

**GLOBAL UTILITY TRENDS IN HYBRID
SOLAR PV + ENERGY STORAGE**

27TH PPA ANNUAL CONFERENCE 2018

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August 2nd, 2018

Topics for Today's Presentation

Canadian Solar Overview

Markets for Hybrid Solar PV + Storage

Today's Storage Technology of Choice

Evolution of Storage Markets

Overview of PV + Storage Applications

Case Study: American Samoa Power Authority

Future of Hybrid Solar PV + Storage

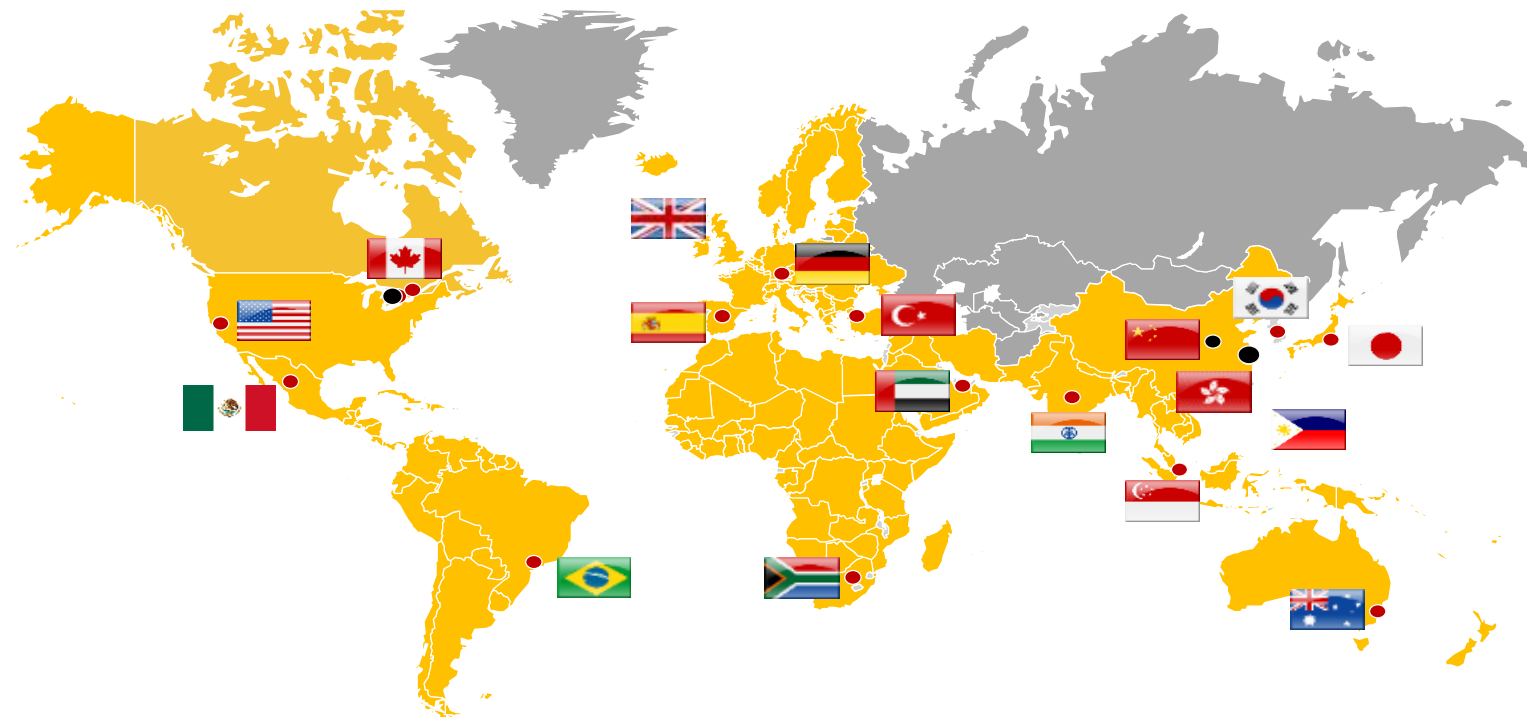
Final Thoughts



Astoria Project developed by Canadian Solar's subsidiary Recurrent Energy (100 MWac/131 MWp)

Company Overview

- Founded in 2001 in Canada, Canadian Solar is one of the world's largest solar power companies.
- As a leading manufacturer of solar photovoltaic modules and a provider of solar energy and energy storage solutions, Canadian Solar has a geographically diversified pipeline of utility-scale power projects in various stages of development around the world.



12,000+
Employees Globally

20+
Countries covered by project
development and financing options

3.2 GW
Solar Project Developed and
Connected cumulatively

27 GW+
Solar modules shipped cumulatively

● Sales office ● Manufacturing facility ■ Regional energy business

Company Overview



Module System Solution (MSS) Group

- Top 3 PV module delivery in the world.
- Solar Module Design, Manufacture, Sales, and System Integration Services.

Energy Group

- 2nd largest global PV Developer in 2017.*
- Utility size solar Project Development, Construction, O&M Services.

* Source: GTM Research

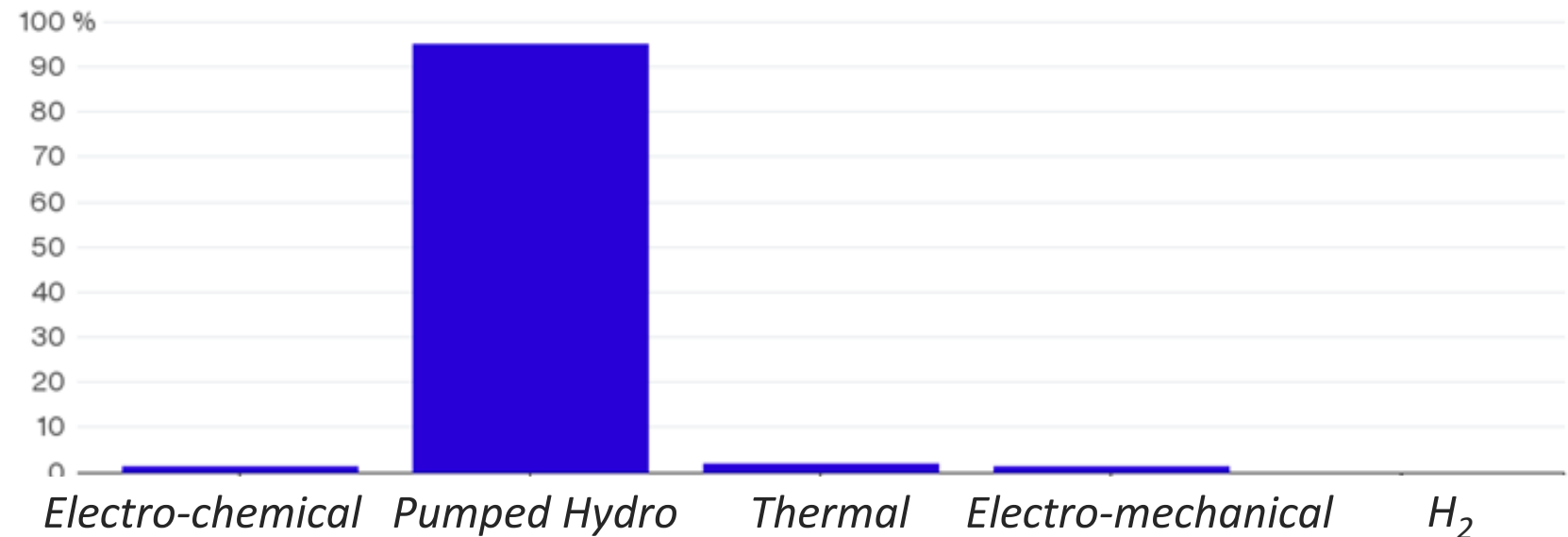
Pumped Hydro Dominates Bulk Energy Storage Today

- Lowest capital cost of bulk storage except compressed air energy storage (CAES).
- Lazard's 2015 Levelized Cost of Storage Analysis shows \$213 to 313/kWh of capacity for pumped hydro (PH).
- *Li-ion will begin to intercept PH LCOS* in 3 years.*

* LCOS = Levelized Cost of Storage

Grid-Connected Energy Storage Projects Worldwide

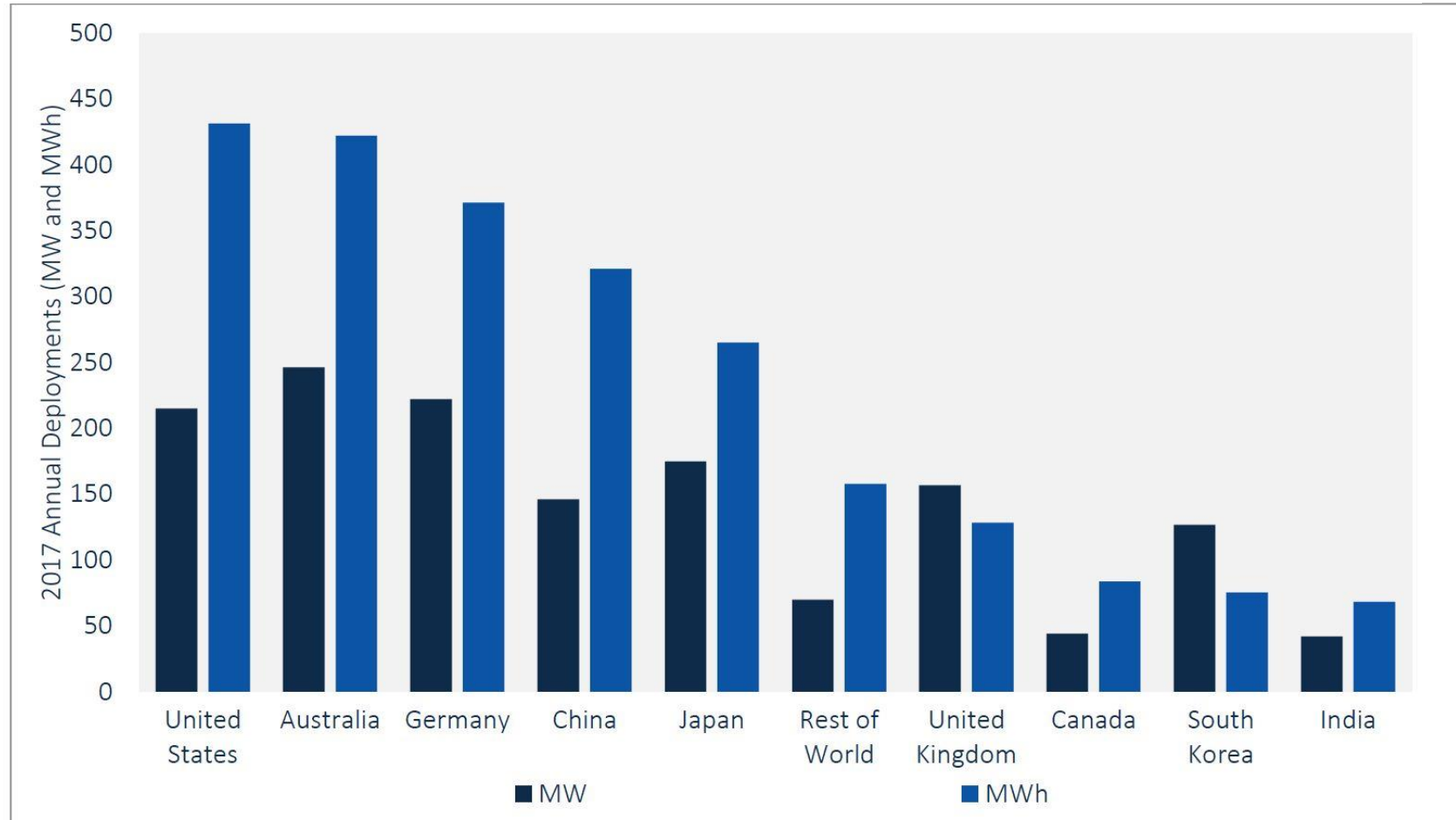
Pumped hydro dominates and batteries of all kinds are barely on the grid



Source: USDOE, BNEF

US Deployments of Energy Storage vs. Other Parts of the World

Annual Energy Storage Deployments by Market, 2017 (MW and MWh)

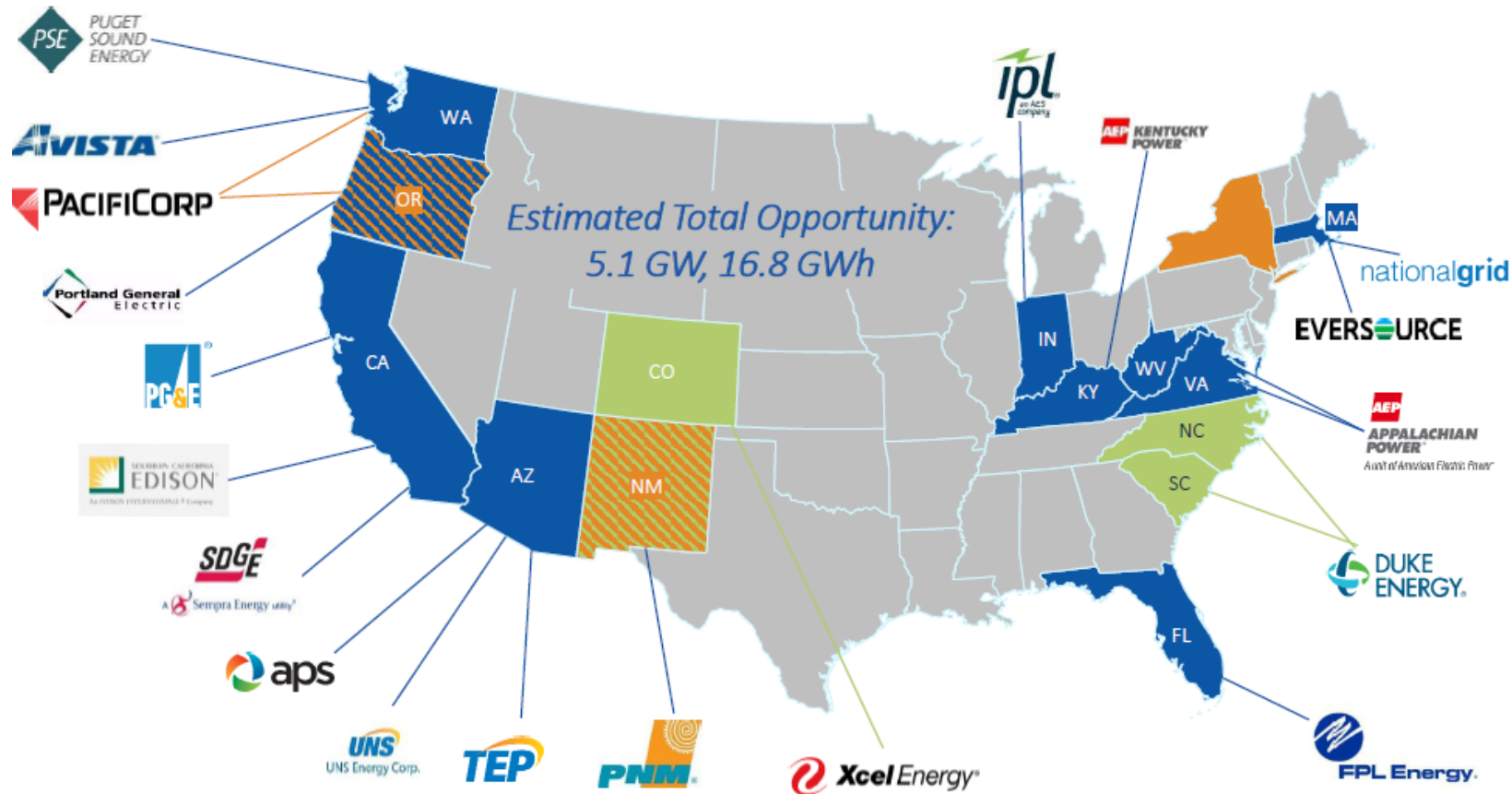


Source: GTM Research, US DOE

- In February 2018, the Federal Energy Regulatory Commission (FERC) passed Order 841, which opens the door for storage to compete in wholesale markets across all three services – capacity, energy and ancillary services.
- FERC’s reform will take 18 months to take full effect – but will greatly accelerate market demand for energy storage when it does.

Utility Planners are Adding Energy Storage to the Resource Mix

Storage is increasingly included in utility IRPs



- There is about 5.1 GW of storage opportunity in existing utility integrated resource plans (IRPs).
- These IRPs view storage as a flexible resource, not necessarily as a direct threat to combustion turbine (CT) plants.

MW in Resource Plan

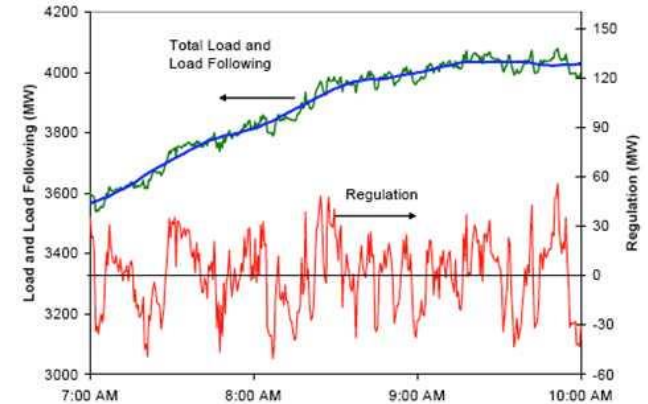
- Specific Storage Capacity
- Part of All-Source Capacity
- Target to Be Determined

Source: GTM Research

Sequence of Grid-scale Storage Evolution in Most Countries

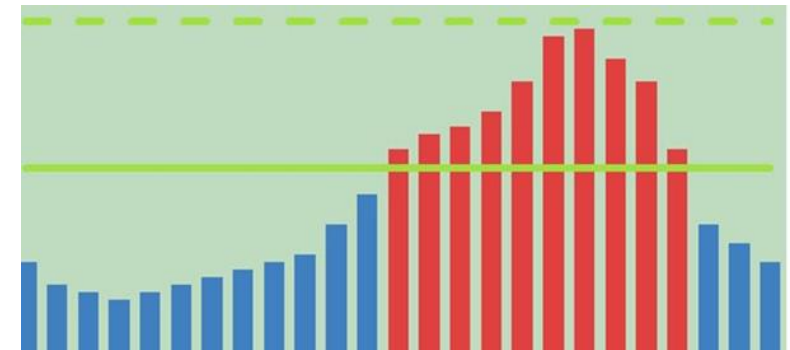
1st Stage (started ~ 10 years ago; small niche market)

- Frequency Regulation – storage only (short time period, 15 to 30-minutes)
- Solar Integration – storage for cloud mitigation (short time period, e.g., 30-minutes discharge)



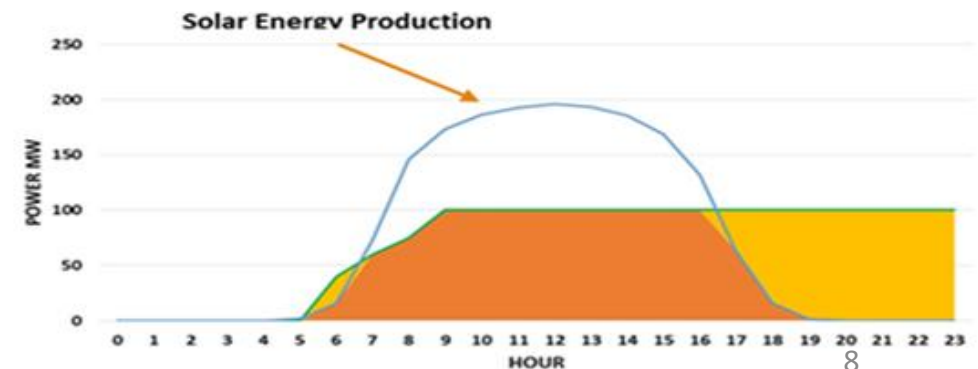
2nd Stage (started 4 years ago, \$30B/yr. global market)

- Li-ion storage replaces simple cycle gas peakers
- 4-hour discharge typical
- Initially storage-only, but can be a combination of PV + storage



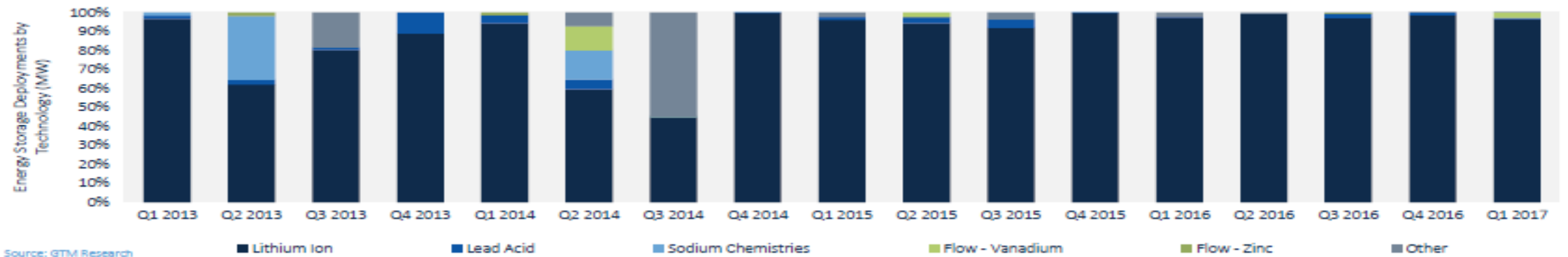
3rd Stage (started 3 years ago, an enormous global market)

- Hybrid asset performs energy shifting and regional peaking support at the same time
- 4 to 6 hours discharge likely
- Will become the biggest utility-scale market segment



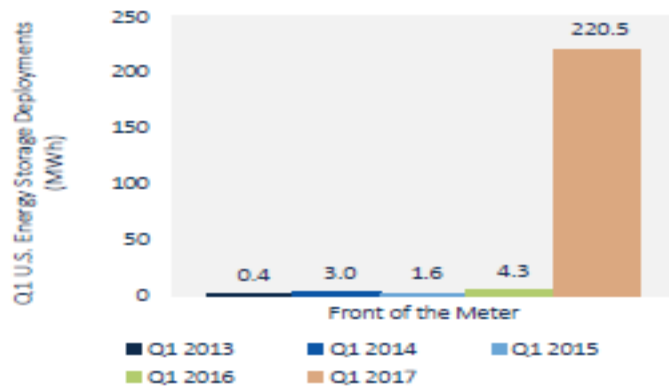
Lithium Ion Batteries and Front of Meter Dominate

Quarterly Energy Storage Deployment Share by Technology (MW %)

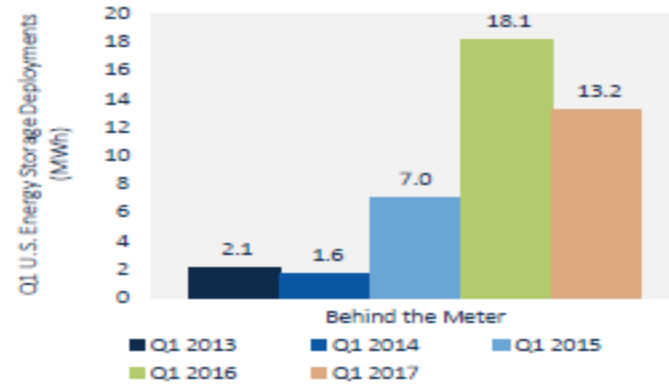


Source: GTM Research

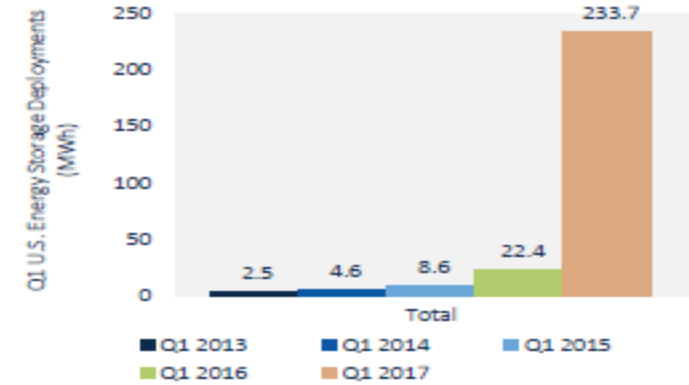
Front of meter



Behind the Meter

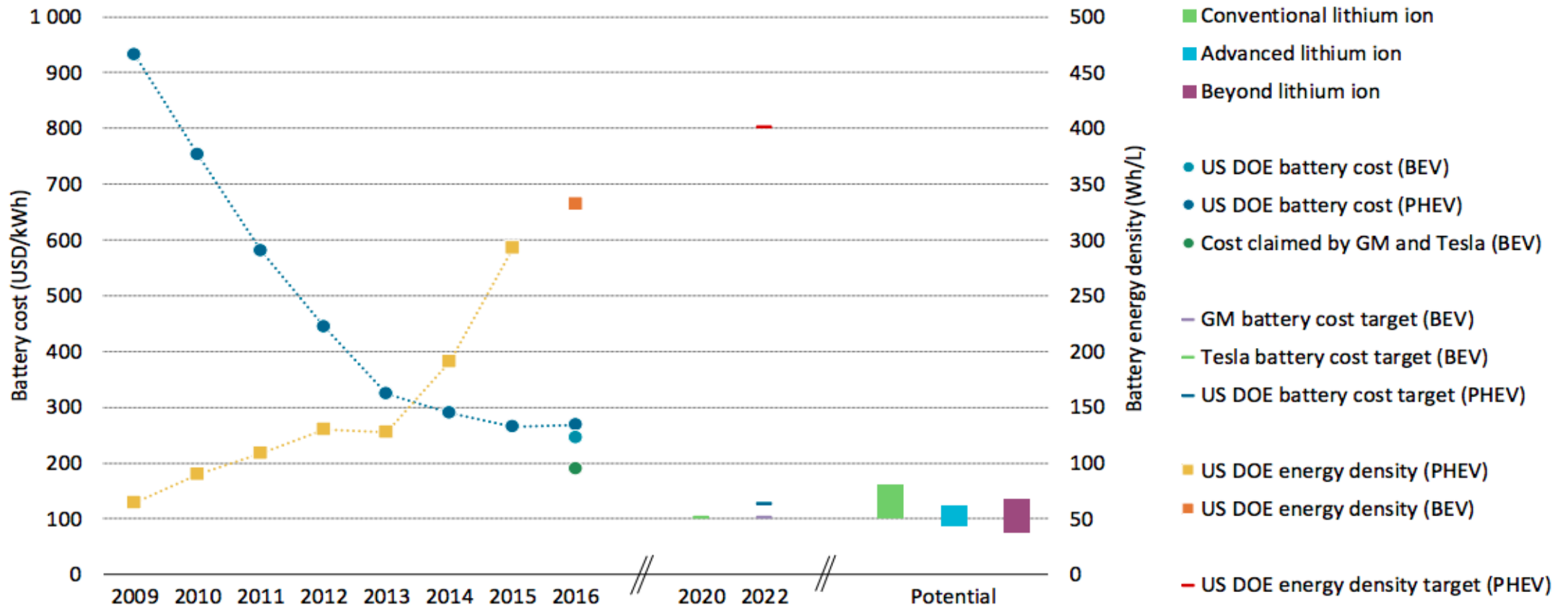


Total



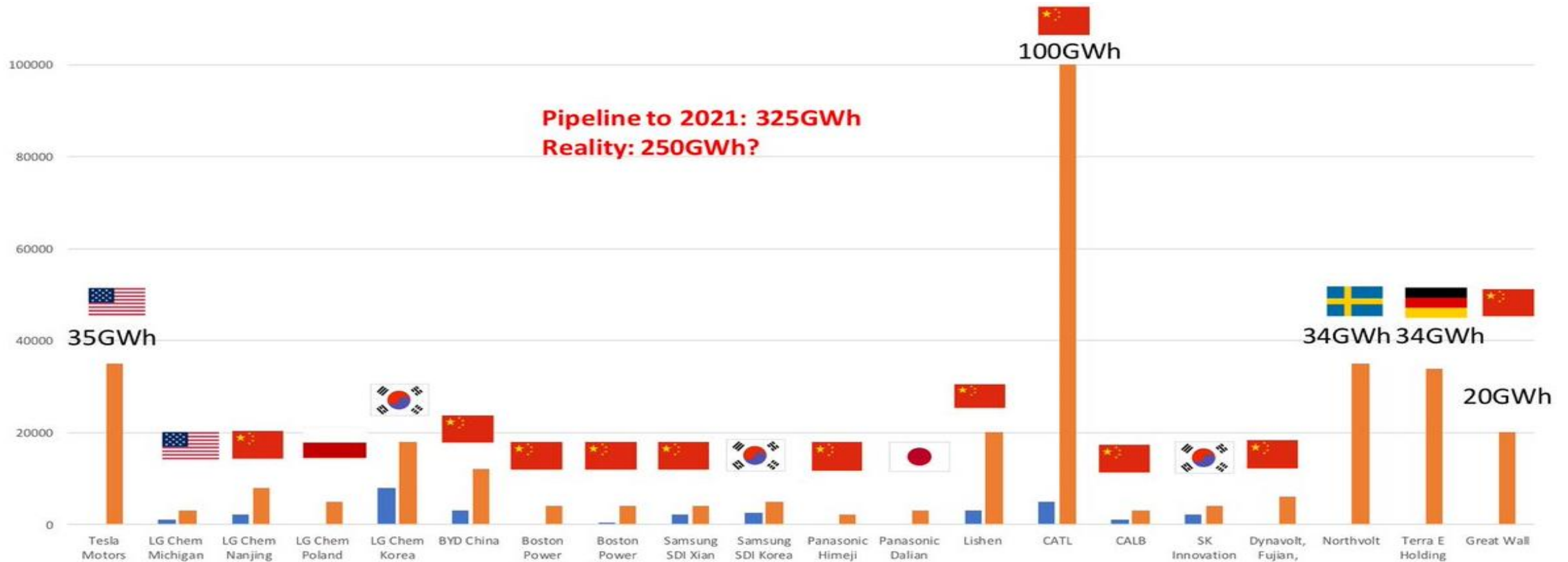
Higher Energy Density Translates to Lower Cost Batteries

Evolution of Battery Energy Density and Cost



More Gigafactories will Push Battery Costs Lower

Announced Capacity Additions in GWh – China will Challenge S. Korean Manufacturers



Fast Response Frequency Regulation

- Jake & Elwood 20MW FR plants
- Developer: RES, 2012



- First frequency regulation (FR) storage projects (AES Energy Services, Beacon Power).
- Frequency regulation was the largest front-of-meter storage application in USA until 2016.
- 265 MW of fast-response storage in PJM.
- Power-to-energy ratio 4:1 (30 minute capacity).
- Asset value: 20MW, 5MWh plant ~ \$15M.
- Volatile pricing, merchant market.
- Limited market: 3/10ths of 1% average peak load.

American Samoa 20MWdc Solar + 12MW, 6MWh Energy Storage

Project Elements

- **Scope:** 20MWdc PV + 12MW, 6MWh energy storage in 2 equal phases
- **EPC:** Canadian Solar providing turnkey finance, engineering, equipment, installation, O&M
- **Sites:** multiple sites close to new distribution circuit
- **Energy Storage:** ramp rate control and distribution circuit stability
- **Battery Type:** Lithium Ion batteries, 2C
- **Contract Management:** Pacific Solar Innovations providing local coordination



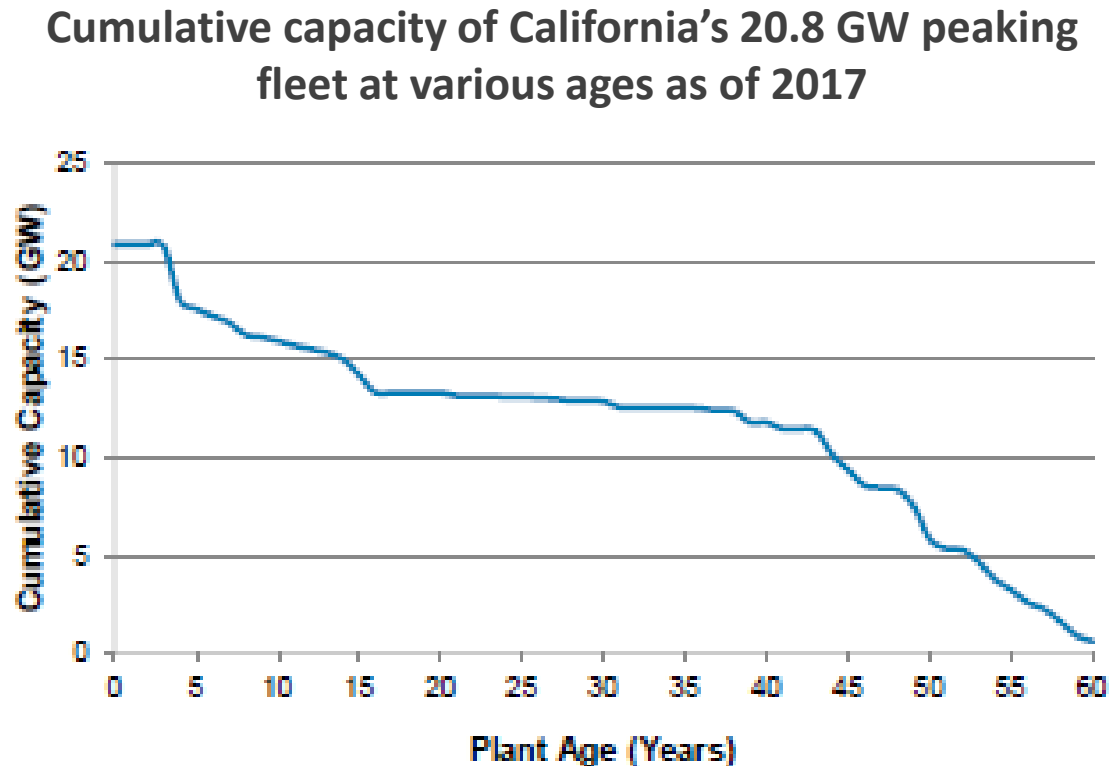
American Samoa Power Authority is dedicated to increasing the use of clean renewables and reducing environmental impacts of fossil fuel generation

Gas Peaker Substitution



- Tesla built a 20MW, 80MWh peaker plant in less than 4-months from award date to COD.
- Timing stunned global utility industry.
- Plant MWh capacity approximately equal to 15% of total installed grid storage globally.
- Primarily a storage-only application.
- Solar PV synergy possible in some markets.
- Merchant play, or utility rate base.
- Asset value: 20MW, 80MWh ~ \$40M @ \$500K/MWh.

“Storage-based Peakers” will Displace Many Fossil Peakers



- The USA has 60 GW of conventional fossil-based peaking plants.
- Of those plants shut down since 1980, their average age was 44 years.
- In California, 272 internal-combustion, simple-cycle, and steam-turbine generators comprise 20.8 GW of peaking capacity.
- 12 GW of California’s 20.8 GW total fleet peaking capacity are 40 years old, or older.

Hybrid Solar PV + Storage Peaker Plant Substitution



- Tucson Electric Power (TEP) 100MW PV + 30MW, 120MWh storage
- 20-yr. PPA for “less than 4.5¢/kWh”
- Large-scale solar PV project with a 4-hour storage-based peaker added
- Not directly comparable to energy shifting projects for KIUC in Hawaii (Tesla, AES)

Solar PV + Storage for Bulk Energy Shifting into Night



- Hawaii: SolarCity built a 13MW PV + 52MWh li-ion storage plant (Tesla batteries).
- 20-year PPA, 13.9 cents/kWh.
- Beats KIUC's 16 cents/kWh wholesale generation.
- Supply power between 5 – 10 PM ("duck" region).

- Hawaii: AES Distributed Energy 20MW PV + storage "peaker plant" on Kauai.
- 20-year PPA, 11.0 cents/kWh; AES will own and operate 5-hour storage duration; most PV energy will be shifted into dark hours.
- 21% cheaper PPA rate vs. 15 months earlier.

Policies and Regulations Often Undervalue Storage

Benefit/cost studies often undervalue:

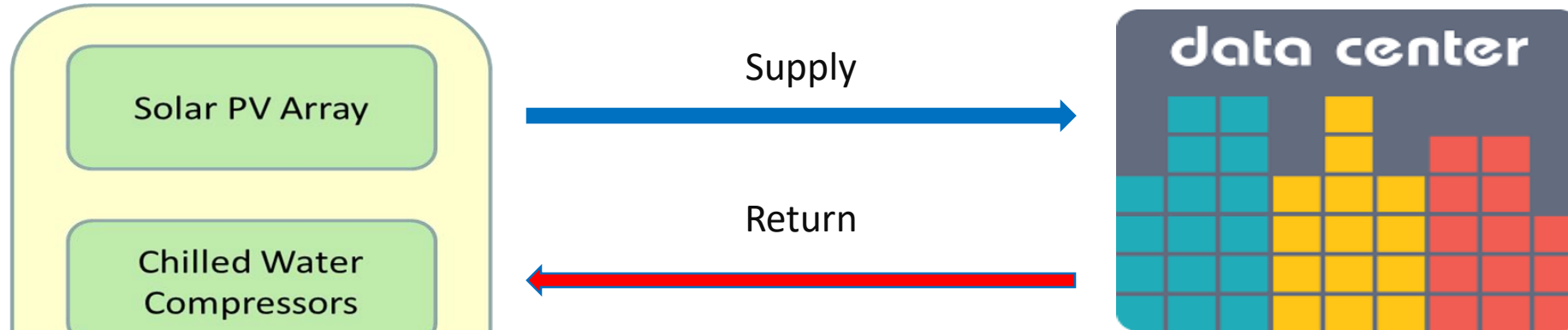
- Current costs of solar PV and storage
- Flexible range, ramp rate, response rate
- Higher reliability
- Lower operating cost
- Multiple value streams
- Speed of installation
- No air emissions
- Less water usage, no natural gas

California Example *

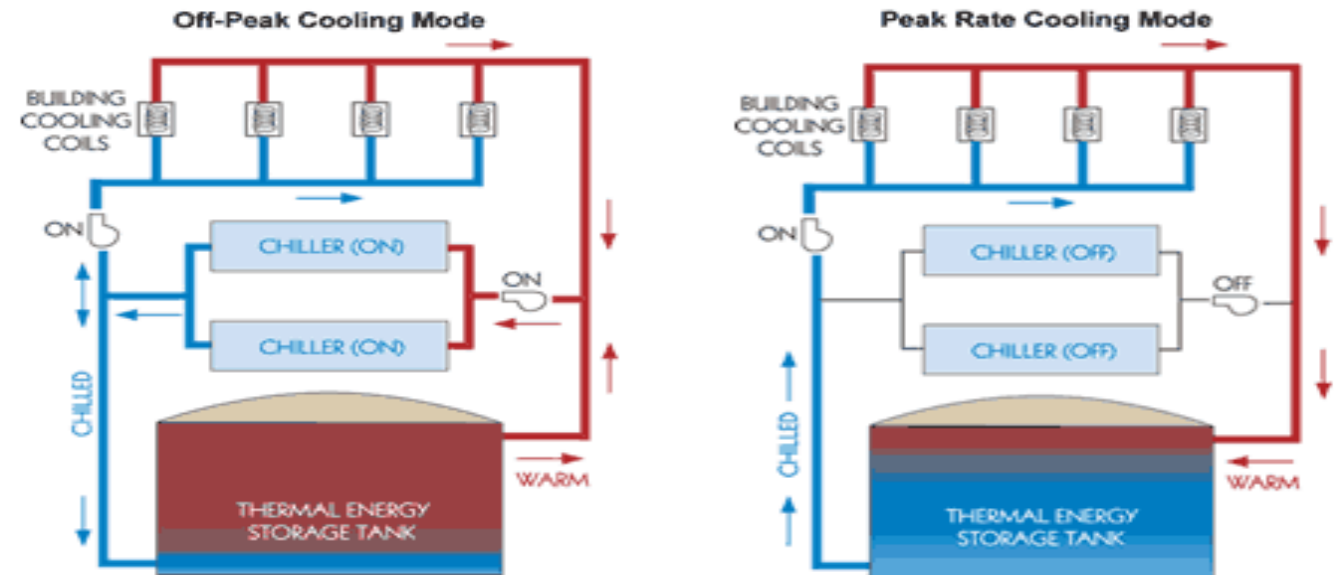
- A hybrid 210 MW solar PV + 130 MW/560 MWh energy storage system could replace both the Puente Power Project and the Ellwood Peaker for less cost than fossil-based generation.
- This hybrid PV + Li-ion system would cost ~ \$430 to \$530 million with ground mount solar compared to \$1.1 billion estimated by CAISO in its grid study (net of solar/storage ITC benefit).

* Source: Cost and Engineering Study of Puente Power Project Cost Effective PV Solar and Storage Capacity; Clean Coalition Study, Aug. 2017.

Solar PV + Thermal Chilled Water Energy Storage



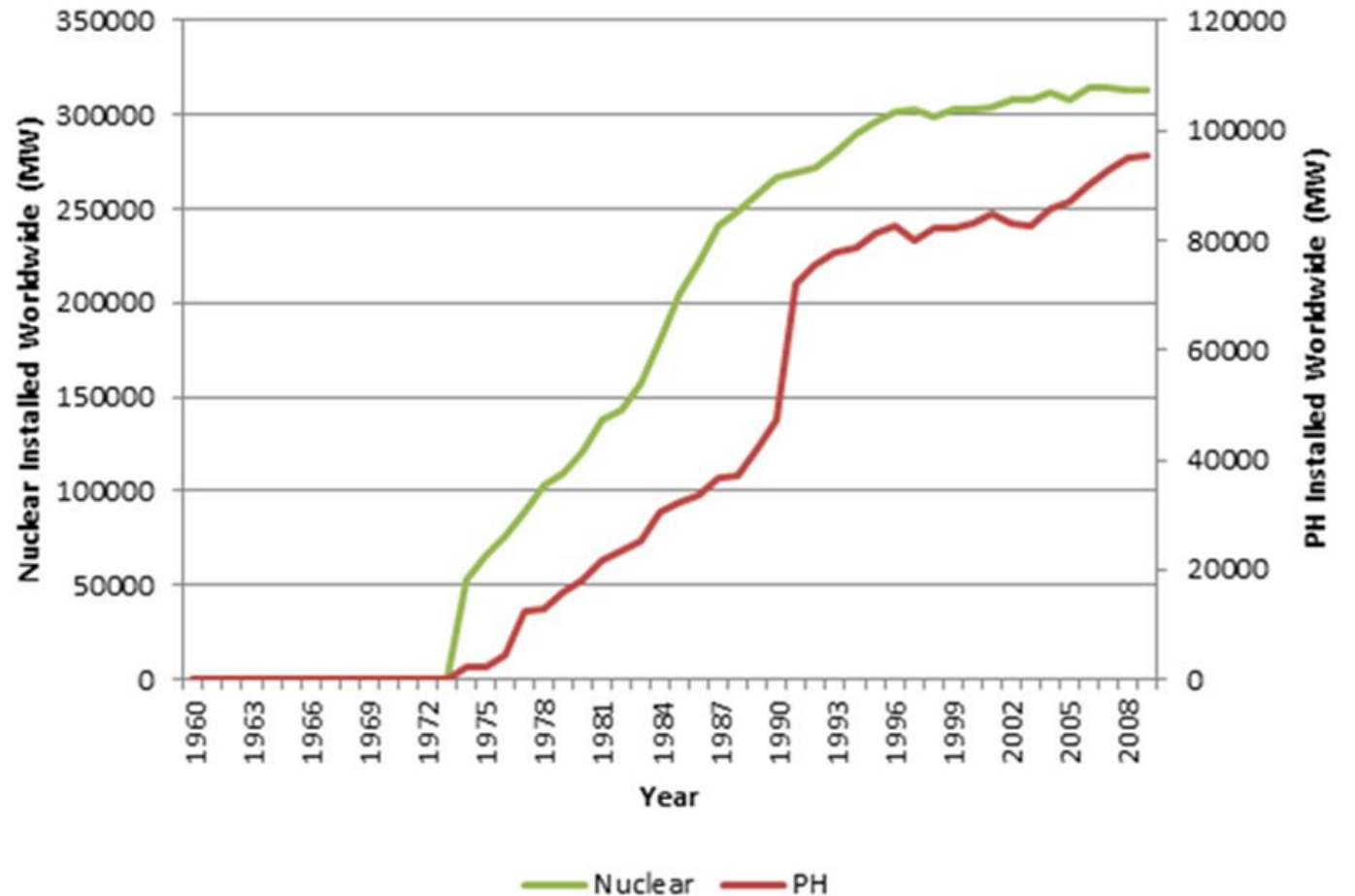
- Solar PV + thermal cold water energy storage for process cooling, district cooling, data centers, etc.
- “Duck curve compliant.”



The End of One Era Marks the Beginning of Another

“Duke Power kills nuclear plant, plans \$6 billion in solar, battery investment”

Tampa Bay Times wrote that Duke “is effectively giving up its long-held belief that nuclear power is a key component to its Florida future and, instead, making a dramatic shift toward more solar power.”





Thank You!

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