

EV Batteries and Geothermal Energy

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Types of Lithium Batteries

- Lithium Iron Phosphate (LFP)
 - Phosphate cathode, graphitic carbon anode (Tesla, new Bolt choice)
 - 2000 cycles life, deep discharge OK, safest
 - Relatively low specific energy, poor low temp performance
- Lithium Cobalt Oxide (LCO)
 - Long-lasting but not for high loads
 - Low specific power, safety concerns
- Lithium Manganese Oxide (LMO)
 - LMO as cathode
 - Quick charging, high specific power, safe at high temps
 - Short life span 300-700 charge cycles

Types of Lithium Batteries (cont'd)

- Lithium Nickel Manganese Oxide (NMC)
 - Nickel, manganese, and cobalt in cathode (Nissan choice)
 - High energy density, longer lifecycle, safer, and lower cost than cobalt batteries
 - Slightly lower voltage, use rare earths
- Lithium Nickel Cobalt Aluminum Oxide (NCA)
 - High load applications with long battery life (Tesla, GM Ultium choice)
 - Not as safe as others, more expensive
- Lithium Titanate (LTO)
 - LMO or NMC as cathode, lithium titanate as anode
 - Extremely safe, faster charging than others, wide operating temps
 - Low energy density, expensive

Lithium Alternative for EVs

- Sodium ion batteries advantages
 - Sodium is 500 times more abundant than lithium
 - Sodium ion charges faster than lithium ion
 - Uses aluminum in place of more expensive copper at 1/3 cost
 - Has higher operating temperature range
 - Less rare earth metals and minerals
 - Safer because they do not explode or catch fire easily
 - Cheaper than lithium batteries
- Sodium battery disadvantages
 - Less dense and less capacity – 160 kWh vs. 260-270 for lithium
 - Lower cycle life than LFP
 - Less developed than lithium batteries
 - More applicable to medium/low speed EVs and large-scale storage

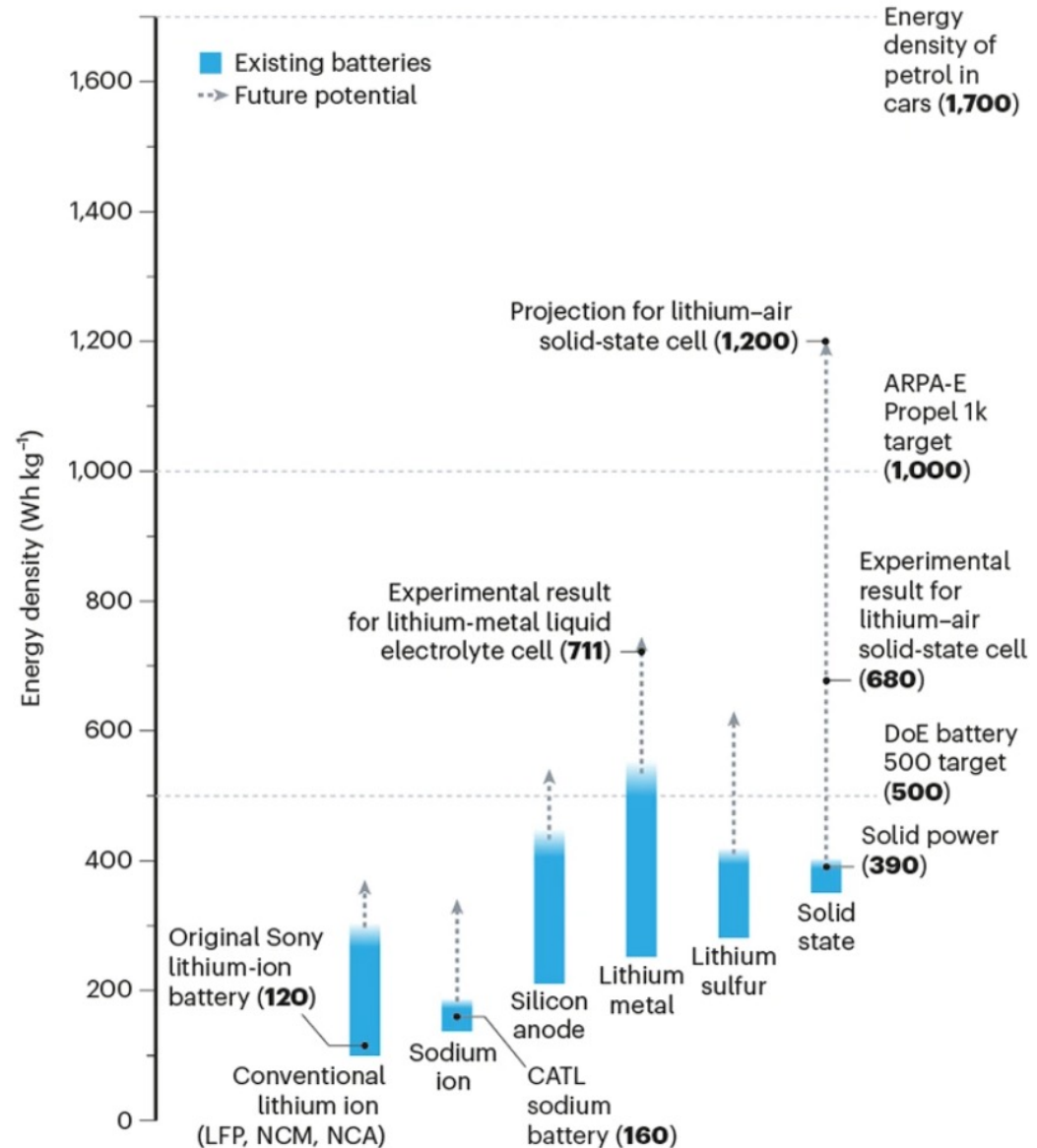
Alternative Batteries

DOE Battery 500 program is aimed at 500 Wh/kg

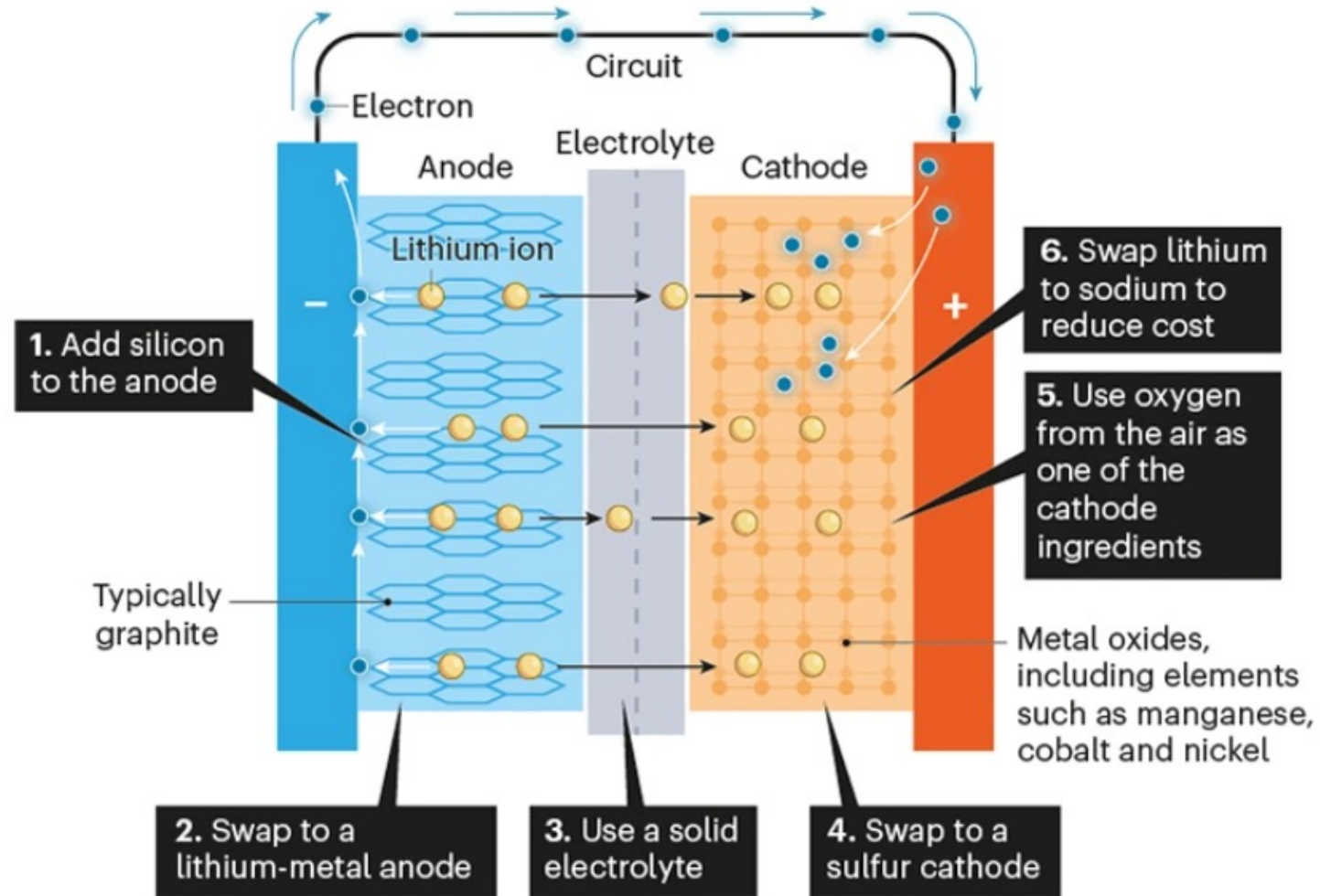
DOE Vehicle Technologies is aimed at \$60/kWh by 2030

POWERING UP

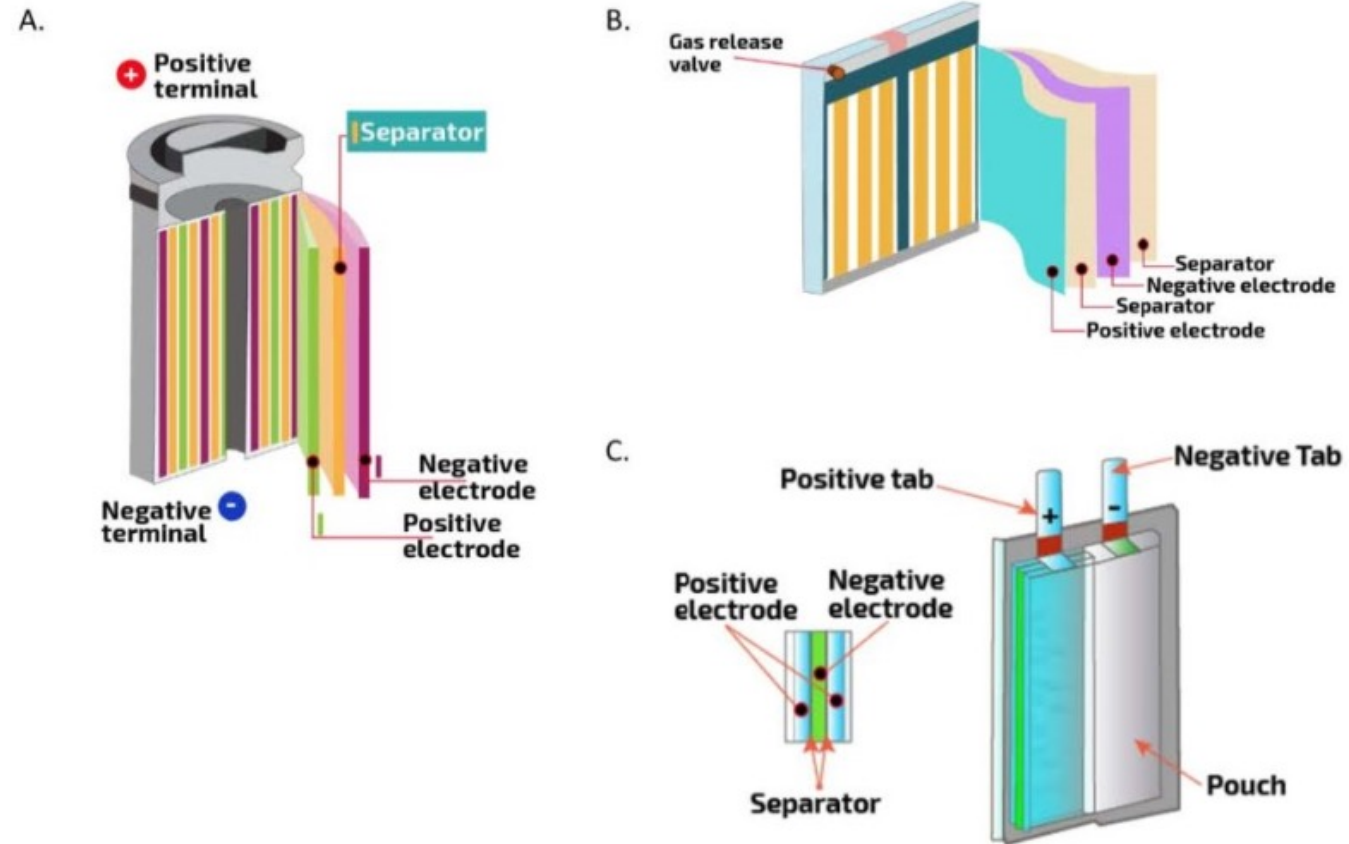
Research is pushing energy density ever higher in all battery types, with some extremely high possibilities. But these can come with some trade-offs on price and other performance measures.



Improving How a Battery Works



Lithium Battery Form Factors

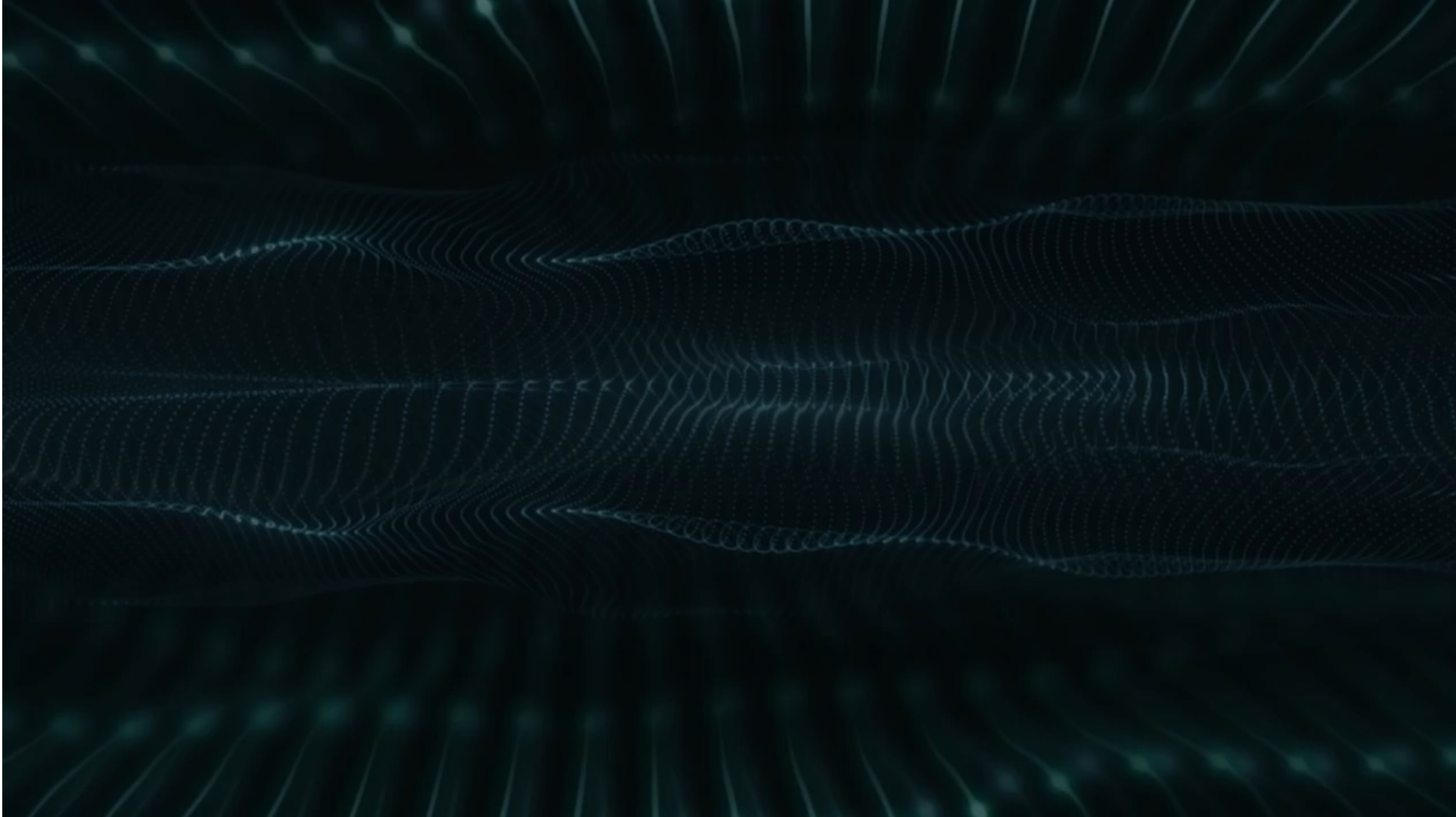


Schematics of various form factors for Li-ion cells, including: A) cylindrical, B) prismatic, and C) pouch. *Source: Sandia National Laboratory. [Click to enlarge.](#)*

Solid State Batteries

- Use a ceramic or solid polymer as the electrolyte
 - Stems dendrite formation
 - Allows all-lithium anode with energy density advantage
 - Removes flammable organic liquid hazard
 - Works better at temperature extremes
- But: there are disadvantages
 - Transport of ions is slower, limiting power
 - Requires new manufacturing process – they're not here yet
 - Two years out, forever?

What Are Solid State Batteries?



Where Can We Get Lithium?

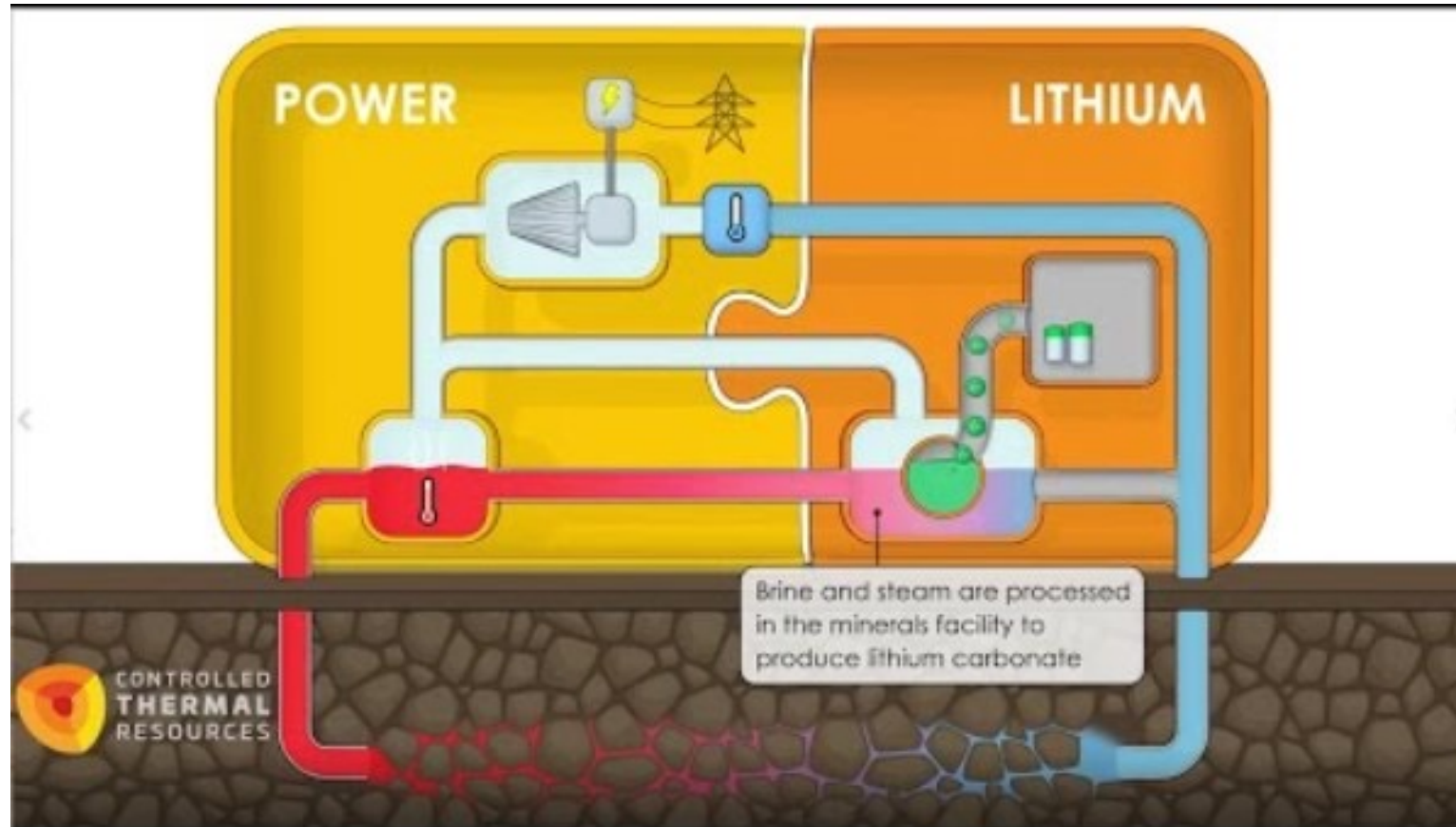


Lithium from Geothermal



FEATHERSTONE GEOTHERMAL POWER PLANT
SALTON SEA

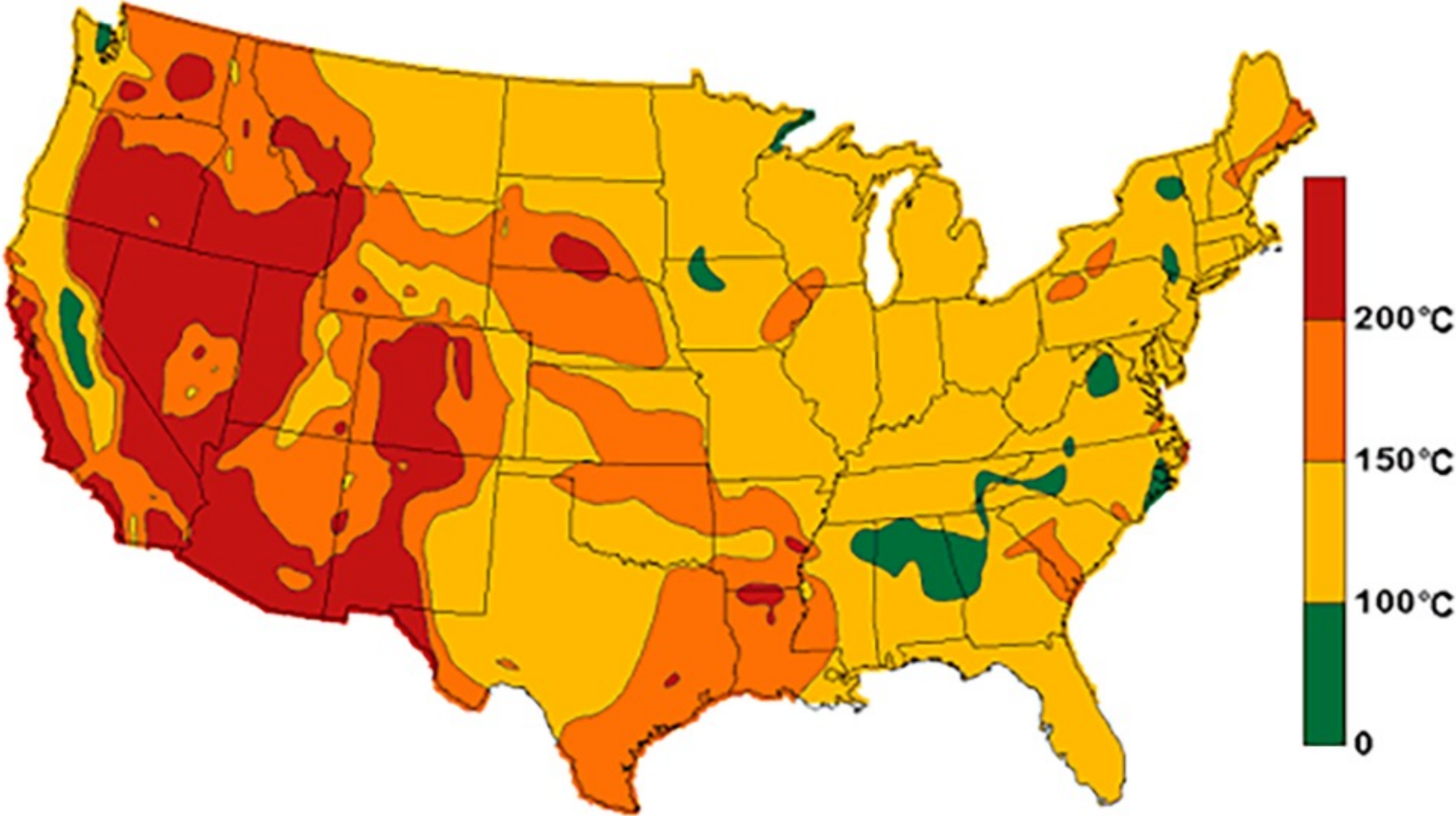
Producing Lithium from Geothermal Brine



Geothermal Energy

- Reservoirs of hot water below earth's surface
 - Few feet to several miles
- Benefits
 - Renewable – hot water isn't going away
 - Baseload – can run 24 hours x 7 days/week
 - Domestic – no imported fuel
 - Small Footprint – less land per GWh than coal, wind, solar
 - Clean – no greenhouse gas, no waste water required/generated
 - 4x lower than solar, 20x lower than natgas
- Growth potential
 - More than 17,000 systems 28 million heat pumps by 2050, 10% of US needs
 - Emissions reduction equivalent to 26 million cars every year
 - Can employ oil/gas drilling experience

Geothermal resources of the United States



Source: U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy (public domain)

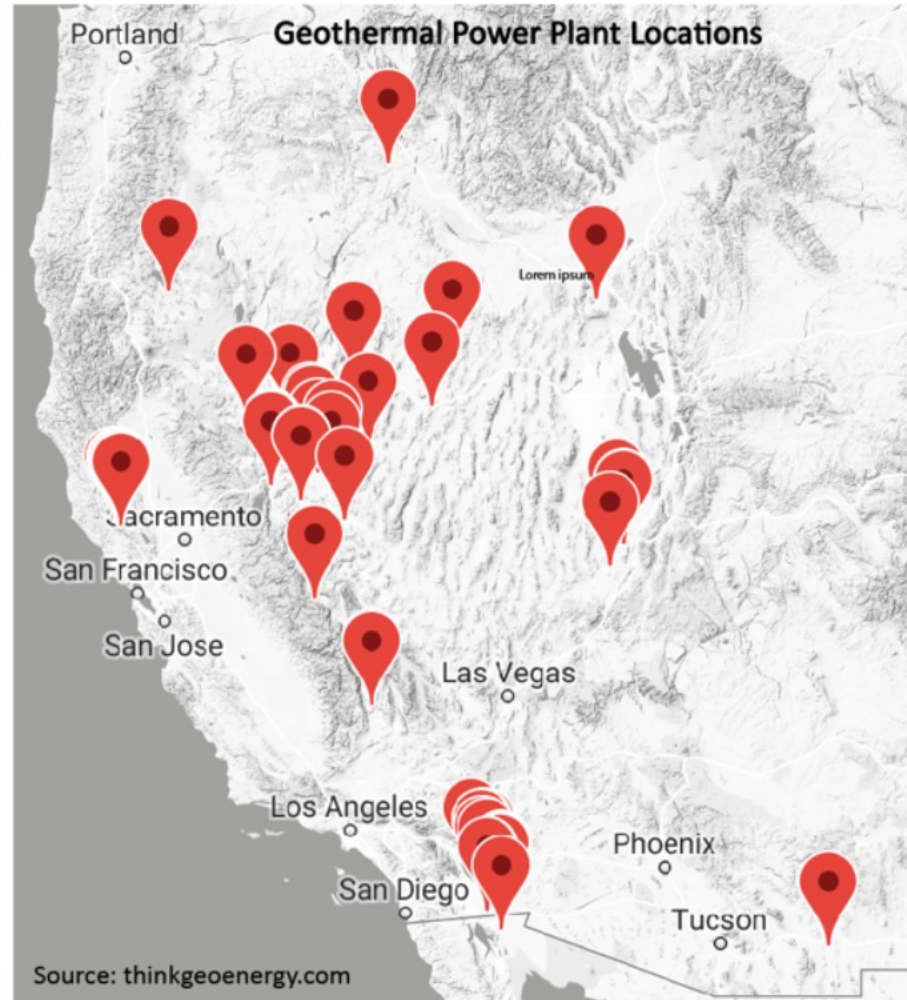
Summary of the United States Geothermal Market

State	Share of National Production	Wells
California	73%	1243
Nevada	21%	430
Utah	3%	24
Hawaii	2%	11
Oregon	1%	15
Idaho	<1%	9
New Mexico	<1%	16

State rankings for geothermal electricity generation, 2017



Source: U.S. Energy Information Administration, *Electric Power Monthly*, Table 16.1.B, February 2018, preliminary data



Source: thinkgeoenergy.com

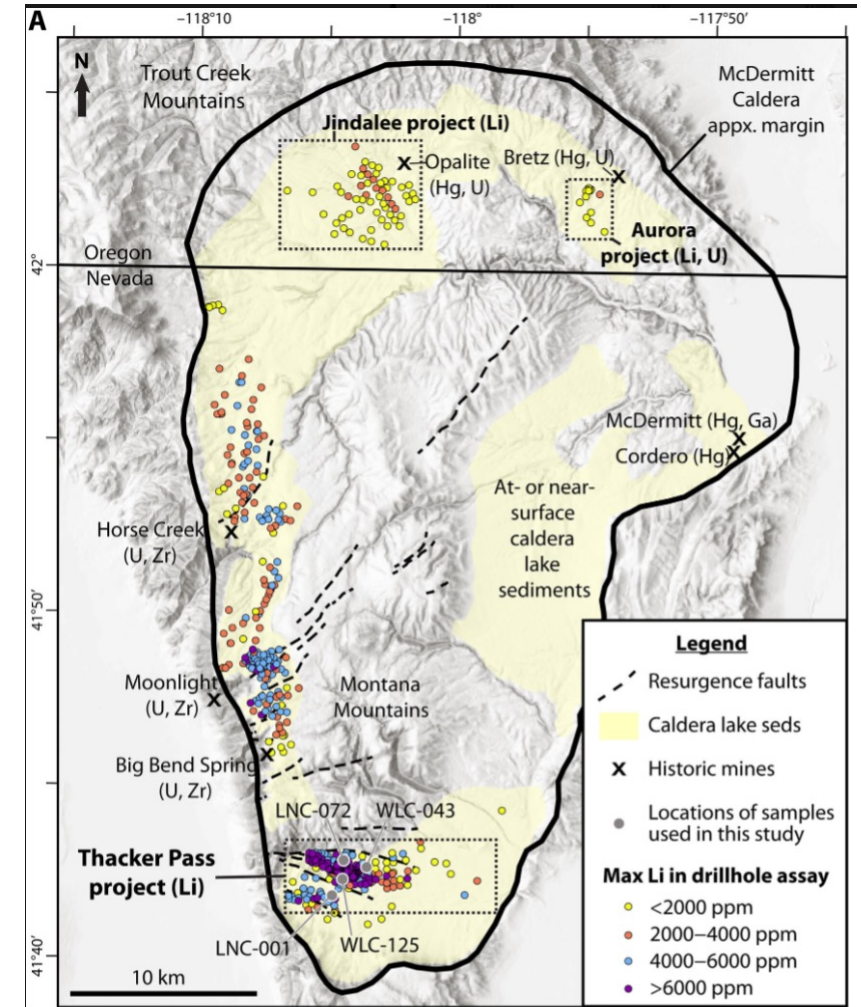
1748 wells in US, most in CA

Geothermal Drilling Using Oil/Gas Expertise



Lithium Mining in US


- Largest lithium deposit in US is McDermitt Caldera in Nevada, N of Winnemucca
 - Largest on Earth– 20 to 40 million metric tons
 - EVs in 2050 could need 0.3 million tons per year
 - Contested by native tribes
- Currently only one lithium mine in US
 - Silver Peak mine in Clayton Valley, NV
 - Uses brine pools
- Most lithium is mined in Chile and Australia



Most Valuable Plot of Land in America



Lithium Battery Recycling

	Natural Resources	Spent Batteries
One ton of battery-grade cobalt can come from:	 300 TONS OF ORE	 5-15 TONS OF SPENT LITHIUM-ION BATTERIES
One ton of battery-grade lithium can come from:	 250 TONS OF ORE	 750 TONS BRINE
		 28 TONS OF LITHIUM-ION BATTERIES

Source: U.S. Department of Energy Vehicle Technologies Office.

Lithium Battery Recycling

- Shredding
 - Black mass (anode/cathode), copper foils, separators, plastics, steel
- Heat based smelting (pyrometallurgy)
 - Can recover cobalt and nickel, extra steps for lithium
- Liquid based leaching (hydrometallurgy)
 - Can recover cobalt, nickel, lithium, and manganese
- Battery reuse
 - Old lithium batteries don't fail, they lose capacity
 - "New" EV battery packs using good recycled cells
 - Stationary storage (e.g., Tesla Powerwall)
- Clean Earth Rancho Cordova - www.cleanearthinc.com
 - Local lithium (and other) recycling company
 - Limited by availability of old recyclable batteries at this time
- Lithium recycling is cheaper than mining - sustainable

References

- Producing Lithium from Geothermal brines
 - <https://www.youtube.com/watch?v=oYtyEVPGEU8>
- CBS News: Geothermal discovery Deep Canada
 - <https://www.youtube.com/watch?v=Qn7lhGitNE4>
- Salton Sea can provide Lithium Valley
 - <https://www.youtube.com/watch?v=zfZqpdt3Zy0>
- Extracting Lithium from Salton Sea
 - <https://www.youtube.com/watch?v=SQWBJJzjB4k>
- Salton Sea Lithium
 - <https://www.youtube.com/watch?v=ApxGBJJH0jw>
- Just Have a Think Geothermal
 - https://www.youtube.com/watch?v=-Ss_wHCS1Aw

References (cont'd)

- Geothermal Can Provide 50% of Electricity
 - <https://www.youtube.com/watch?v=g0sHVSc1cF4>
- Lithium Refining and extraction process biggest game changer of 2022
 - https://www.youtube.com/watch?v=Zz_HUxgmtYE
- Solid State Batteries Just Have a Think
 - <https://www.youtube.com/watch?v=suNUPGC2pwM>
- What are Solid State Batteries QuantumScape
 - <https://www.youtube.com/watch?v=azACL3ILMo8>
- QuantumScapes Solid-State battery – Electric Viking
 - <https://www.youtube.com/watch?v=9tPoaJZpdfU>
- Solid State Batteries – Just Have a think
 - <https://www.youtube.com/watch?v=suNUPGC2pwM>