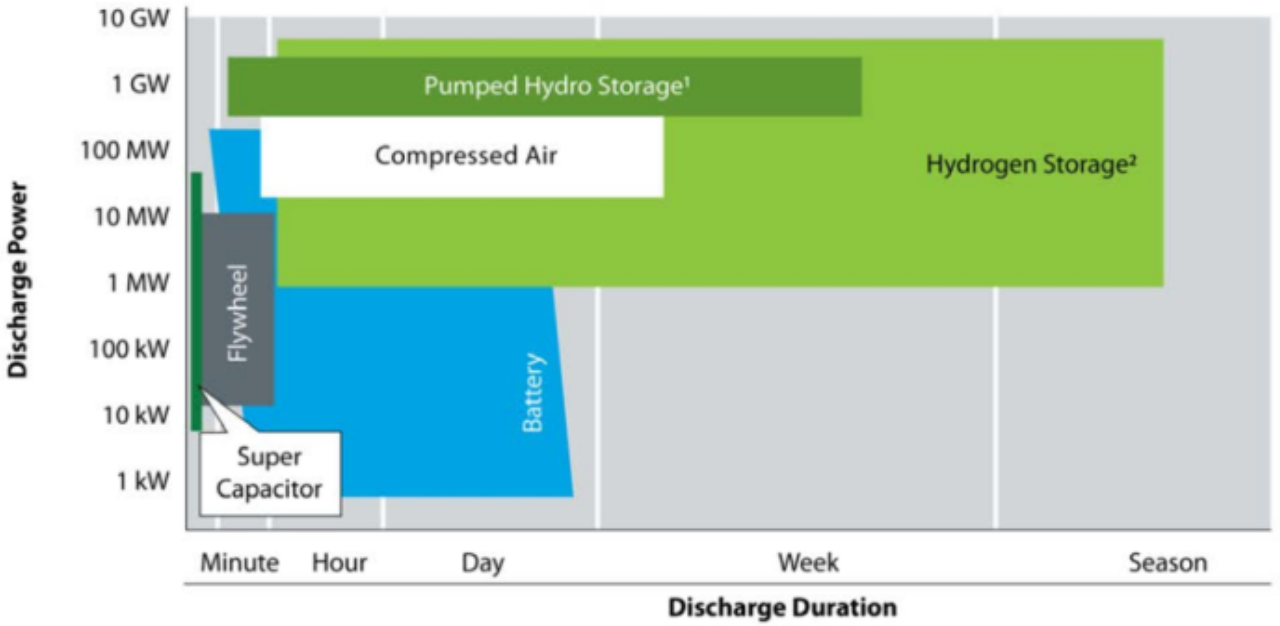


Source: Our World in Data based on BP Statistical Review of World Energy (2020)
Note: Primary energy is calculated using the 'substitution method' which takes account of the inefficiencies energy production from fossil fuels.

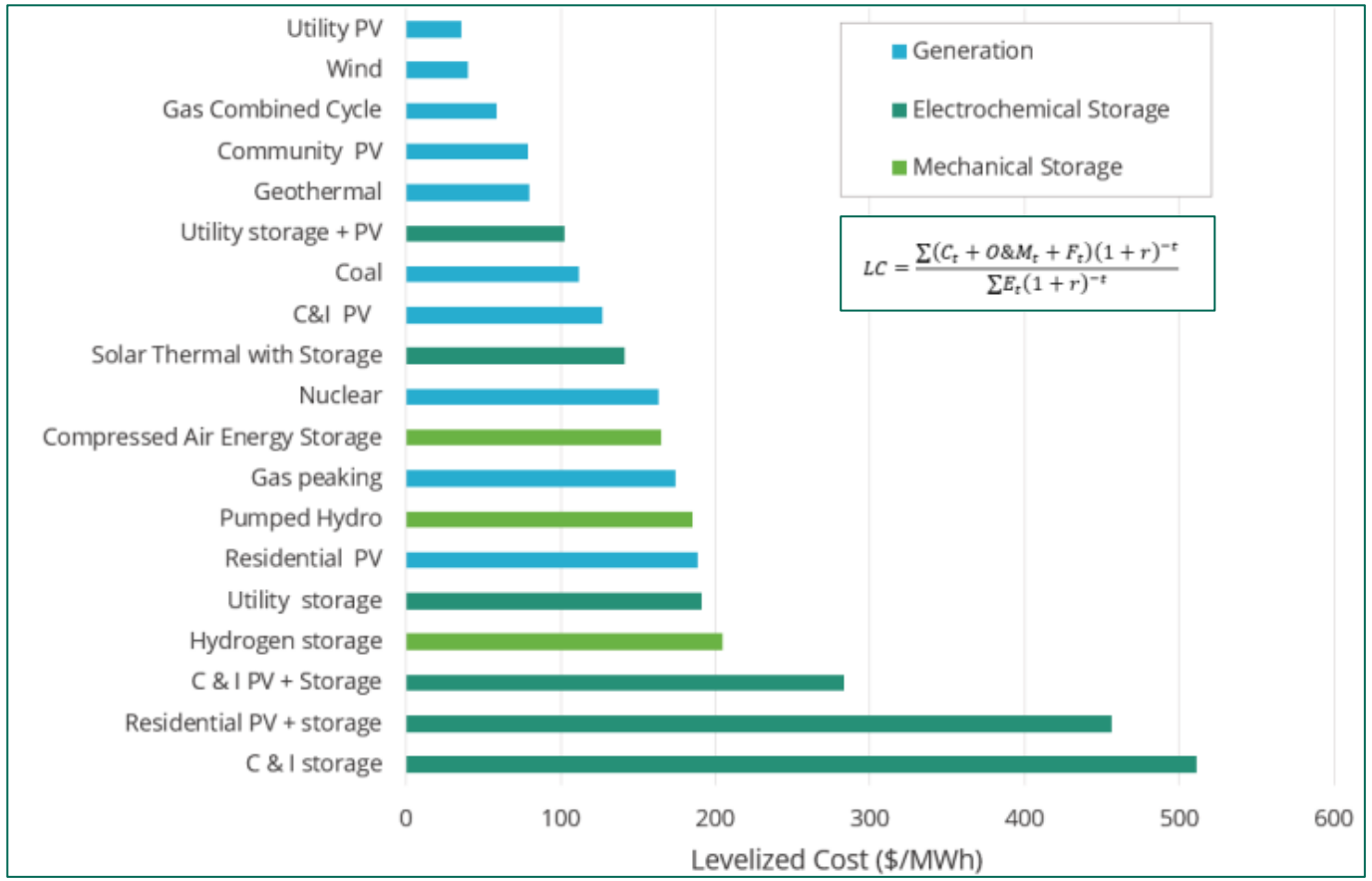
Long duration storage is needed to firm solar and other sources of renewable generation



https://doi.org/10.1016/j.joule.2019.11.009



Energy storage is competitive in some cases with conventional generation

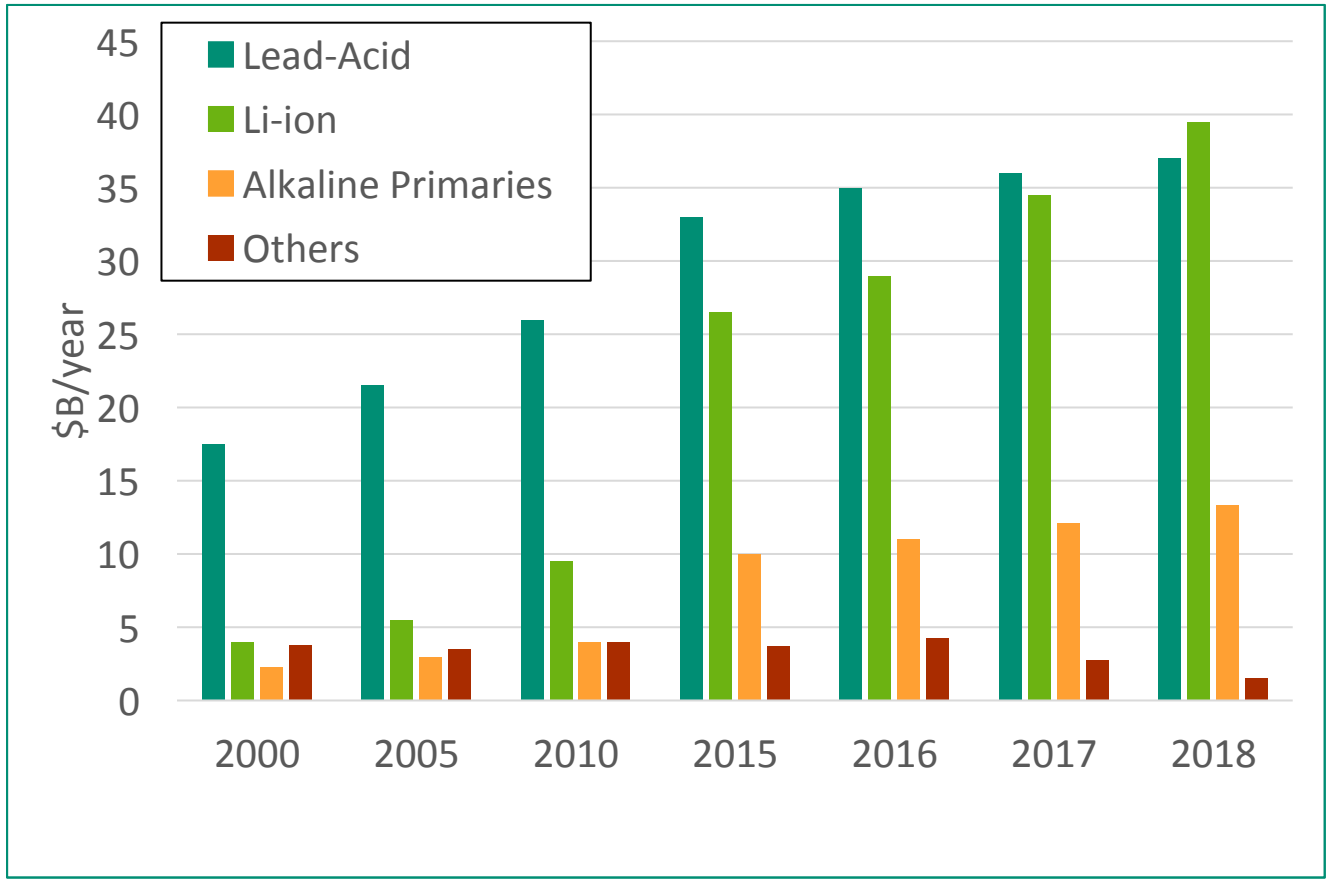


Source: Lazard

Advantages of solar generation

- Solar enables a distributed infrastructure
- A decentralized infrastructure can be easier to operate and maintain

Battery technologies take time to develop

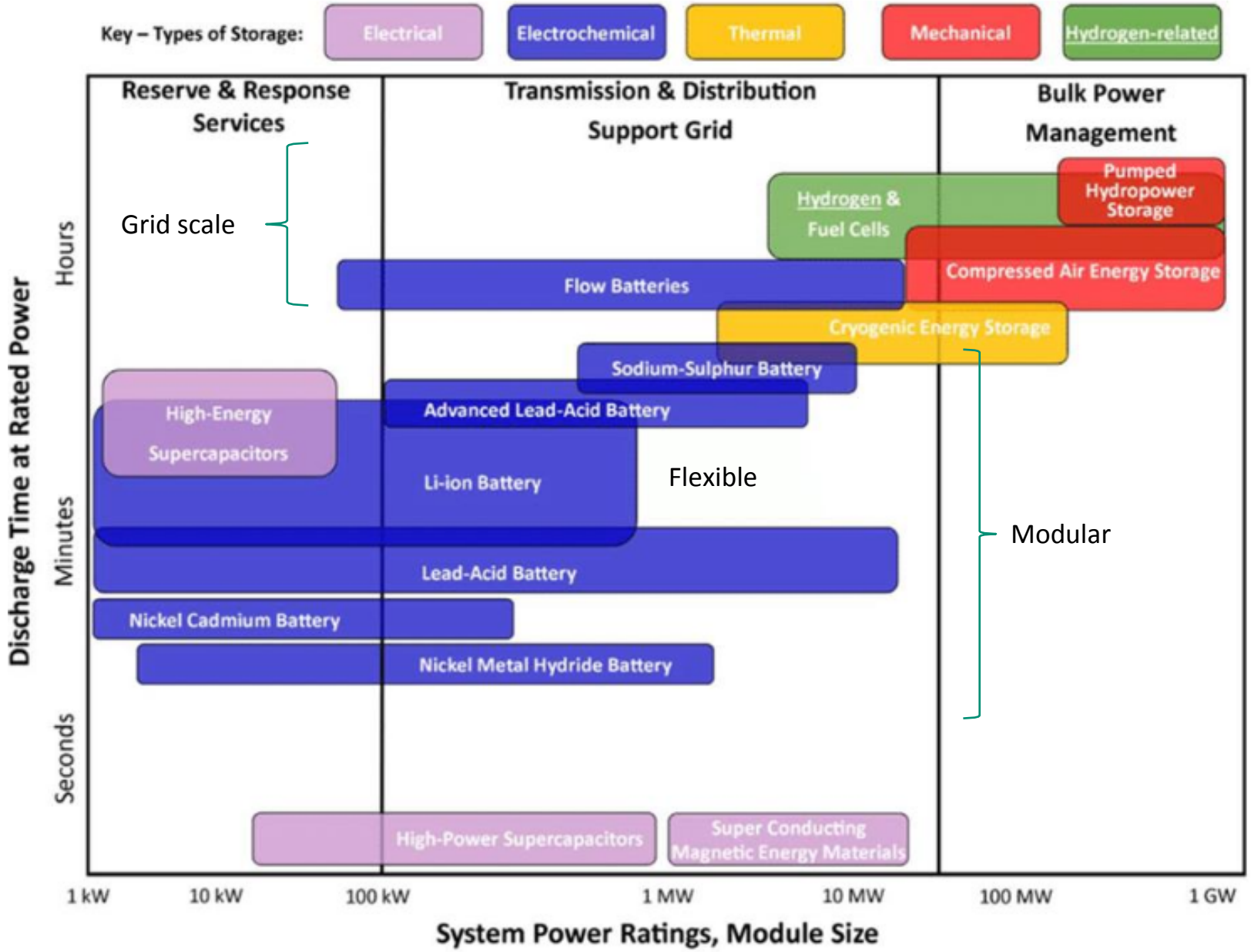


Source: Avicenne Energy

Battery manufacturing

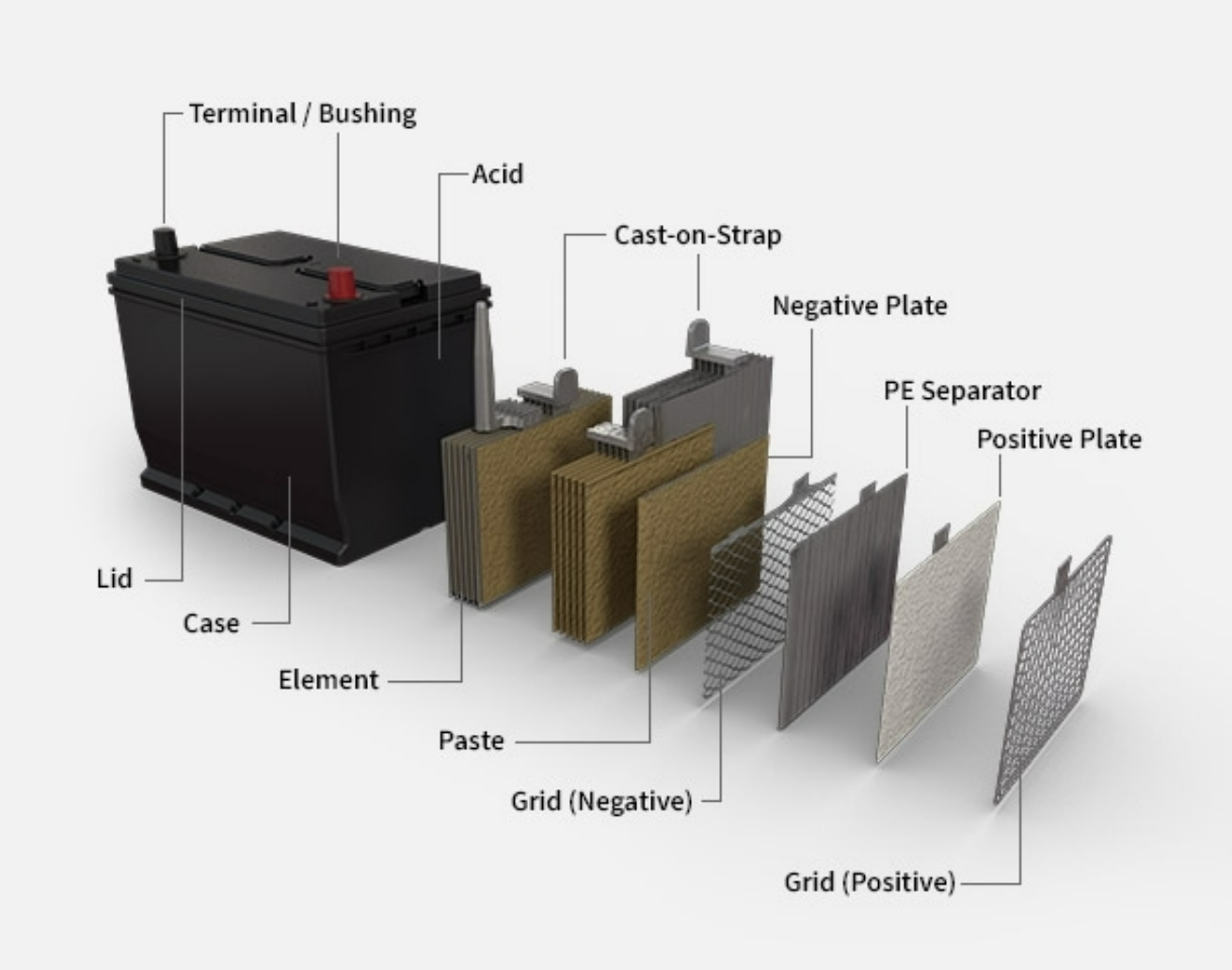
- Growing Li-ion market (EV, Portable)
- Stable and mature Lead-Acid market
- Established primary Alkaline market
- Other battery technologies are not well developed
- Supply chains take decades to develop

Several options for energy storage are available

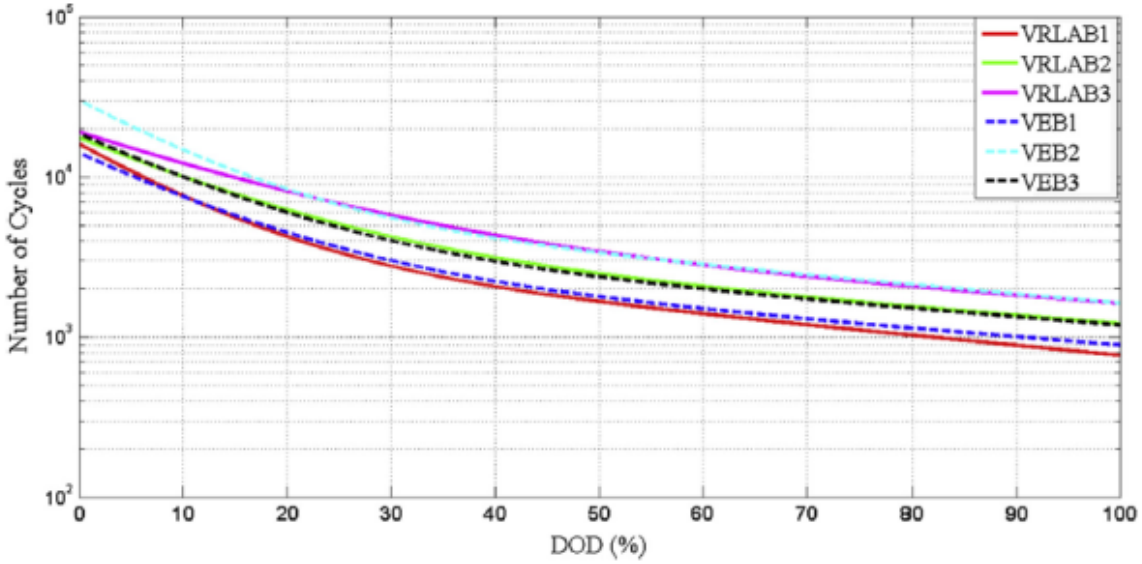


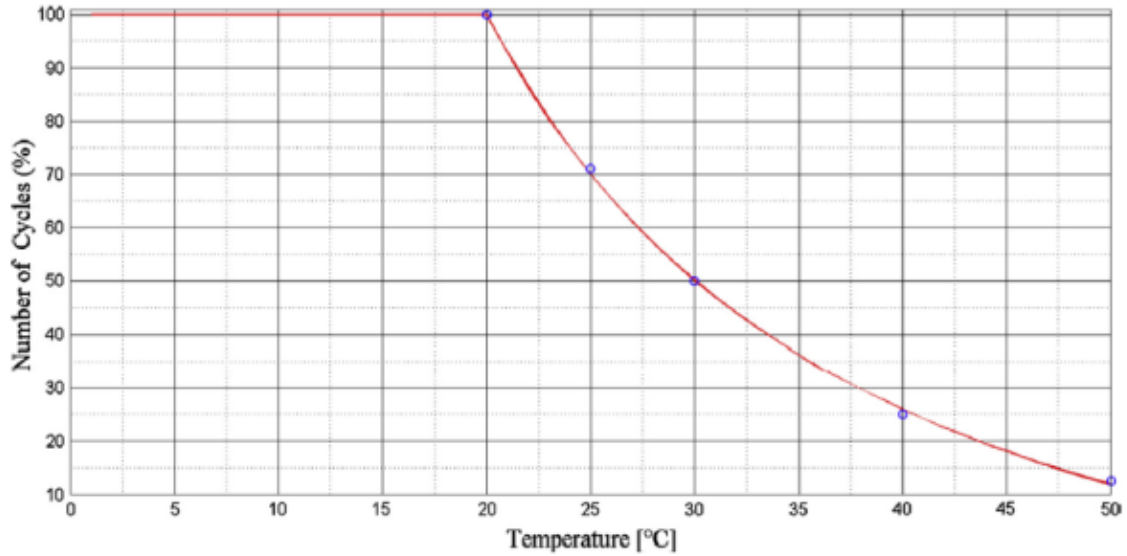
Lead Acid is used for UPS and for solar firming

Simple & standardized construction

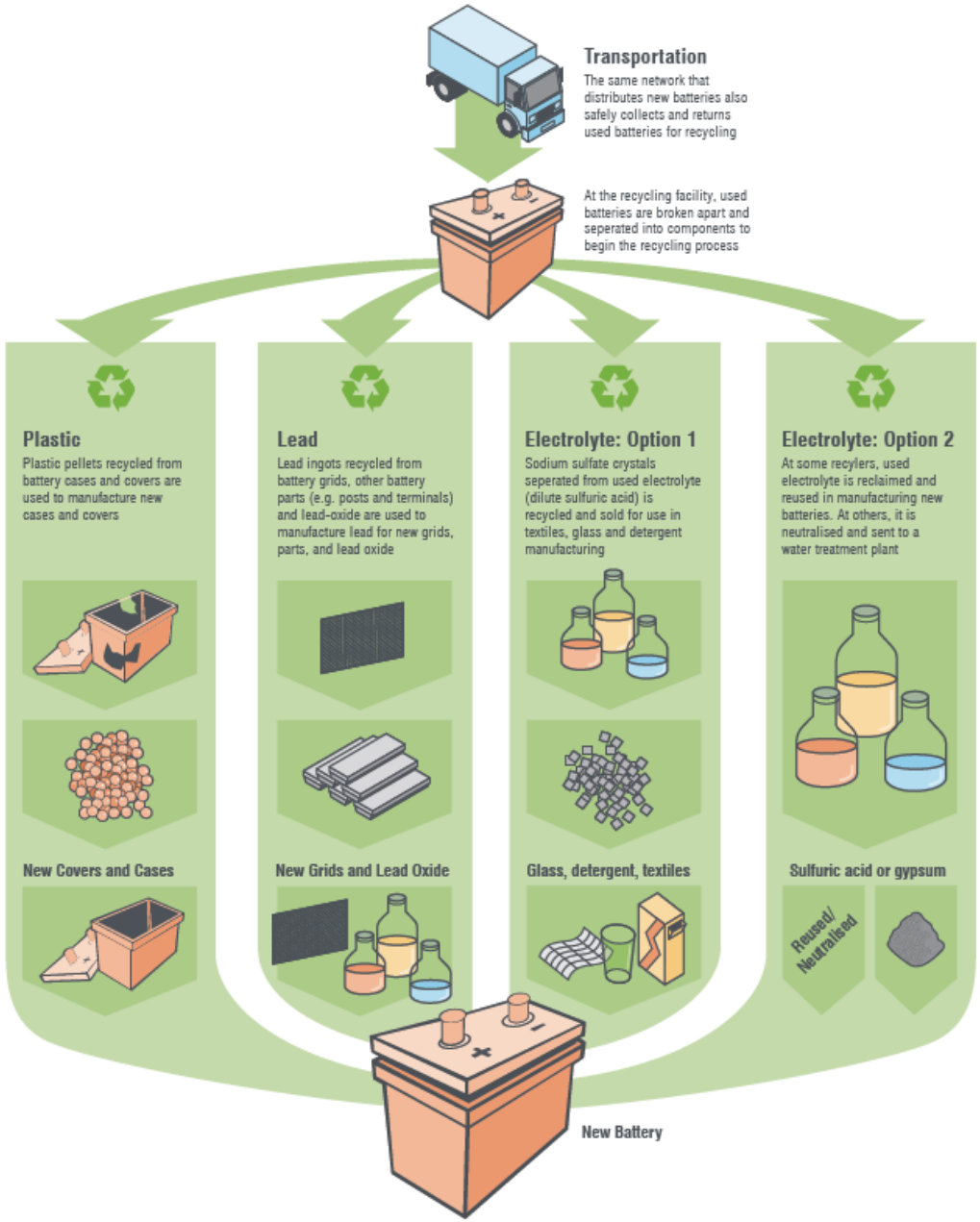


Performance degrades with temperature

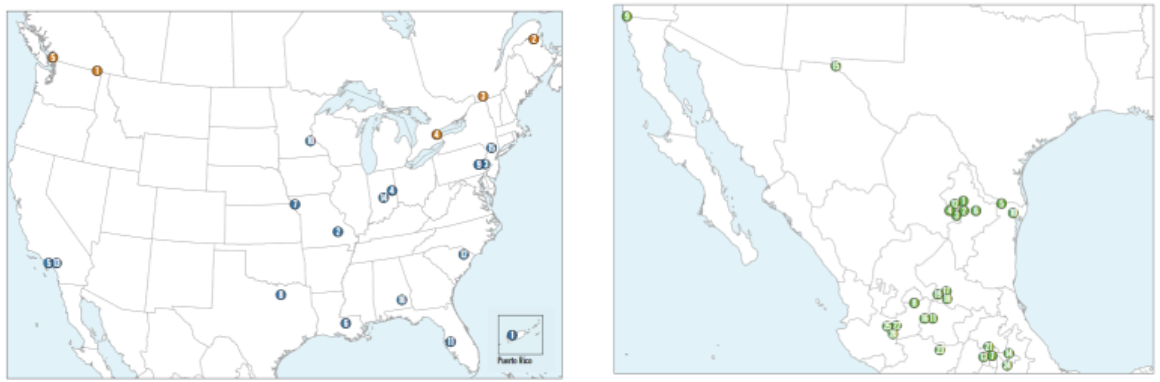


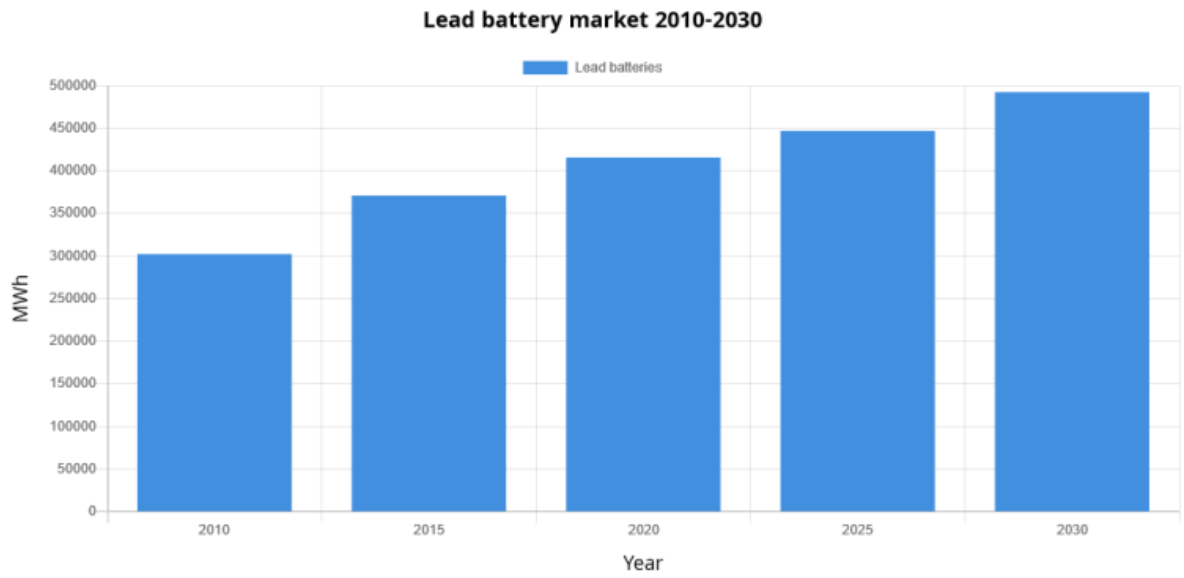


The lead-acid industry has an established recycling infrastructure



Recycling centers in the US and Mexico

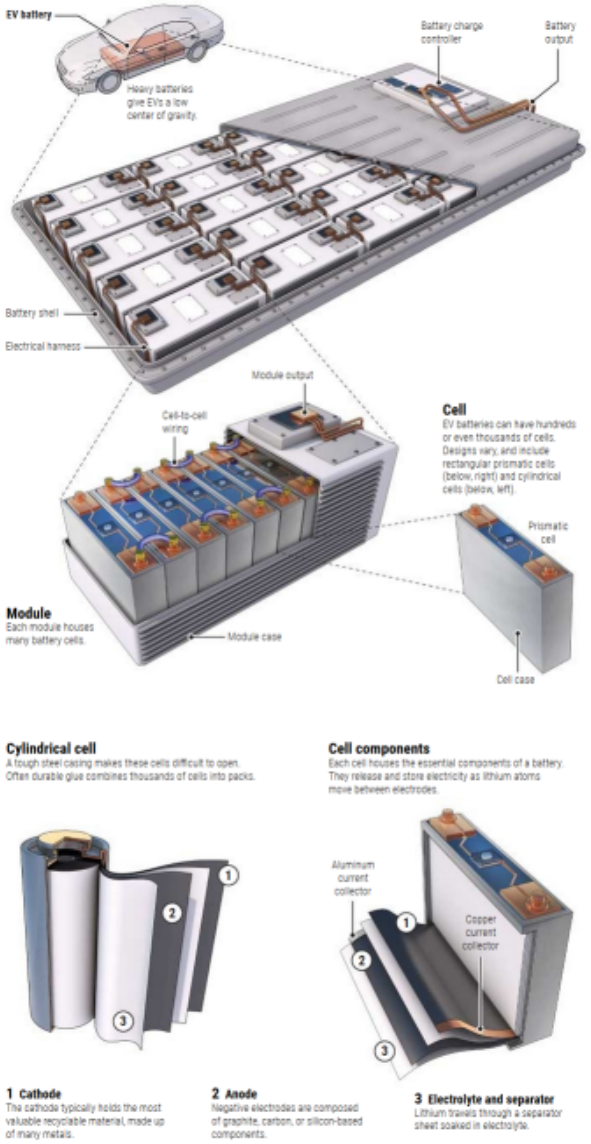


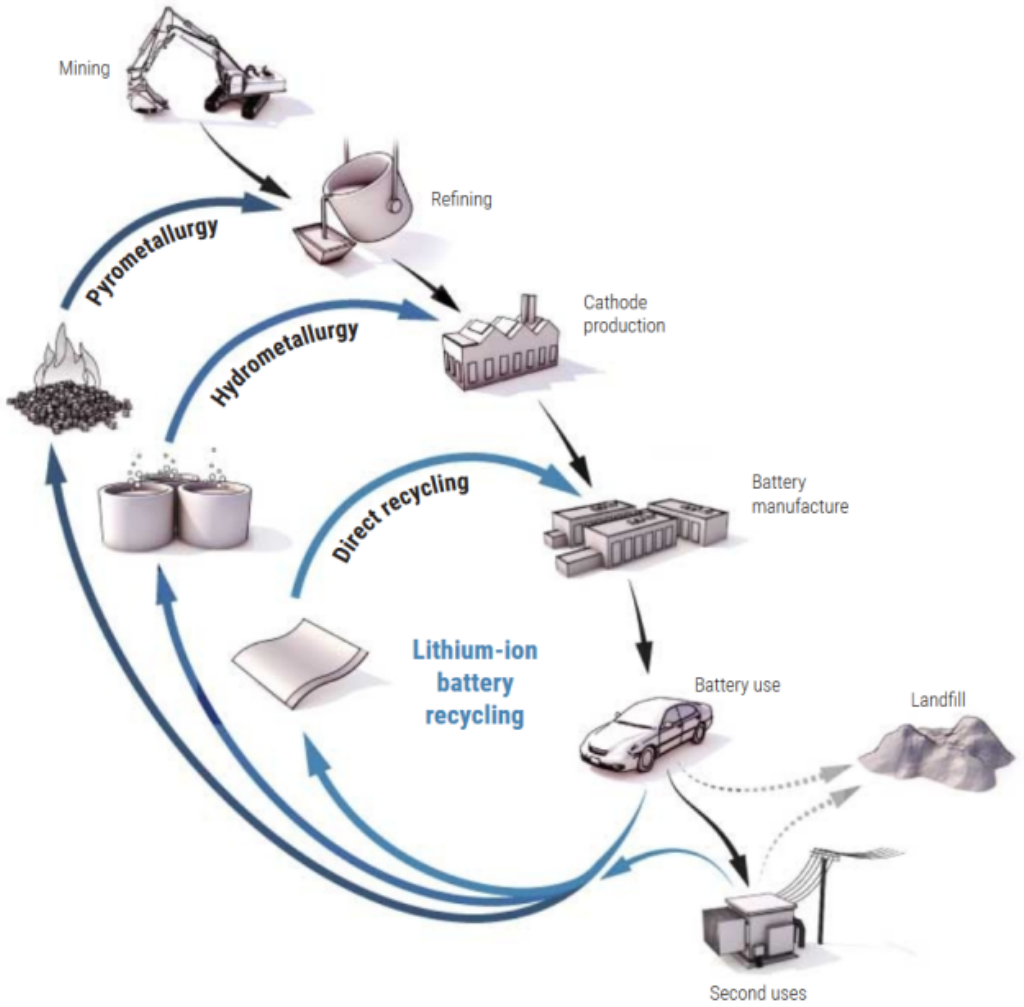


https://batteryinnovation.org/resources/lead-battery-market-data/

Recycle of lead-acid batteries in imperfect by recycling of Li-ion batteries is harder

Recycling concerns are not unique to lead-acid batteries

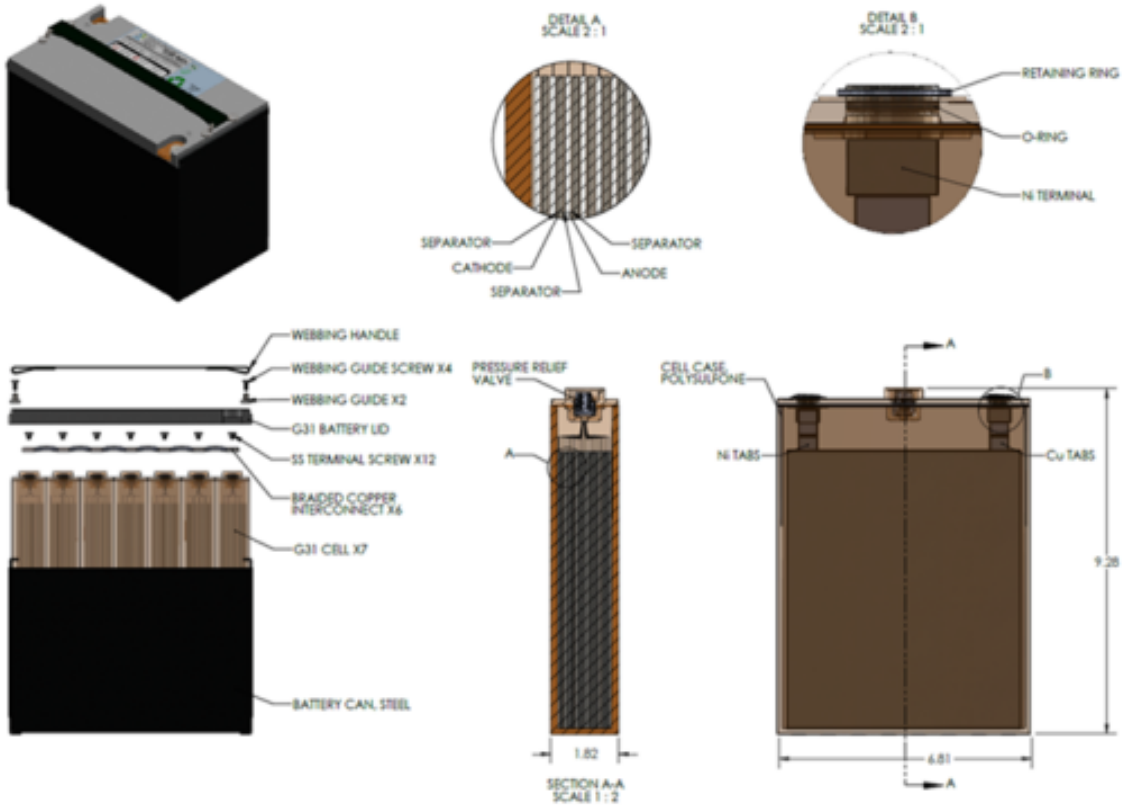




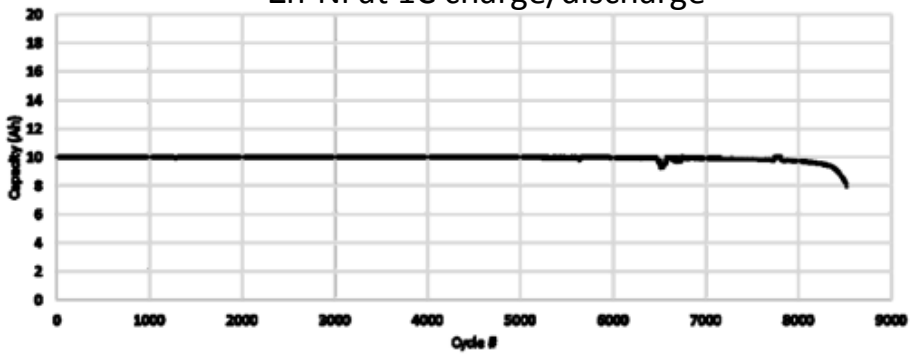
https://www.science.org/content/article/millions-electric-cars-are-coming-what-happens-all-dead-batteries
https://www.anl.gov/manufacturing/recycling

Zn-based batteries are an environmentally friendlier alternative to lead acid

More complex construction

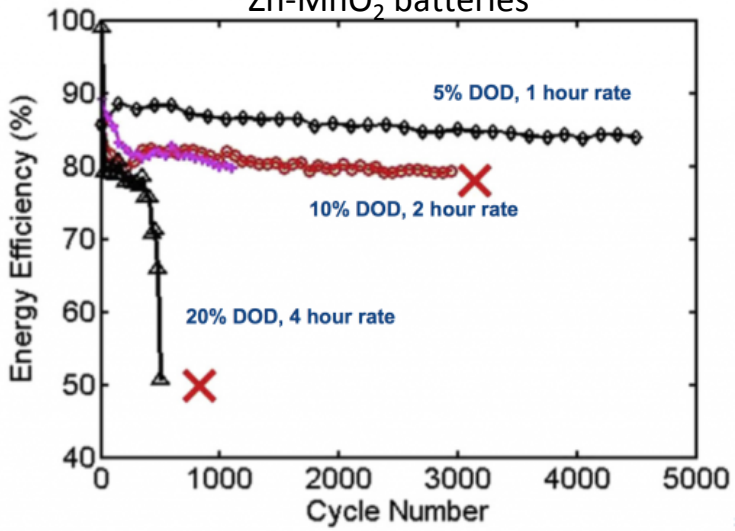


Zn-Ni at 1C charge/discharge



Source: Design and Performance of Large Format Nickel-Zinc Batteries E. Listerud and A. Weisenstein ZAF Energy Systems

Zn-MnO_2 batteries



Source: http://www.joshuagallaway.com/?p=265

Zn-based batteries can replace lead-acid batteries

Gear Box

Charge Controller

400 W Wind Generator

OutBack Power

Inverter/Charger
Model FX 3048T

110 Vac, 30A, Entry Panel

1770 W PV Array, 2 Series, 3 parallel

Battery Bank

Deka 8G8D Batteries
480 Vdc
Total 530 Ahr (C/100)

Urban Electric Power (UEP)

Zinc Manganese Dioxide (Zn-MnO2) Batteries

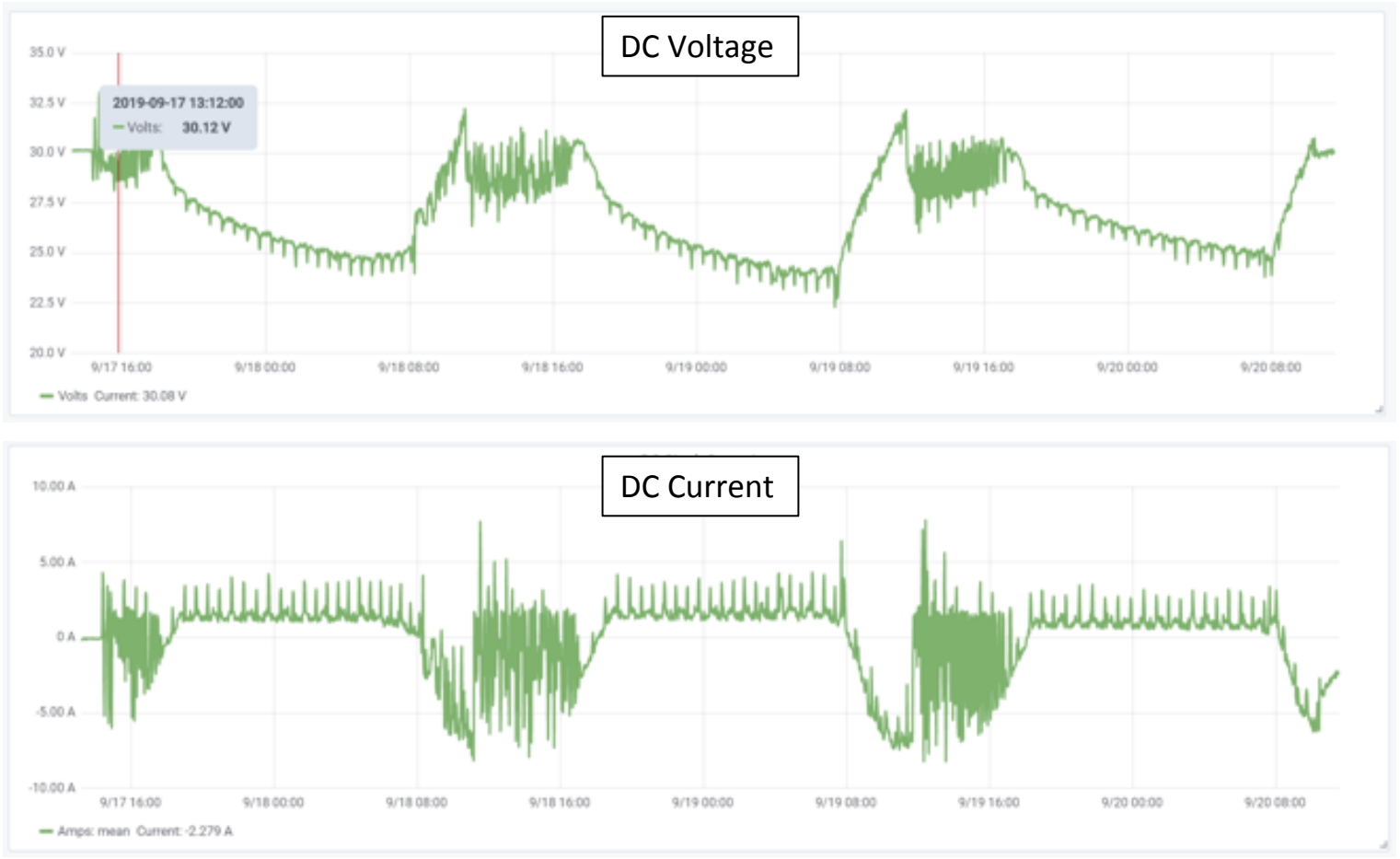
1800 W Remote Power System

Navajo Nation Single Home

Typical Loads

Refrigerator
Lights
General appliances such as microwave oven, coffee maker, and hairdryer
No water heater
No running water
No range
No furnace

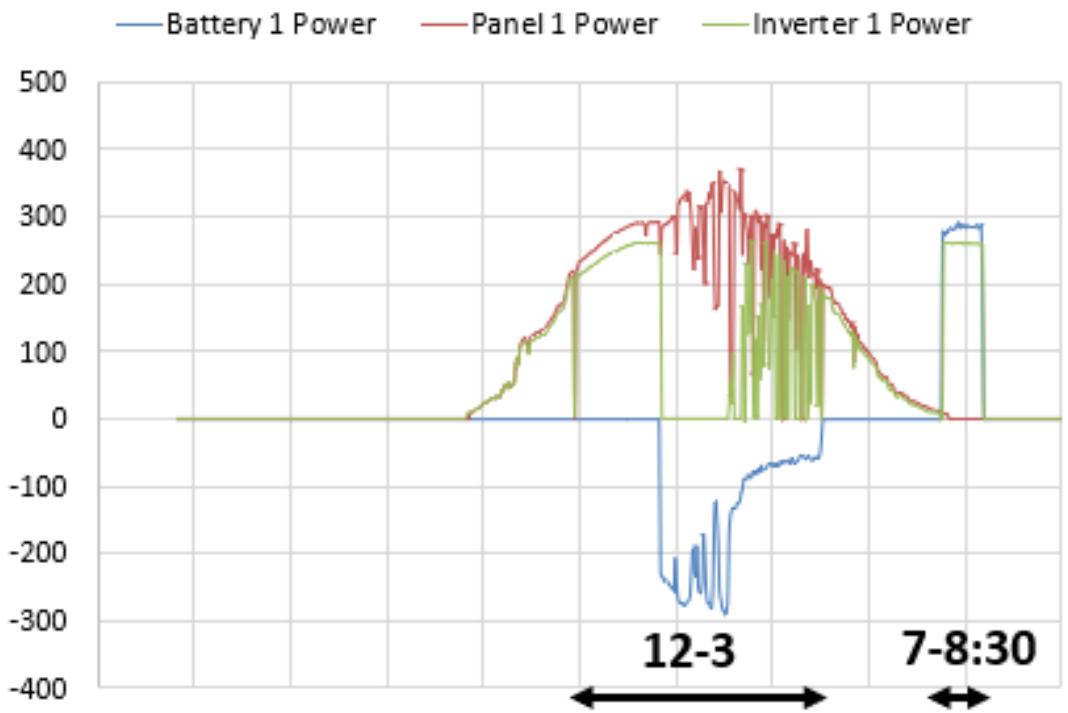
Data for the Zn-MnO_2 batteries used with converters designed for lead-acid batteries



Top: Voltage; Bottom: Current: System test for 3 days. The system ran for 3 days paired with solar: charging when the sun was available and discharging during other times

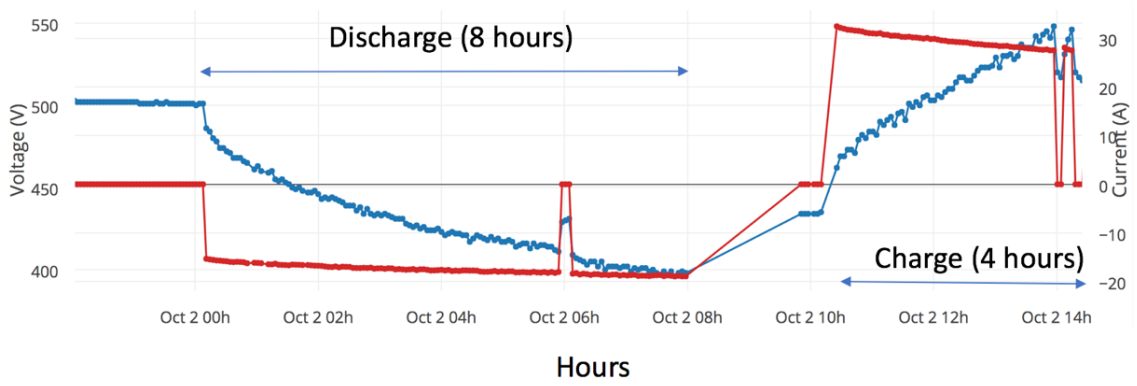
Data from

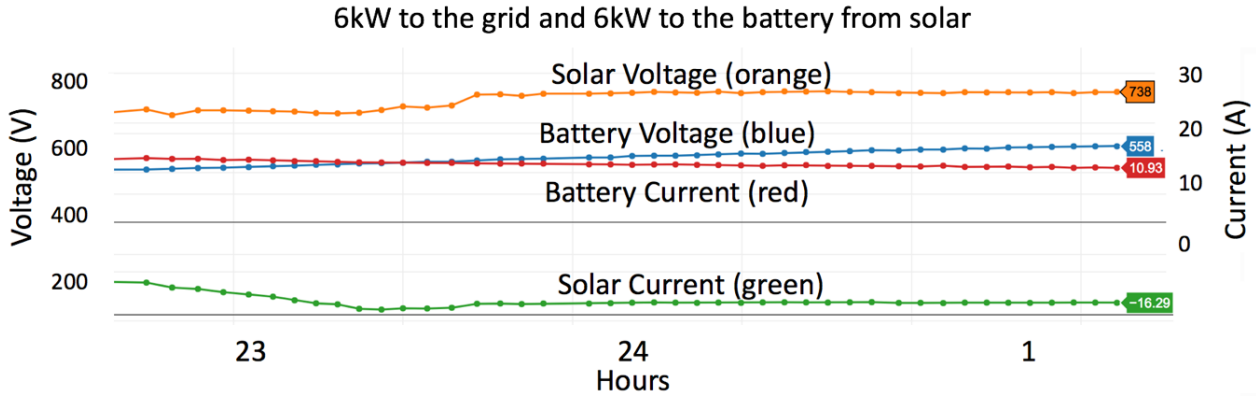
Zinc-based batteries can operate under solar panels



Data from

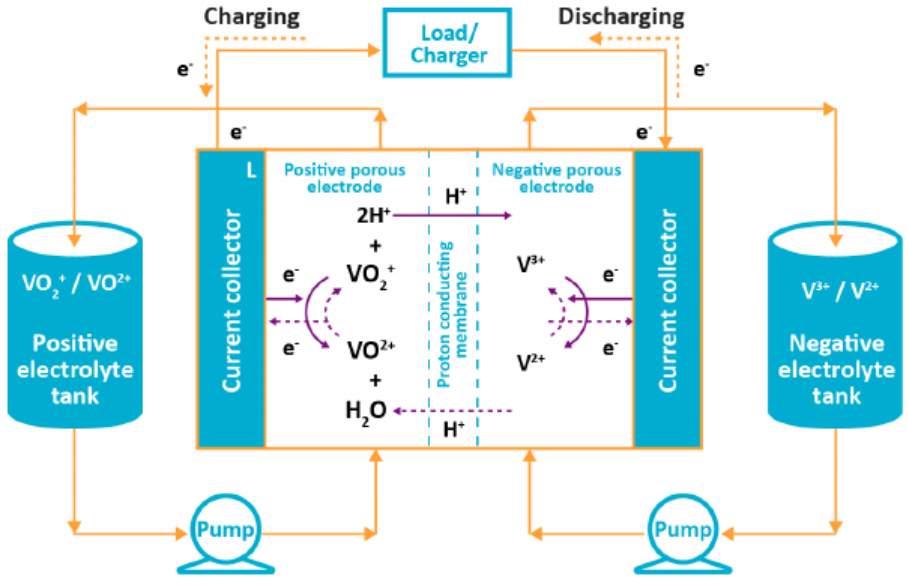
Container-based $ZnMnO_2$ system built in India using Li-ion BMS and power converter





Data from

Flow batteries allow decoupling of energy and power



Benefits:

- Decouple energy and power
- The electrolyte has a long life

Issues:

- Costs remain high
- Energy density is low
- Many mechanical parts

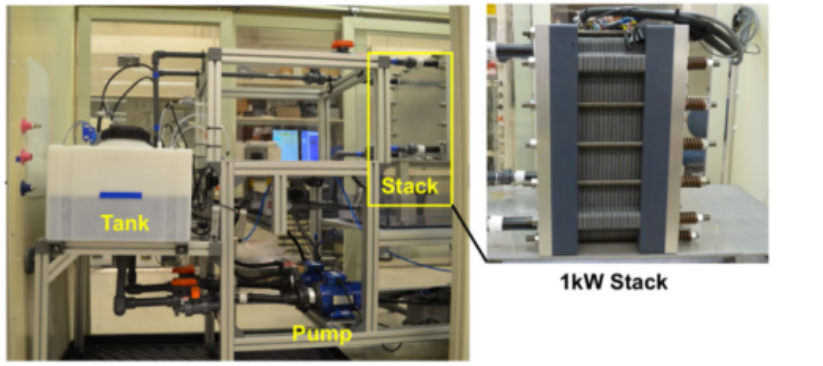


Figure 2. Photograph of vanadium RFB (VRFB) test bed developed at Pacific Northwest National Laboratory for RFB evaluation. A zoomed in image of the electrochemical cell stack is provided at right.

Modular systems (<50kWh)

Utility scale systems

Figure 3. Photograph of EnerVault Corp.'s 250kW/1MWh Fe-Cr RFB in Turlock, California. Electrolyte is held in the four tanks in the lower right [34].

Hydrogen has high energy density but no established supply chain

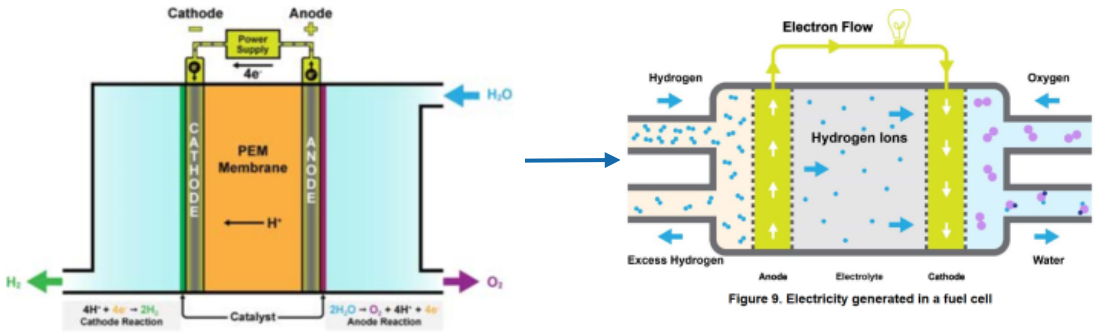
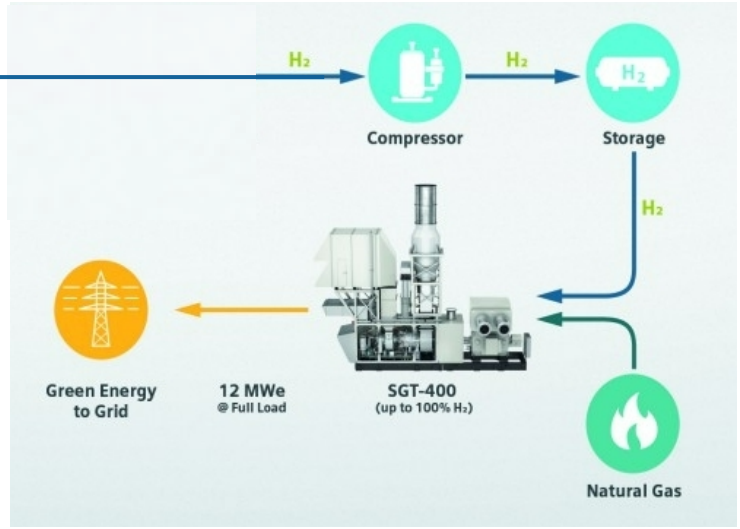


Figure 9. Electricity generated in a fuel cell



Benefits:

- High density of the fuel
- Potential for transport
- Reuse of existing infrastructure

Issues:

- Proton exchange membranes
- Expensive catalyst
- Low efficiency
- NOx production

Figure 4. ITM Power 1 MW electrolyzer

Figure 5. Photo of hydrogen gas cylinders on a tube trailer [15]

Figure 10. Fuel cell stationary power plant

Source: Sandia Energy Storage Handbook

Summary

Specifications

- Solar technology is mature and inexpensive
- The existing grid infrastructure will evolve
- Developing countries can take advantage of new decentralized technologies
- The competition for Li cells will increase as the penetration of EV's goes up
- Lead-acid and new Zn-technologies can hit low price points and be easy to manage
- Other, non-modular options, like flow batteries and H_2 systems are coming to market

Acknowledgements

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