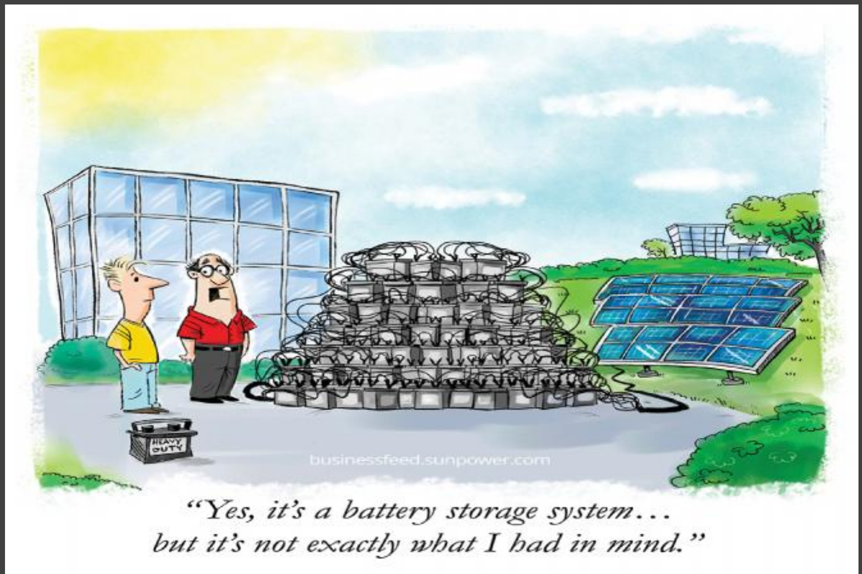
Solar plus Battery Storage
Overhyped or Understated?



Source: Sunpower Corporation

Mort Cohen
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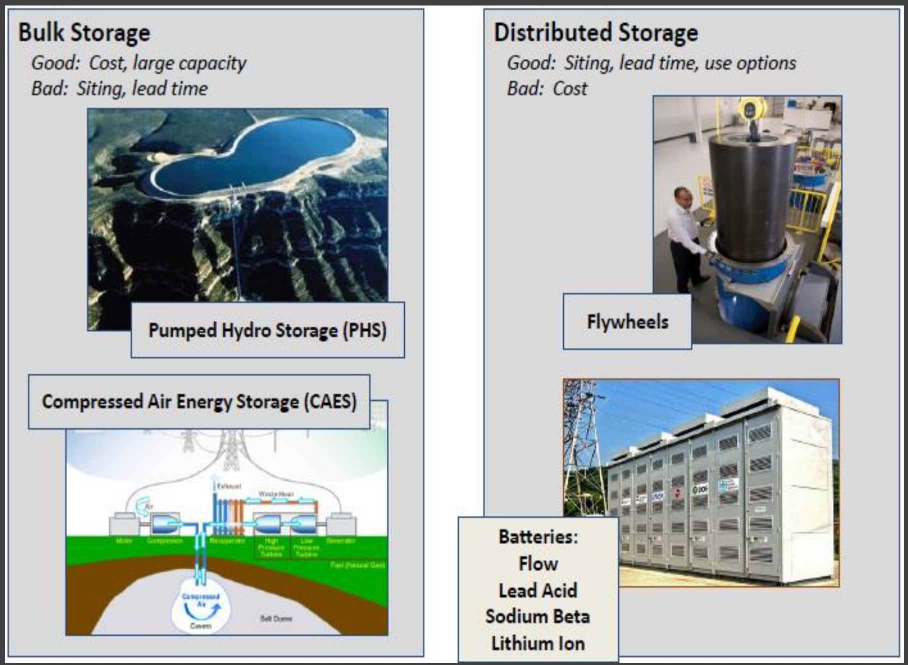
June 2019

What are The Key Energy Storage Technologies?

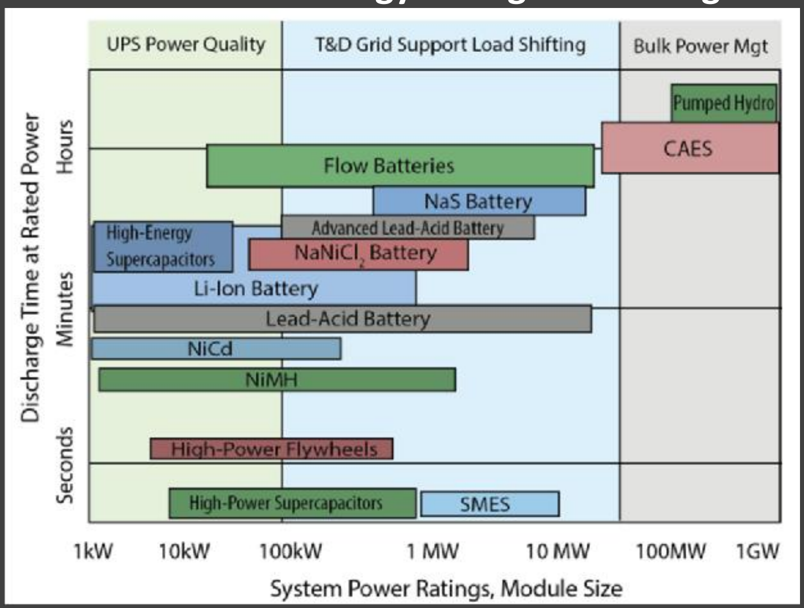


Source: National Renewable Energy Laboratory Presentation, Energy Storage Economics, August 2017

- **Pumped Hydroelectric Storage (PHS)** systems pump water from a low to a high reservoir, releasing the water from the higher reservoir through a hydroelectric turbine when electricity is needed.
- **Compressed Air Energy Storage (CAES)** captures and stores compressed air in an underground cavern. The pressurized air is heated and expanded in an expansion turbine, driving a generator.
- **Flywheel Energy Storage (FES)** store electric energy via kinetic energy by spinning a rotor in a frictionless enclosure. The rotor is sped up or down to shift energy to or from the grid, which steadies the power supply.

What are the Promising Battery Technologies?

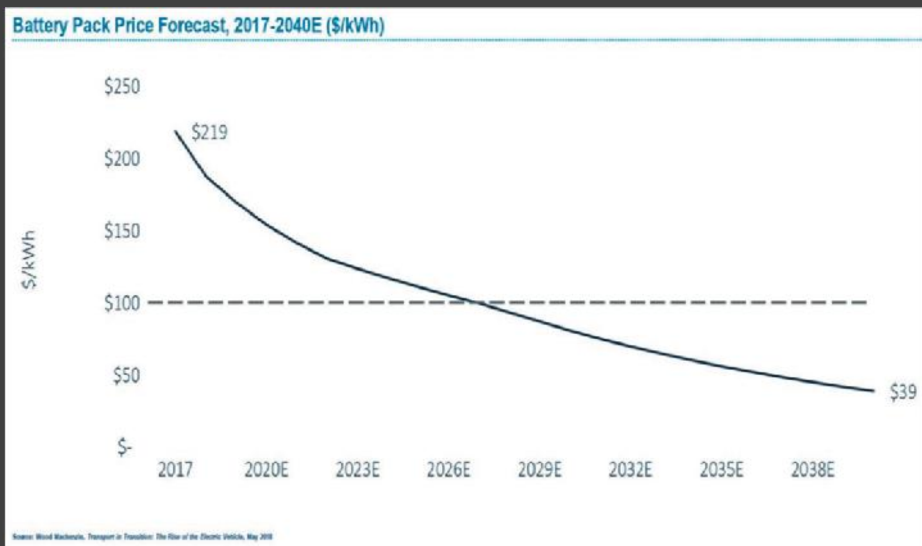
Characteristics of Energy Storage Technologies



Source: EPRI & U.S. DOE Electricity Storage Handbook in Collaboration with National Rural Electric Cooperative Association

- Dominant technology is lithium-ion chemistries due to relatively high energy and power density, and plunging prices from increased production scale
- Lithium-ion battery R&D activities include new anode materials (e.g., silicon-based powder instead of graphite to increase energy storage), inorganic electrolyte, and lighter-weight, fire resistant battery cases for better energy density and improved safety
- Solid-state batteries hold the promise of greater energy density at a competitive price (with potentially lower power density), but the technology is still in the prototype R&D stage
- Flow batteries permit energy draw for five to eight hours, much more than lithium-ion batteries. Several utility-scale flow-battery demonstration projects are currently underway

Is Battery Storage Becoming a Player in the Energy Industry?



- Wood-Mackenzie predicts battery pack prices will decrease from $219/kWh in 2017 to $39/kWh in 2040 (1)
- AES Next predicts, by 2020, four-hour energy storage systems will cost less than $1000/kW making it competitive with daily natural gas peaking plants in the US (2)
- Wood-Mackenzie predicts the global energy storage market will increase from 12GWh in 2018 to 158GWh in 2024 (3)

Sources:

(1) Wood Mackenzie, Transport in Transition: The Rise of Electric Vehicles, May 2018
(2) Chris Shelton, President AES Next, Bloomberg New Energy Finance New York Summit, April 2019
(3) Wood Mackenzie, Global Energy Storage Outlook 2019, April 2019

How does Battery Storage Help Utilities?

Value Streams for Battery Storage

Service	Description	Potential Value	Grid
Demand charge reduction	Use stored energy to reduce demand charges on utility bills	H	
Energy arbitrage	Buying energy in off-peak hours, consuming during peak hours	H	
Demand response	Utility programs that pay customers to lower demand during system peaks	H	
Resiliency / Back-up power	Using battery to sustain a critical load during grid outages	H	✔
Frequency regulation	Stabilize frequency on moment-to-moment basis	H	✔
Capacity markets	Supply spinning, non-spinning reserves	M	✔
Voltage support	Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system	L	✔
T&D Upgrade Deferral	Deferring the need for transmission or distribution system upgrades, e.g. via system peak shaving	Site specific	✔

Source: National Renewable Energy Laboratory Presentation, Energy Storage Economics, August 2017

- Handles short duration fluctuations in electricity supply and demand (e.g., frequency regulation and spinning reserves)
- Sustains critical load during grid outages
- Defers T&D upgrades; provides flexible capacity at substations while maintaining grid stability
- Reduces solar curtailment during peak solar generation periods by pairing energy storage with PV facilities

How does Battery Storage Help Commercial and Industrial Customers?

Value Streams for Battery Storage

Service	Description	Potential Value	Commercial
Demand charge reduction	Use stored energy to reduce demand charges on utility bills	H	✔
Energy arbitrage	Buying energy in off-peak hours, consuming during peak hours	H	✔
Demand response	Utility programs that pay customers to lower demand during system peaks	H	✔
Resiliency / Back-up power	Using battery to sustain a critical load during grid outages	H	✔
Frequency regulation	Stabilize frequency on moment-to-moment basis	H	✔
Capacity markets	Supply spinning, non-spinning reserves	M	✔
Voltage support	Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system	L	
T&D Upgrade Deferral	Deferring the need for transmission or distribution system upgrades, e.g. via system peak shaving	Site specific	

Source: National Renewable Energy Laboratory Presentation, Energy Storage Economics, August 2017

- Battery Storage Only: Behind-the-meter peak shaving and demand charge reduction
- PV + Battery Storage: On-site solar generation to reduce grid power draw, minimize impacts of grid power outages, and bill management from behind-the-meter peak shaving and demand charge reduction
- Pairing PV with Battery Storage reduces the Levelized Cost of Storage to less than half that of standalone battery storage

How does Battery Storage Help Residential Customers?

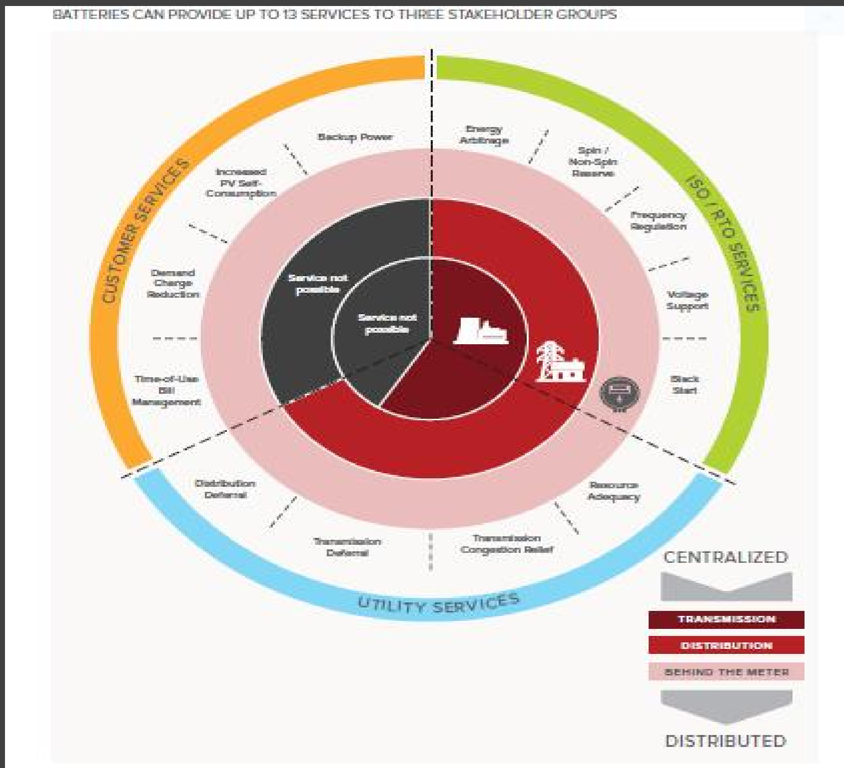
Value Streams for Battery Storage

Service	Description	Potential Value	Residential
Demand charge reduction	Use stored energy to reduce demand charges on utility bills	H	✔
Energy arbitrage	Buying energy in off-peak hours, consuming during peak hours	H	✔
Demand response	Utility programs that pay customers to lower demand during system peaks	H	✔
Resiliency / Back-up power	Using battery to sustain a critical load during grid outages	H	✔
Frequency regulation	Stabilize frequency on moment-to-moment basis	H	
Capacity markets	Supply spinning, non-spinning reserves	M	
Voltage support	Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system	L	
T&D Upgrade Deferral	Deferring the need for transmission or distribution system upgrades, e.g. via system peak shaving	Site specific	

Source: National Renewable Energy Laboratory Presentation, Energy Storage Economics, August 2017

- Battery Storage Only: Provide backup power during outages or emergencies, and improve power quality
- PV + Battery Storage: Provide on-site solar generation to reduce grid power draw, and allows a shift of grid power usage to less expensive time periods
- Pairing PV with Battery Storage also helps reduce demand charges, and incentivizes homeowners to participate in demand response programs

What Obstacles Still Remain?



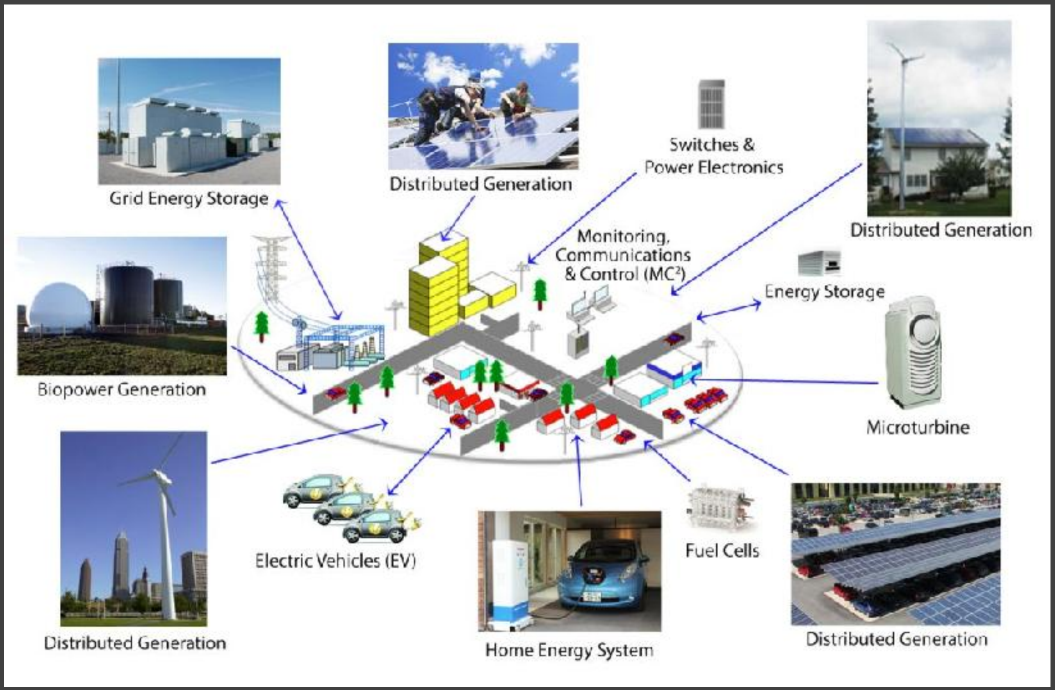
Source: The Economics of Battery Energy Storage, Rocky Mountain Institute, October 2015

- Battery storage Levelized Cost of Energy (LCOE [(1)]) is currently about 30% to 40% higher than a combined-cycle natural gas peaking plant. Forecasts indicate U.S. storage LCOE costs could be lower than gas peaking plants in 2 to 3 years, but longer duration (6-hour) batteries are required for peaker applications.
- Current regulatory and utility business models present barriers to unlocking the multi-faceted benefits of battery storage depicted in the figure.
- More data on long-term battery performance, useful life, and safety are required to bolster commitment to the technology.
- Tariff disputes with China could result in higher battery material costs and possible material shortages

(1) LCOE is a measure of a power source that allows comparison of different methods of electricity generation on a consistent basis. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset over that lifetime.

What is a Community Microgrid and How Does it Help?

Elements of a Community Microgrid

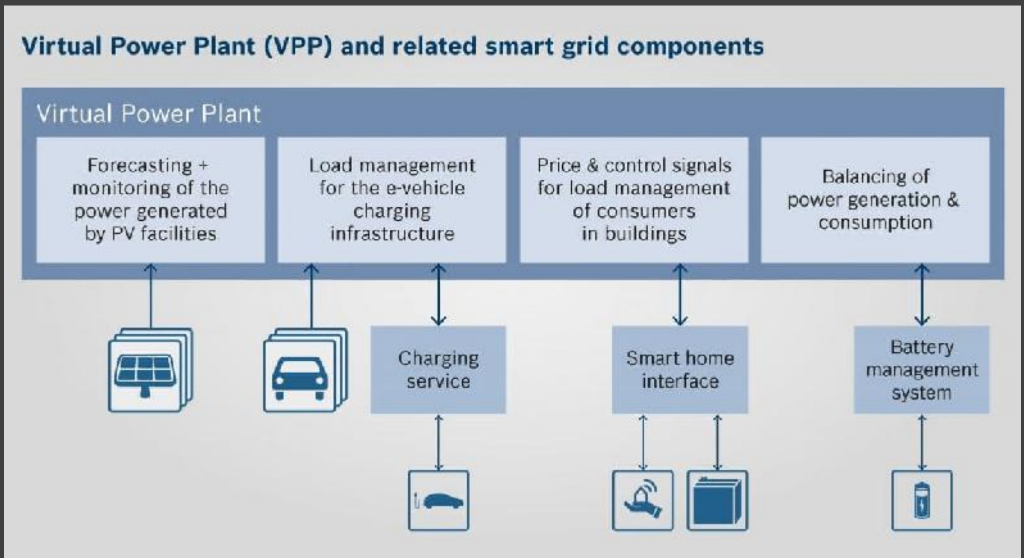


Community Microgrids provide sustainable, secure, backup power to a coordinated local grid area using distributed energy sources, battery storage and software-controlled electronics

- Provides indefinite backup power to prioritized loads that are critical to an entire community
- Isolates itself from the grid in case of electrical outage or cyber threat
- Lowers costs by identifying optimal DER locations, deploying DER more broadly, and providing scalability
- Spans an entire substation grid area, benefitting thousands of customers
- Enables easy replication and scaling across any distribution grid area

Source: What is a Community Microgrid, Clean Coalition, April 2019

What is a Virtual Power Plant (VPP) and How Does it Help?

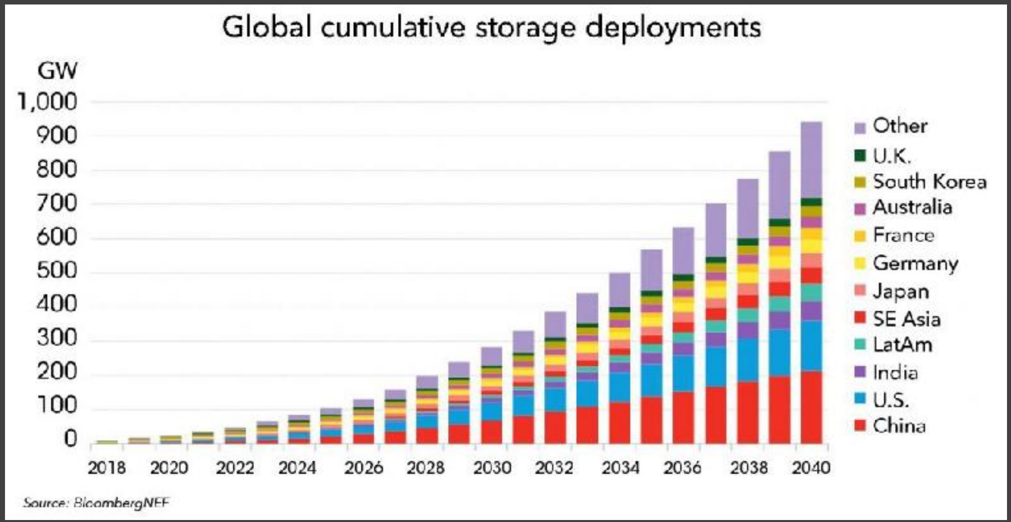


Source: Smart City Rheintal VPP Project, Bosch Software Innovations, April 2019

Virtual Power Plants are cloud-based distributed power plants that aggregate the power from a cluster of different types of generation sources to dynamically deliver power to wholesale electricity markets while quickly reacting to changing customer load conditions

- Unlike microgrids, which are often isolated and islanded, VPPs are meant to be aggregated into the broader grid
- Construction of new, centralized generation facilities can be delayed or eliminated
- Distributed systems can reduce the stress on transmission and distribution systems
- Consumers who generate electricity can sell excess power into the grid
- Through the use of energy storage, rapid demand response can be instituted to manage the natural variability of wind and solar power
- Security of power supply can be enhanced

Can We Expect Continued Energy Storage Market Growth?



Source: Bloomberg New Energy Finance, Long-Term Energy Storage Outlook, November 2018

- Bloomberg New Energy Finance forecasts the global energy storage market (excluding pumped hydro) will grow to a cumulative 942GW/2,857GWh by 2040, attracting $620 billion in investment over the next 22 years
- Arizona Public Service Co. will deploy 850MW of battery storage by 2024 in lieu of new gas-fired generation plants. The proposed storage exceeds the cumulative amount of the currently deployed battery storage in the U.S.
- Shell New Energies believes that the share of electricity in final energy consumption will increase from around 22 percent currently to 50% by 2070 for power generation, transportation, and industrial processes enabled primarily by energy storage

For further insights on the topic, view
"Solar plus Battery Storage Industry Trends" at:

http://www.revgengroup.com/MortCohen.html