



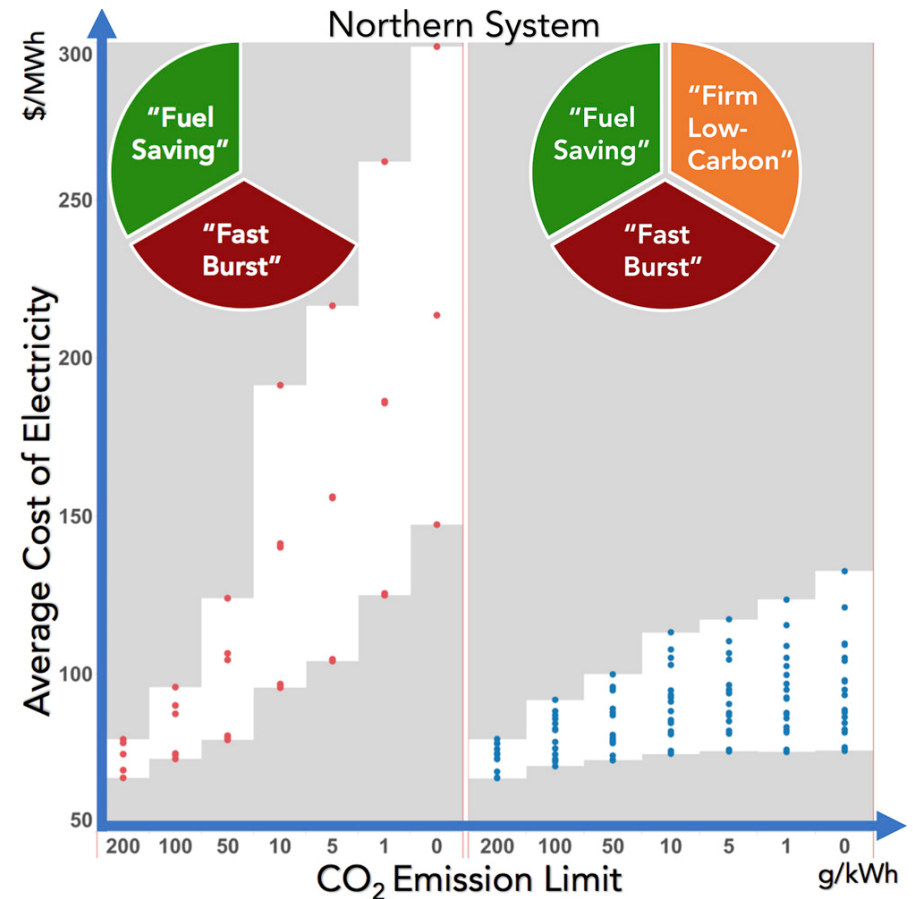
Energy Storage for the Grid: A Problem of Technology AND Scale

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Why We Need Firm Generation

- “Without these [firm] resources, electricity costs rise rapidly as CO₂ limits approach zero. Batteries and demand flexibility do not substitute for firm resources.” – Sepulveda et al.
- “Energy markets may not appropriately compensate dispatchable resources for the availability, flexibility, and other attributes they provide.” – MISO Forward Plan



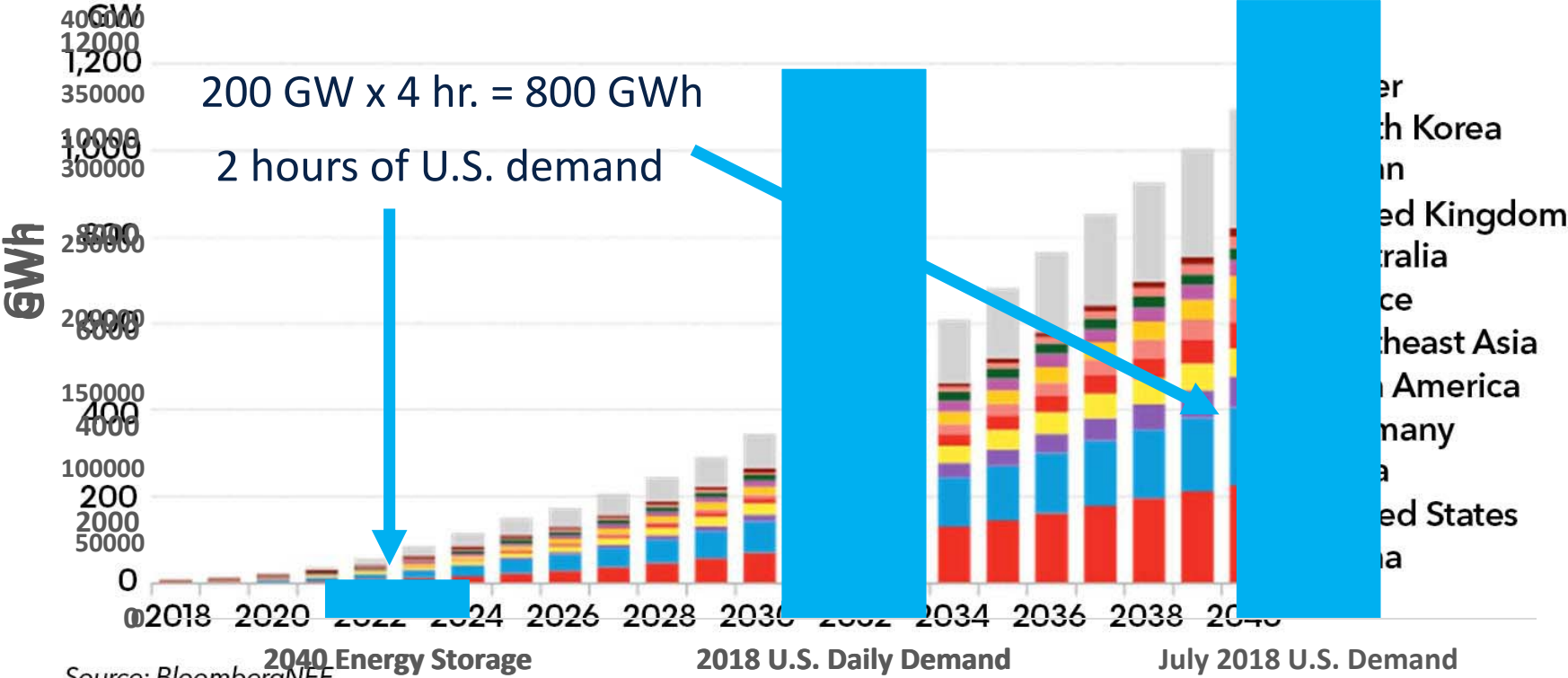
Texas is a Good Case Study

	2018	Current Policies	50 Percent Renewables	80 Percent Renewables	100 Percent Renewables
Wind Capacity (MW)	22,066	37,596	49,877	102,928	107,737
Solar Capacity (MW)	1,861	11,019	25,372	86,091	91,597
Battery Capacity (MW)	87	527	10,626	23,260	533,833
Nuclear Capacity (MW)	4,960	4,960	4,960	4,960	-
Gas Capacity (MW)	45,449	51,997	54,700	42,000	-
Coal Capacity (MW)	14,225	14,225	-	-	-
Annual Cost (\$ Billion)	13	19	33	61	120
Annual Cost (\$/MWh)	36	44	73	138	270

Source: *Life:Powered*, 2019. <https://lifepowered.org/wp-content/uploads/2019/10/2019-08-PP-LP-Bennett-Green-New-Deal.pdf>

Technology Is Not the Problem, Scale Is

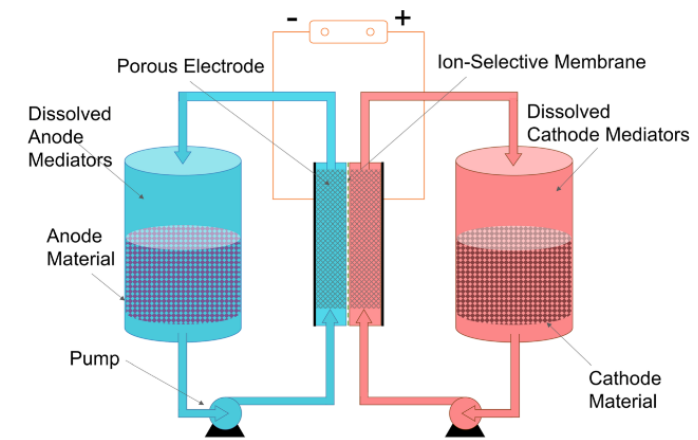
Global cumulative energy storage installations



Note: Demand forecasts are from Bloomberg New Energy Finance.

Future Possibilities for Grid Storage

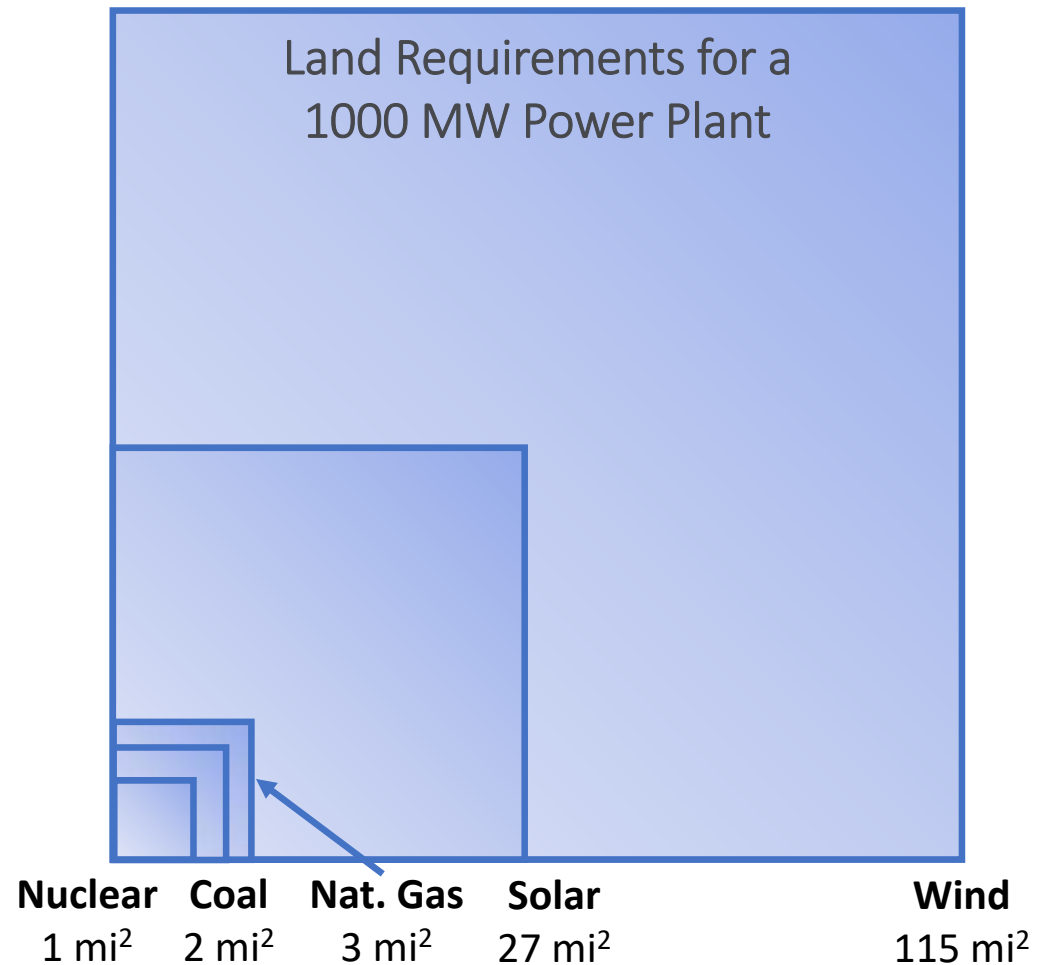
- Mechanical and thermal storage: cheap, low density, difficult to deploy
- Low energy density batteries: cheap materials but overall expensive
- High energy density batteries: expensive materials, safety concerns



Energy Density = Environmental Stewardship

Density of U.S. Energy Resources

Power Source	Acres/MW
Nuclear	0.8
Coal	1.4
Natural Gas	2.4
Crude Oil	11.2
Solar	30.9
Hydroelectric	145.4
Wind	247.1
Ethanol	823.7



Source: Vaclav Smil, *Power Density*, MIT Press 2015

Key Takeaways

- The falling cost to install wind and solar will not mean they can displace the need for firm generation. It is not a problem of technology but one of scale.
- Texas offers a number of instructive examples. Going 100% wind and solar is prohibitively expensive even with good resources. Only with firm generation can CO₂ reduction
- Many technologies are being developed for utility-scale energy storage, but they are all challenged by the immense scale required by the electric grid.