Energy Storage Bootcamp: From the Basics to the Complex

November 14, 2019

BayREN Presentation

CALIFORNIA ENERGY STORAGE ALLIANCE

Agenda

- **About CESA**
- **Energy Storage 101**
  - Why energy storage?
  - What is energy storage?
  - Identifying best-fit storage resource
- **Energy Storage 201**
  - Microgrids definitions
  - Energy storage and energy efficiency
  - Incentive programs for cities

About CESA

The **California Energy Storage Alliance (CESA)** is a 501c(6) membership-based advocacy group committed to advancing the role of energy storage in the electric power sector through policy, education, outreach, and research.

CESA's **mission** is to make energy storage a mainstream resource to advance a more affordable, efficient, reliable, safe and sustainable electric power system for all Californians

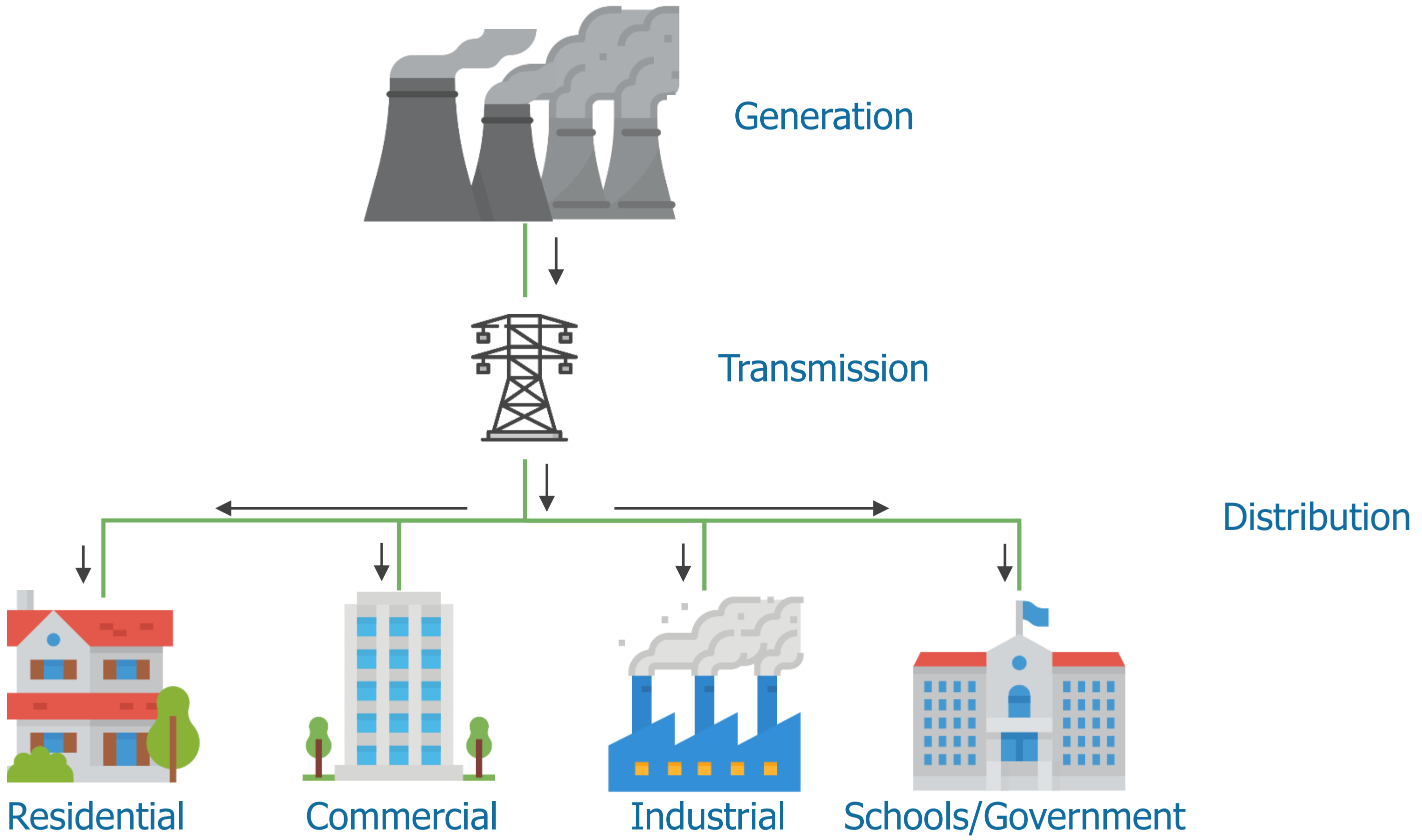
We are technology and business model-neutral and are supported solely by the contributions and coordinated activities of our members.

Energy Storage 101

- What is energy storage?
- Why energy storage?
- Landscape of storage resources and characteristics

The 20th Century Grid

One-way flow of electricity



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Technological Innovations

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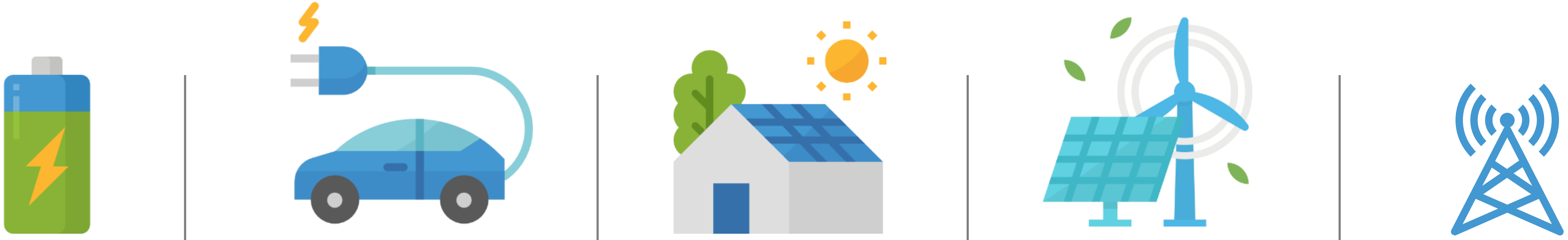
Falling technology costs and increased consumer choice



Energy storage | Electric vehicles | Distributed energy resources | Renewable resources | Internet and software

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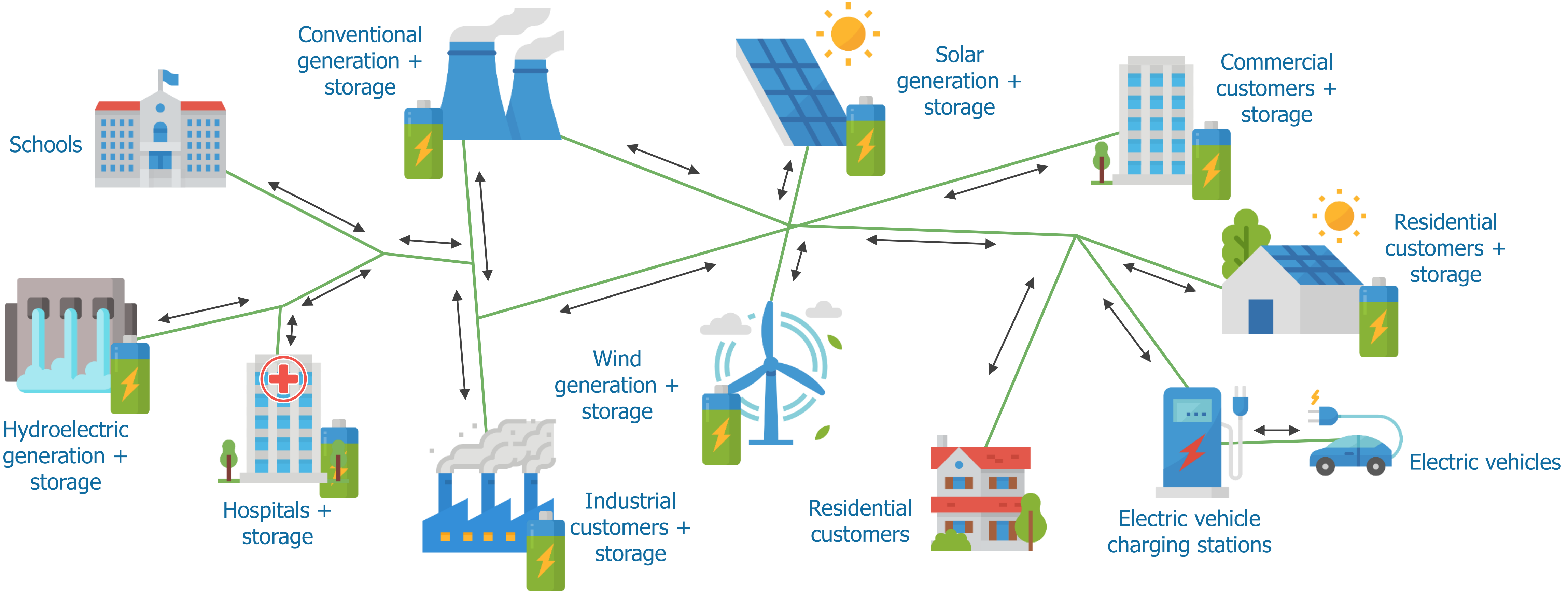
The 21st Century Grid

Bi-directional flow of electricity

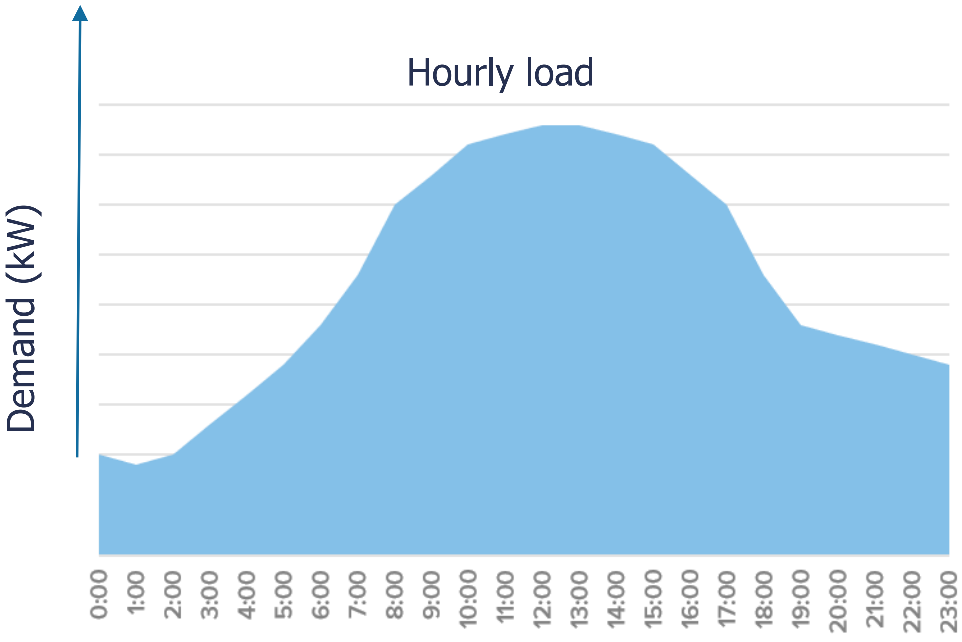


Why energy storage?

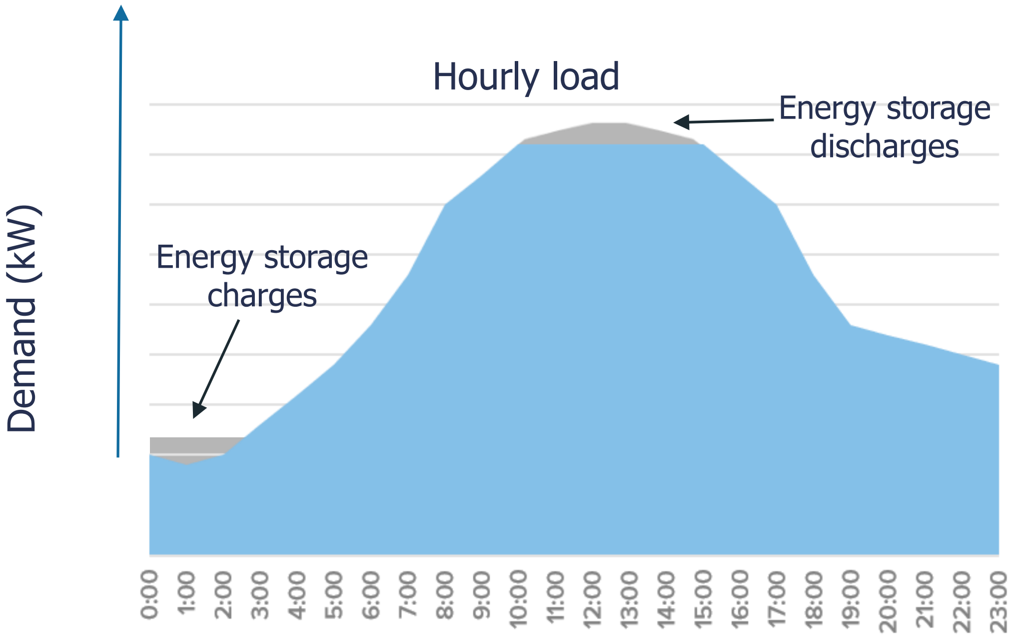
- Can increase grid resiliency and flexibility
- Can reduce total generation costs
- Can diversify the resource mix
- Can empower customer choice and reduce energy bill
- Can reduce transmission infrastructure costs
- Can deploy fast in modular sizes and in diverse settings

Customer Bill Management

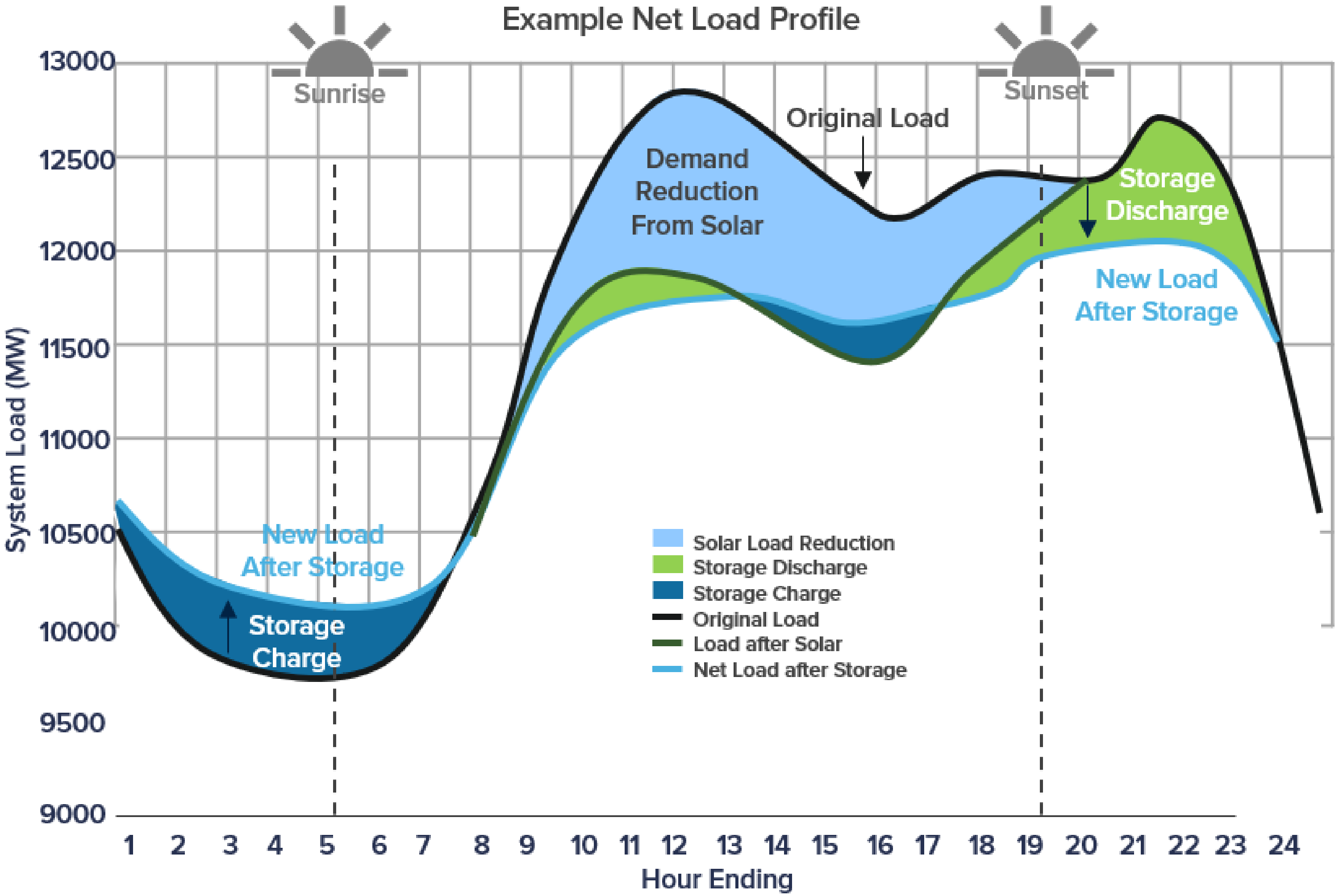
- **Demand charge**
  - Customer is charged $/kW during peak hours
  - Large component of monthly electricity bill for many commercial and industrial customers
- **Time-varying energy rates**
  - Customer is charged low $/kWh during off-peak hours and high $/kWh during peak hours



- **Energy storage can charge during off-peak hours and discharge during the peak hours, lowering cost of monthly electricity bill**
  - Reduces observed peak for those with demand charges, avoiding demand charges
  - Shifts observed energy consumption from peak hours to off-peak hours, saving on energy cost

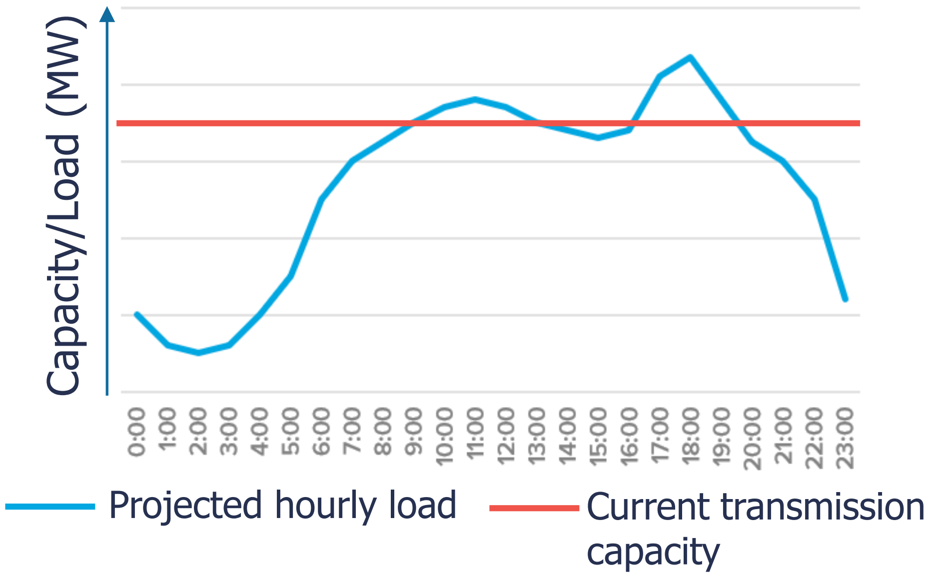


Renewable Energy Time Shifting

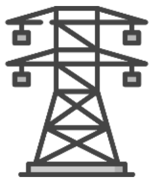


Infrastructure Investment deferral

- **“Wires” capacity is exceeded based on load growth forecasts**
- **Energy storage can defer infrastructure upgrades as a more cost-effective economic alternative**
  - When not needed for transmission or distribution services, the storage resource can provide value and services elsewhere

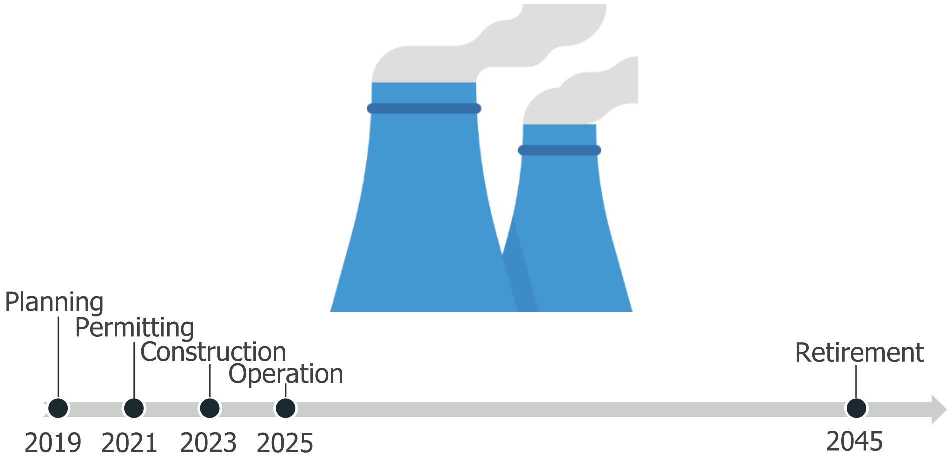


Traditional solution	Non-wires solution



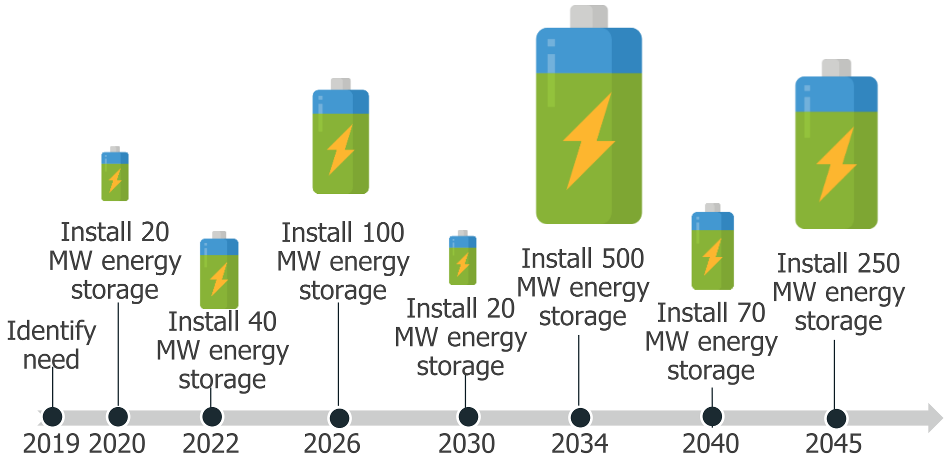
Modular, Fast Deployment Reduces Risk

- 1 GW conventional power plant



- Non-modular
- High capital expenditure
- May over- or under-size
- Built to replace the previous
- Centralized

- Modular energy storage systems



- Modular
- Size to fit specific use case and incremental need
- Deploy as, when, and where needed

2019 PG&E PSPS Overview

	JUNE 8 - 9	SEPT 23 - 26	OCT 5 - 6	OCT 9 - 12
	~22,000 customers impacted	**~75,000** customers impacted	**~11,000** customers impacted	**~738,000** customers impacted
	5 counties in scope	**7** counties in scope	**3** counties in scope	**35** counties in scope
	4 Community Resource Centers	**8** Community Resource Centers	**3** Community Resource Centers	**30+** Community Resource Centers
	63 MPH peak wind gusts recorded	**58 MPH** peak wind gusts recorded	**51 MPH** peak wind gusts recorded	**77 MPH** peak wind gusts recorded
	5 system damage/ hazard incidents	**4** system damage/ hazard incidents	**2** system damage/ hazard incidents	**100+** system damage/hazard incidents

PSPS vs CPUC Fire Map Correlation

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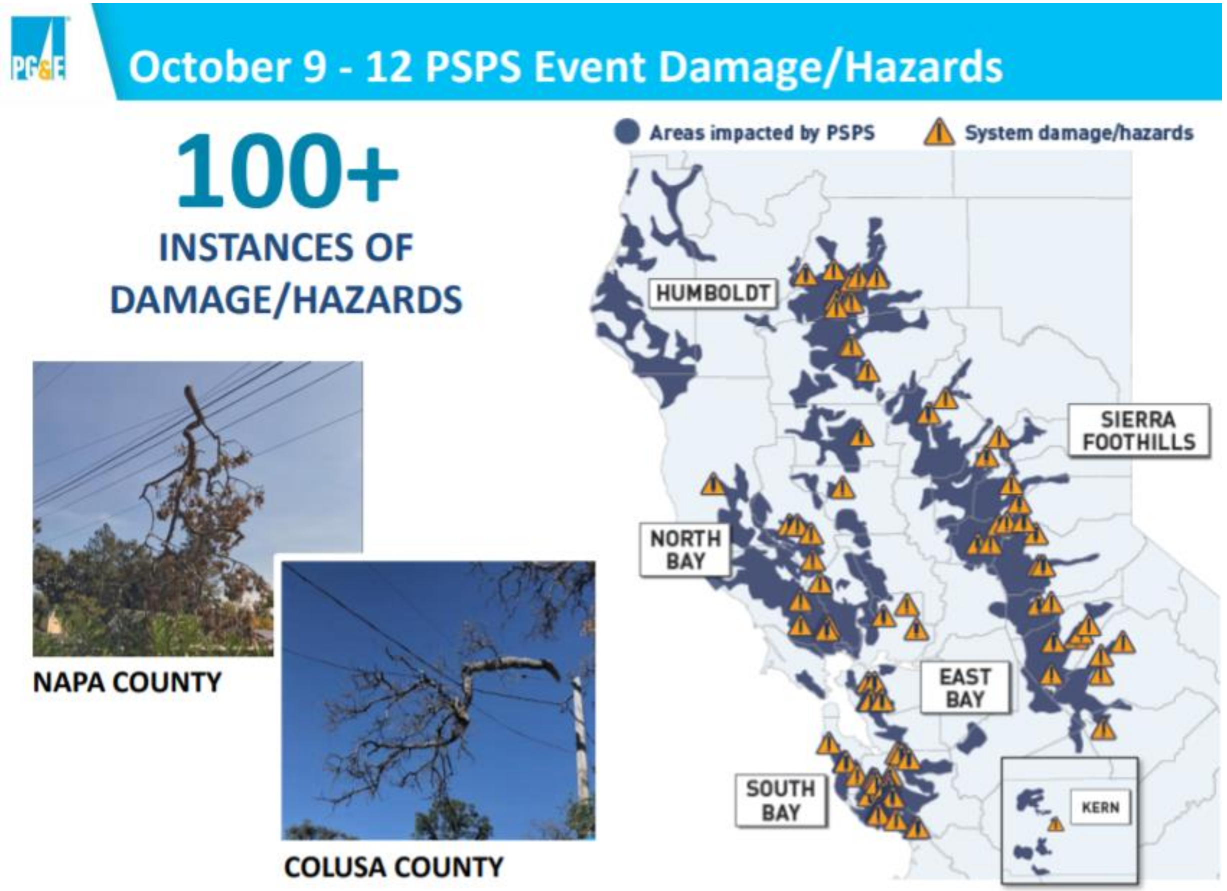
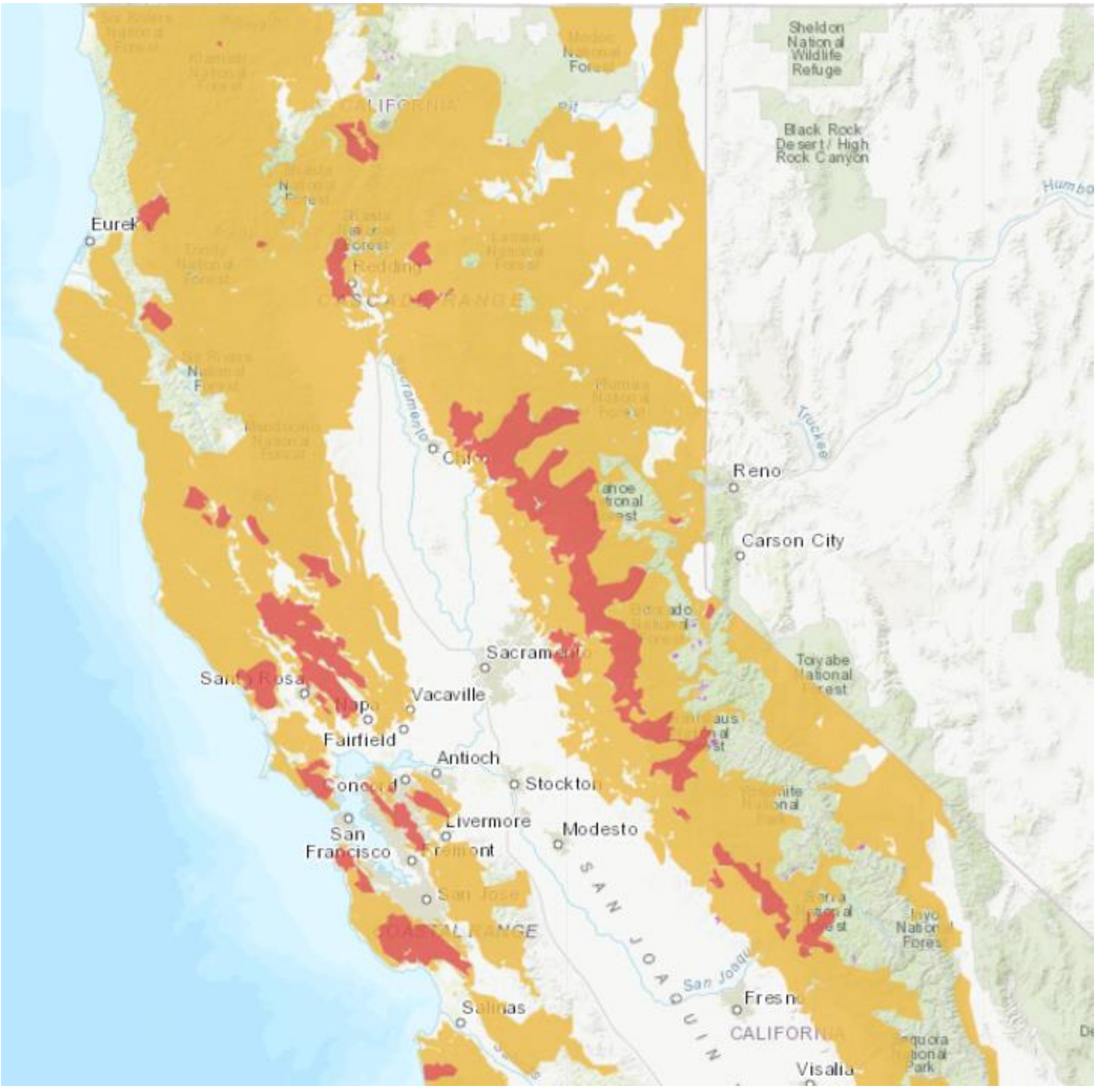
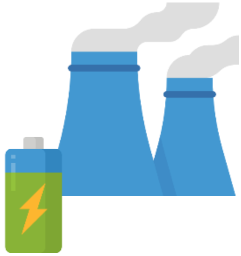


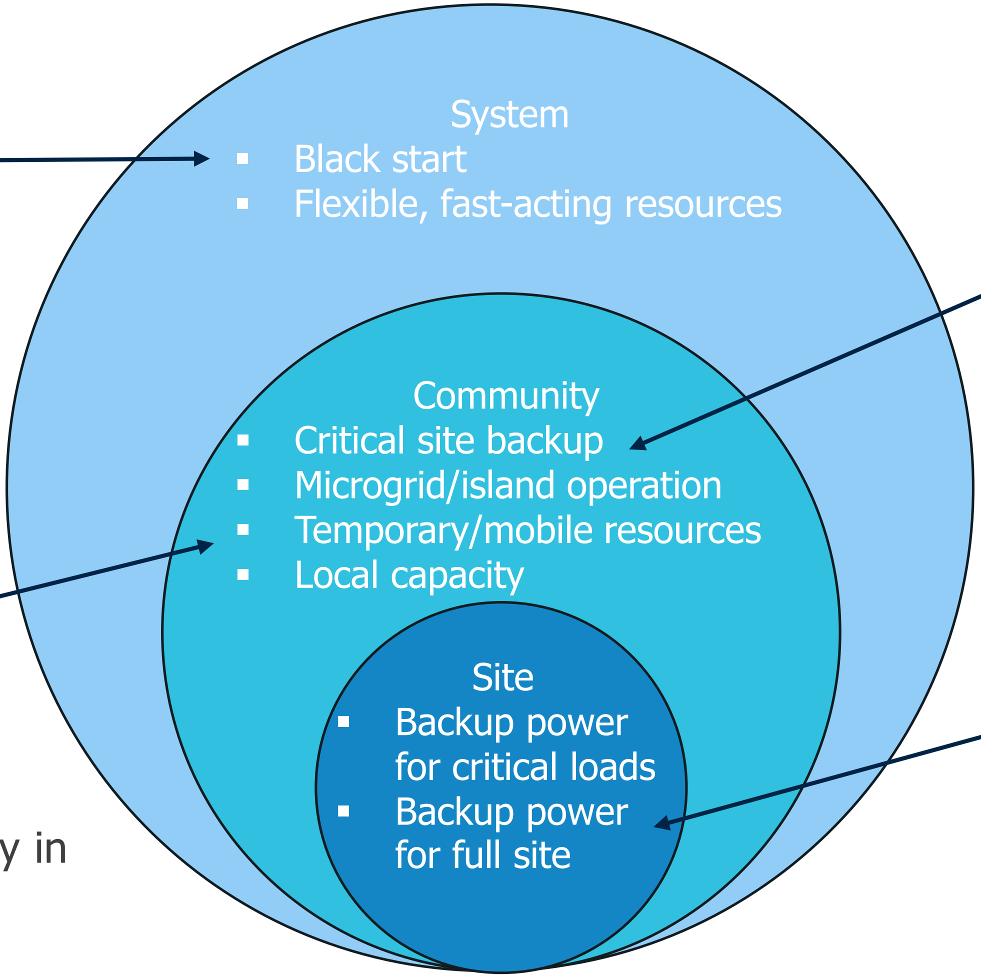


Storage-Enabled Resilience

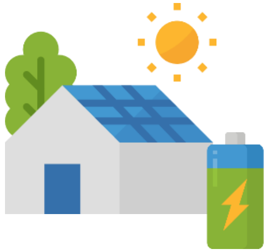


2017: First US demonstration of battery storage for black start (Imperial Irrigation District, CA)

2017-18: Solar-paired storage systems providing partial restoration of electricity in Puerto Rico after Hurricane Maria

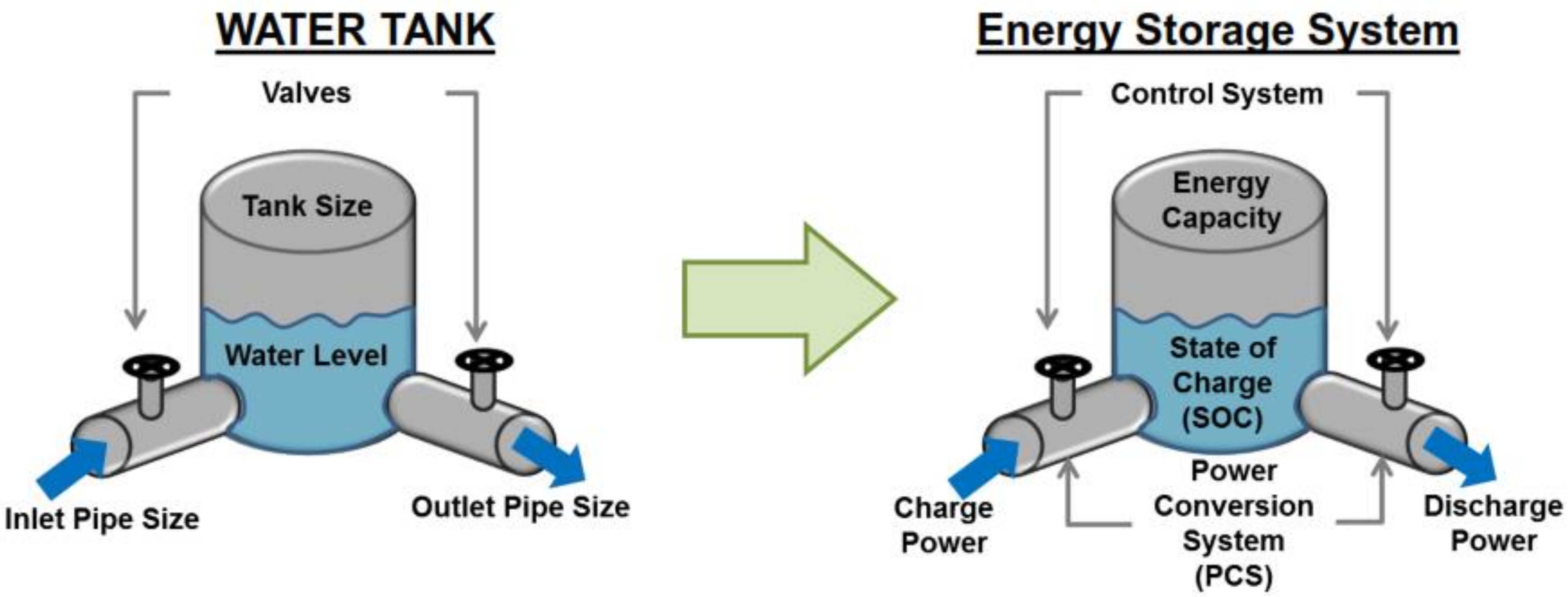


2017: San Francisco solar-paired storage for resiliency project – planning roadmap, best practices guide, and online sizing tool (DOE-funded)



Storage systems for site backup are commercially available

Energy Storage Basics: Energy vs. Power



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Energy Storage Technology Types

Grid-connected energy storage captures energy for later use.

Mechanical

Pumped Hydro
Water stored in a reservoir to provide energy on demand

Compressed air
Captures and stores compressed air in underground structures

Flywheels
Systems that store energy in a spinning mass

Electrochemical

Batteries or flow batteries that contain chemicals that store energy

Thermal

Excess heat (e.g., hot water) or cold (e.g., ice blocks) stored for later use

Chemical

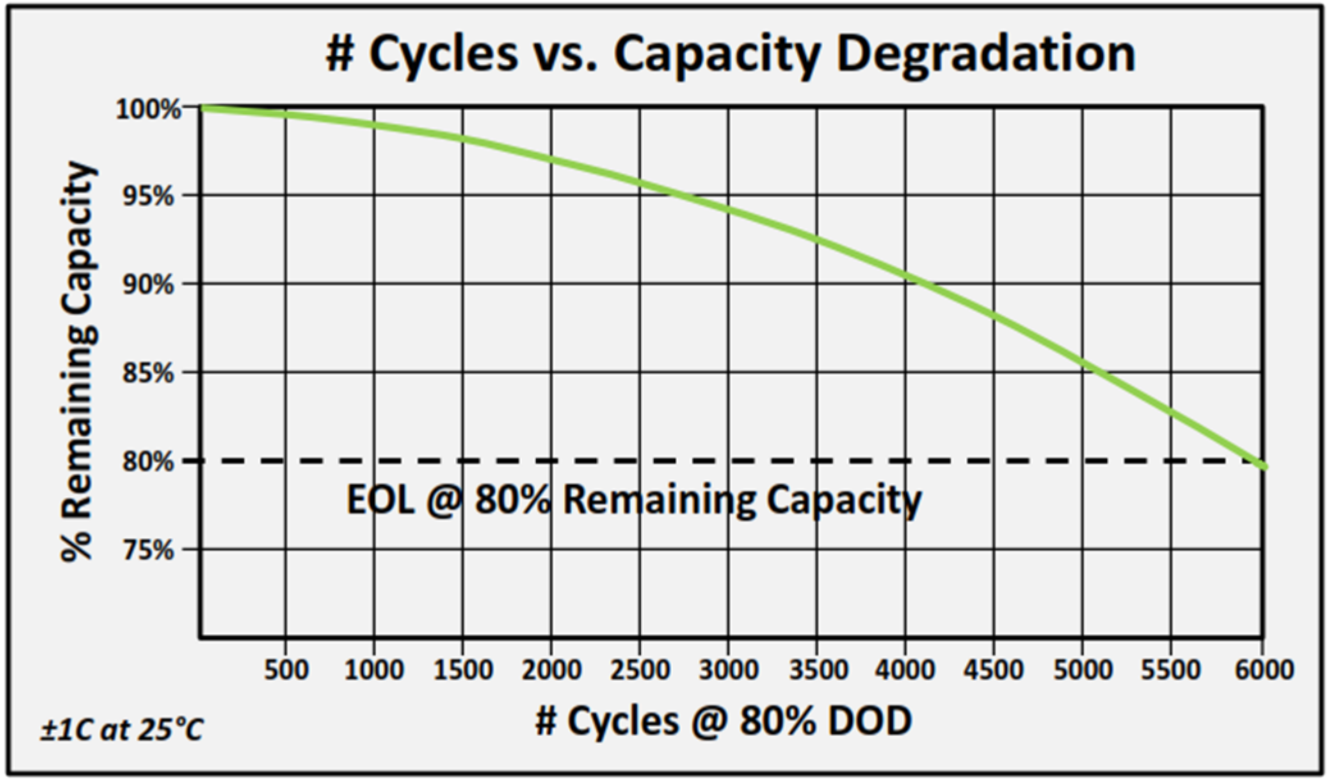
Hydrogen produced from renewable electricity for later use

Generalized Technology Characteristics

Technology	Strengths	Weaknesses	Best Fit Applications
Lithium-ion battery storage	• High energy density • Ease of deployment • Relatively low $/kWh and $/kW due to economies of scale • Good roundtrip efficiency (> 80%) • Fast response time (milliseconds)	• High cost for long durations • Safety perceptions for some chemistries • Energy degradation depending on technology and cycling needs • Relatively lower usable SOC	• Demand charge management • TOU arbitrage • Frequency regulation • Flexible ramping
Thermal storage	• Established technology • Good cycle life • Low $/kWh for load shifting	• Low energy density • Lower efficiency (< 70%) • Mediocre response time • Pump maintenance needed	• Permanent load shifting • PV integration
Flow battery storage	• Relatively low $/kWh • Scalable/flexible power-to-energy ratio • Good cycle life & high usable SOC	• Low energy density • Lower efficiency (< 70%) • Mediocre response time • Pump maintenance needed	• Load shifting & balancing • PV integration • Flexible ramping
Flywheel	• High power-to-energy ratio • Very fast response (milliseconds) • Excellent cycle life & full usable SOC • High roundtrip efficiency (> 85%)	• Low energy density • Less suited for long durations • High self-discharge rate	• Frequency regulation • Power quality/UPS • Spinning reserves

Complexities to Storage Characteristics

- **It is important to pay attention to technology specifications (*e.g.*, degradation, useful capacity, operating temperatures) and warranties in considering the selection, sizing, and controlling of energy storage technologies**



Note that most SGIP-funded storage is required to have 10+ year warranties. More on that later

No 'Goldilocks' Storage Tech (Yet)

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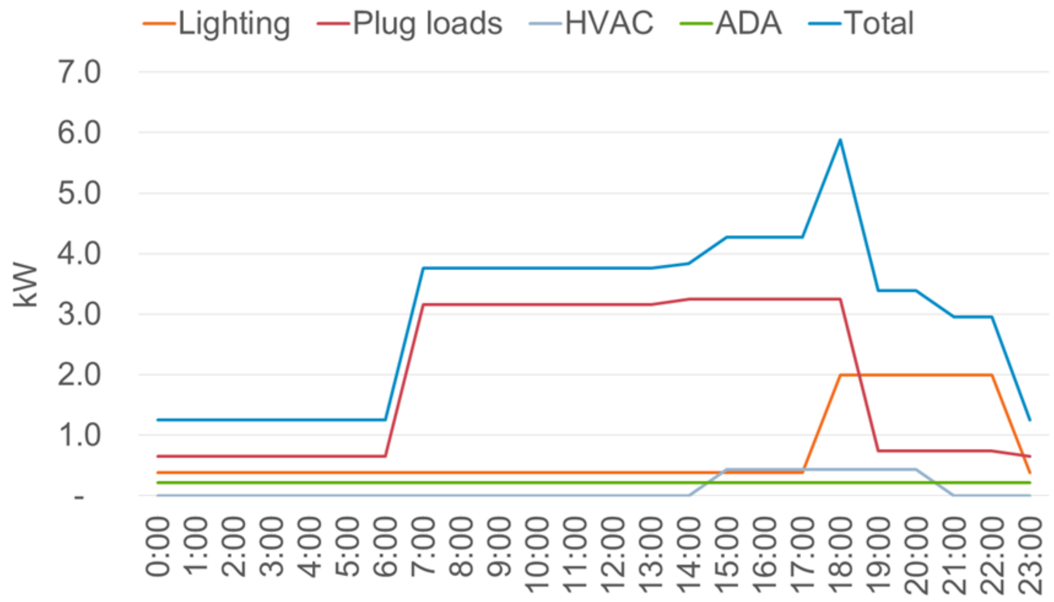
Chemistry	Shorthand	Scale 1-5 with 5 Best and 1 Worst					Summary
		Safety	Energy	Power	Life	Cost/kWh	
Lithium Manganese Oxide	LMO	3	4	3	3	4	Versatile with good overall peformance & cost
Lithium Iron Phoshphate	LFP	4	3	4	4	3	Similar to LMO but with slightly more power
Lithium Nickel Cobalt Aluminum	NCA	1	3	4	4	2	Good for power applications; poor safety & high cost/kWh
Lithium Titanate	LTO	5	2	5	5	1	Excelent cycle life & power; High $/kWh cost
Lithium Nickel Manganese Cobalt Oxide	NMC	3	3	4	4	4	Versatile with good overall peformance & cost
Sodium Nickel Chloride	NaX	3	4	1	4	3	Good energy but low power capability
Advanded Lead Acid	PbA	4	1	3	2	5	Safe & inexpensive but low cycle life and poor energy
Zinc Based (various)	Zinc	5	2	2	4	5	Very safe & low cost but poor power and energy density

Energy Storage 201

- **Assessing your load (and needs)**

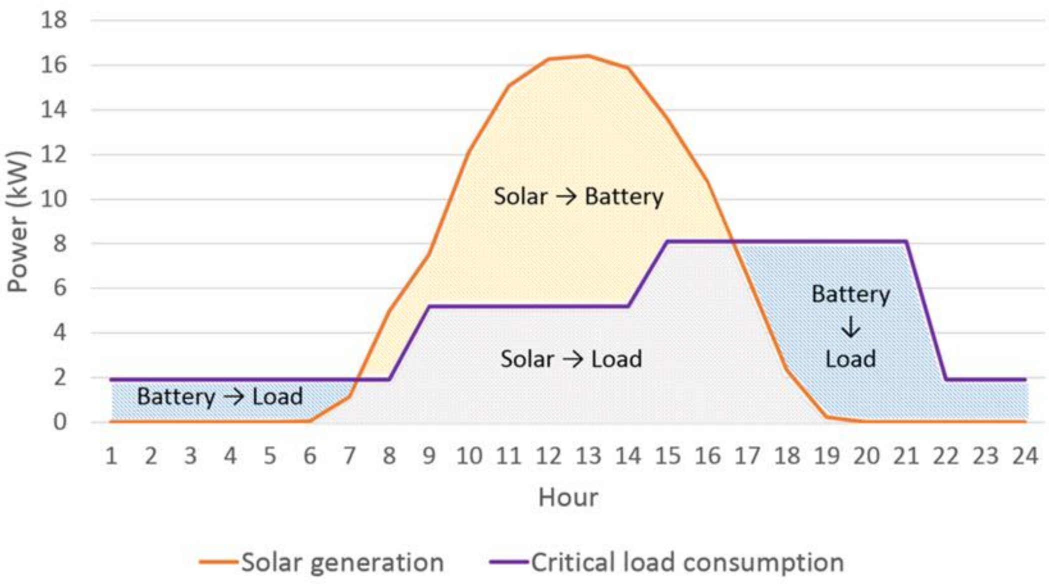
Assess Your Load (and Needs)

- **Most customer-sited energy storage systems must be selected and sized to meet the customer need first before pursuing additional revenue streams from the grid**
- **Therefore, a load assessment is needed to identify the most effective cost reductions and/or critical loads**



Identify Load Management Strategies

- **Depending on the load profile and the rate schedule, different energy storage technologies and operational strategies may be needed (*e.g.*, clipping of 'peakiest' loads vs. shifting of solar generation)**



Identify Facility Resiliency Strategy

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- **Serving critical loads only require re-wiring breaker panels and installation of specialized switchgear:**
  - The cost to make solar+storage islandable can add incremental expenses ranging from 10%-50%, but NREL-CEG study found that maximum cost to island should not exceed 3%-21% (added bill savings exceed added islanding costs)
  - Lithium-ion battery serving critical loads and paired with solar can ride-through multi-hour outage, or sometimes multi-day, depending on application and customer load
  - Some battery technologies or configurations, including flow or zinc-air solutions with 4- to 10-hour energy durations can provide longer load shifting and resiliency capabilities
  - Powerwall paired with 7.6-kWh solar should be able to serve 75% of average residential load (18.56 kWh) - subject to solar insolation and other factors
  - Standalone storage or specialized long-durations storage technologies can be sufficient for shorter-duration needs

Duration of resiliency benefit

- Type of storage device (duration)
- Whether storage is paired with onsite generation
- Whether full or critical wires are wired for storage device to provide resiliency

Finding the Best-Fit Technology

<table>
<tr><th>Domain</th><th>Short Duration (0-2 hrs)</th><th>Medium Duration (2-4 hrs)</th><th>Long Duration (6+ hrs)</th></tr>
<tr><td rowspan="5">Customer</td><td>Demand Charge Management</td><td></td><td></td></tr>
<tr><td>Power Quality</td><td></td><td></td></tr>
<tr><td colspan="2">Resiliency</td><td></td></tr>
<tr><td colspan="2">TOU Bill Management</td><td></td></tr>
<tr><td colspan="2">PV Self Consumption</td><td></td></tr>
<tr><td rowspan="3">Distribution</td><td></td><td>Local/Flex RA</td><td></td></tr>
<tr><td></td><td colspan="2">Reliability/Resiliency</td></tr>
<tr><td>Voltage Support</td><td></td><td rowspan="2">Deferral</td></tr>
<tr><td rowspan="2">Transmission</td><td>Black Start</td><td></td></tr>
<tr><td></td><td>System RA</td><td></td></tr>
<tr><td rowspan="3">Wholesale</td><td>Frequency Regulation</td><td></td><td></td></tr>
<tr><td colspan="2">Primary Frequency Response</td><td></td></tr>
<tr><td colspan="2">Spinning/Non-Spinning Reserves</td><td></td></tr>
</table>

Storage's Fit with Energy Efficiency Strategy

- **Storage plays into building electrification and efficiency strategy per Title 24**
- **Storage and (targeted) energy efficiency resources can be substitutes for each other at times**
- **Energy efficiency investments can reduce curtailable load for storage – *i.e.*, less load to offset when storage is providing self-consumption or demand response**
- **Some energy efficiency investments can "become" storage with smart controls (see recent SGIP changes):**
  - Heat pump water heater (HPWH) investment has efficiency and/or fuel-switching benefits, and with a grid-integrated control, it can provide dynamic load shift
  - Example: $500 per smart controller on EWHs for 10-year life gives you 0.5 kW (5 kWh) of storage-like assets, so with just $1M in SGIP incentives, California could get 2,000 participating DAC customers and 1 MW of smart DERs

Equity Resiliency Incentives

- **The CPUC allocated $100 million in the Self-Generation Incentive Program (SGIP) for energy storage investments in High Fire Threat Districts (HFTDs) to provide resiliency to most vulnerable**
- **On average, incentive rates should cover around 100% of installed cost**
- **More money could be on the way (future SB 700 decision)**

Discharge Duration (Hours)	Percent of Base Incentive (Previous)	Percent of Base Incentive (Adopted)	Equity Incentive Rate (Previous)	Equity Incentive Rate (Adopted)	Equity Resiliency Incentive Rate (Adopted)
0-2	100%	100%	**$0.50/Wh**	**$0.85/Wh**	**$1.00/Wh**
2-4	50%	100%	$0.25/Wh	$0.85/Wh	$1.00/Wh
4-6	25%	50%	$0.125/Wh	$0.425/Wh	$0.50/Wh
6+	0%	0%	$0.00/Wh	$0.00/Wh	$0.00/Wh

Recent SGIP Updates

- **GHG Emission Reduction Requirements** - August 1, 2019 (D.19-09-011)
  - Requires new commercial systems to reduce emissions by at least 5 kg-CO2/kWh and sets compliance options for legacy commercial systems
  - Sets deemed compliance pathways for new and legacy residential projects
  - Establishes new 5-minute GHG signal for compliance and adjusts cycling requirements
- **Equity and Equity Resiliency Budget** - September 12, 2019 (D.19-09-027)
  - Application to include estimates and attestations
  - An Authority Having Jurisdiction (AHJ) must approve plans showing that storage can operate in island mode and inspect/authorize operation after installation
  - Many questions related to eligibility and other specifics are still TBD
  - Launch of this budget category expected April 1, 2020 (along with GHG Signal)

Equity Resiliency Eligibility

- **Residential customers located either in a Tier 2 or Tier 3 HFTD; and, meet one of the following:**
  - Eligible for the Equity budget; or,
  - Medical Baseline (MB) customer; or,
  - Customer that has notified their utility of serious illness or condition that could become life-threatening if electricity is disconnected
- **Non-residential customers that provide critical facilities or critical infrastructure to a community that is eligible for the equity budget located either in a Tier 2 or Tier 3 HFTD:**
  - At least 50% of customers served by these facilities must be Equity customers (*i.e.*, located in disadvantaged community [DAC] per CalEnviroScreen, or located in "low-income" census tract)
  - Burden of proof on applicant
  - Certain facilities may become eligible if designated by IOU as, for example, community resource center or cooling center

Equity Resiliency Application

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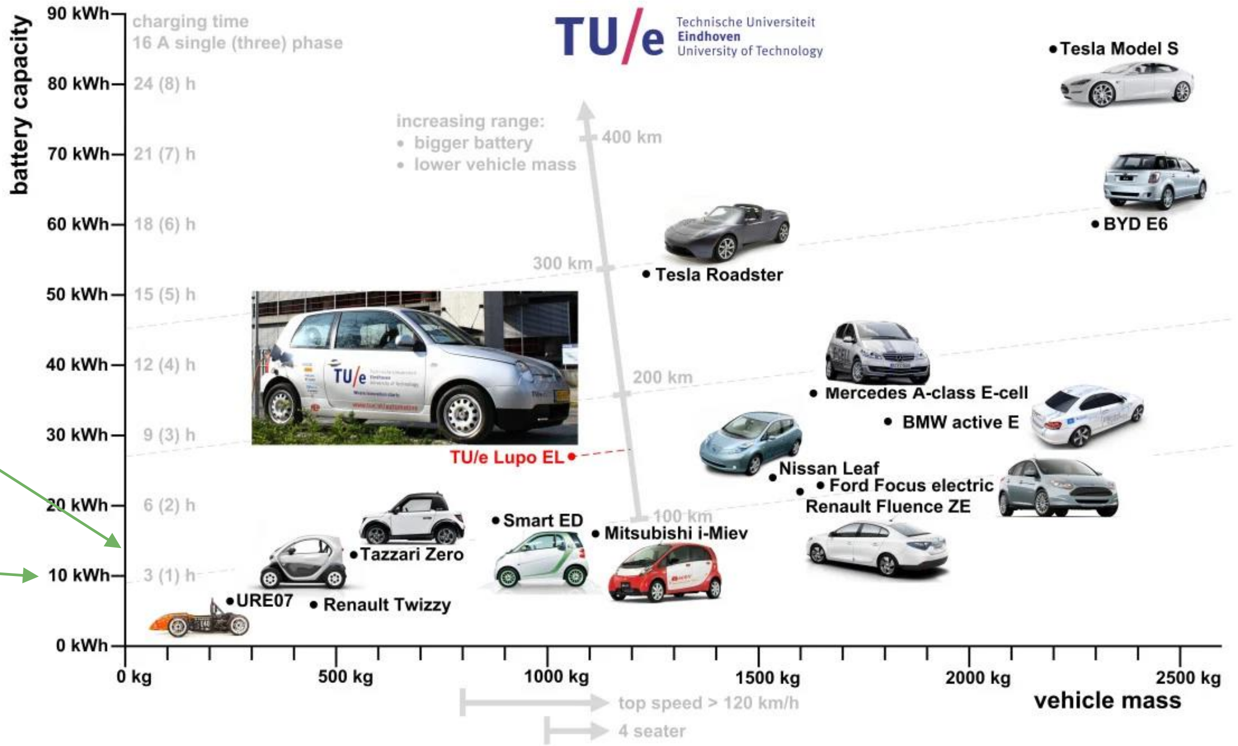
- **Equity Resiliency SGIP Application will require the following:**
  - Estimate of how long a project's fully charged battery will provide electricity for the relevant facility average load during outage
  - Indicate whether a project's critical loads can and will be isolated
  - Provide an estimate of how long the project's fully charged battery will provide electricity to critical uses during an outage
  - Provide an estimate of how long the project can operate in less-than favorable circumstances, such as if an outage occurs when the battery has been discharged or during the winter (if paired with solar)
  - Summarize information given to the customer about how the customer may best prepare the storage system to provide backup power, in the case of a PSPS event announced in advance
  - Attest to the truth of the information provided and provide an attestation from the customer indicating that he or she received this information prior to signing a contract

Future of V2H/V2B for Resiliency?

- **Stationary storage is great, but vehicle-to-home (V2H) and vehicle-to-building (V2B) is also a high-potential resource, including for resiliency:**
  - Various barriers to interconnection currently exist



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Microgrids for Resiliency

- **Two broad types of microgrid exist**
  - Customer Facility (Single User) Microgrid
  - Utility or Community (Multi-User) Microgrid
- **SB 1339 defined "microgrid" as:**
  - "an interconnected system of loads and energy resources, including, but not limited to, distributed energy resources, ***energy storage***, demand response tools, or other management, forecasting, and analytical tools, *appropriately sized to meet customer needs*, within a *clearly defined electrical boundary* that can act as a *single, controllable entity*, and can *connect to, disconnect from, or run in parallel with*, larger portions of the electrical grid, or can be *managed and isolated* to withstand larger disturbances and maintain electrical supply to connected critical infrastructure."

Source: lbnl.gov

End-of-Life Considerations

- ‘Second-life’ lithium-ion batteries from Evs can be used at end of life – *e.g.*, ongoing pilots at UCSD microgrid
- Recycling lithium-ion batteries allows for resource conservation by recovering viable materials including cobalt, lead, iron, plastic, lithium, aluminum, etc.
- Recycled materials from lithium-ion batteries can reduce production costs of new lithiumion batteries by 10% to 30%

End-of-Life Considerations

Recyclable materials in different lithium-ion battery types

Material	USD/kg	% Content in a cylindrical cell (18650)							
		NCM111	NCM523	NCM622	NCM811	NCA	LFP	LMO	LCO
Casing									
Steel	0,29	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Aluminium	1,8	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Current collectors									
Aluminium	1,8	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Copper	6,0	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%
Anode material									
Graphite	1,2	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%	18.1%
Cathode material									
Manganese	2,4	6.1%	5.5%	3.6%	1.8%			19.4%	
Lithium	70,0	2.3%	2.3%	2.3%	1.9%	2.3%	1.4%	1.2%	2.3%
Cobalt	30,0	6.5%	3.9%	3.9%	1.9%	2.9%			19.3%
Nickel	12,0	6.5%	9.7%	11.6%	15.4%	15.6%			
Aluminium	1,8					0.4%			
Iron	0,4						11.3%		
Total value per kg		**5.42**	**5.02**	**5.19**	**4.77**	**5.32**	**1.97**	**2.26**	**8.30**

Source: Circular Energy Storage

Key Takeaways & Conclusions

- Energy storage can meet a wide variety of grid needs but it is important to consider the technological characteristics, configurations, and customer(s) needs (*e.g.*, load profile, bill savings, resiliency) to identify the best-fit technology and project
- Energy storage can be an important tool to provide customer and grid resiliency, whether for a single site or for multiple users, but the opportunity has yet to scale – take advantage of SGIP!
- Energy storage for grid services can provide additional value and revenue streams but there are added complexities to aligning project, customer, and "buyer" needs

Thank You

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