U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Introduction to Battery Energy Storage

FEMP
Federal Energy Management Program

Navigation

Contents

Learning Objectives

Upon completion of this course, attendees will understand:

- Different types of storage and which technologies make sense at federal sites
- Key factors that influence battery storage economics
- How batteries can support site goals
- Different methods and considerations for procuring battery storage.

Storage at Federal Sites

History of Energy Storage at Federal Sites: Off-Grid Applications

- **Long history of implementing storage systems primarily at remote sites (i.e., off-grid)**
- **Renewable energy (RE) is often paired with storage at these remote sites**
- **Off-grid hybrid RE-plus-storage systems lower costs and provide a sustainable alternative to diesel generators.**

Alcatraz solar photovoltaic (PV)-battery-diesel hybrid system:

- Construction completed in 2012
- Two 220-kW diesel engine generators
- 305 kW direct current (DC) of solar PV
- 1,400 kW/1,900 kWh of lead acid batteries.

Credit: National Park Service (top); Byron Stafford, NREL (bottom)

Renewables and Storage at Federal Sites

Renewable Energy

- Agencies have more experience with RE
- Agency deployment goals focused on environmental benefits.

Storage

- Lithium-ion (Li-ion) battery cost reductions are making storage systems economically attractive in grid-connected applications
- Agency deployment goals more focused on resilience, flexibility
- Can support RE integration.

Storage Technology Basics

What Is Energy Storage?

Energy storage can charge energy from an external source and discharge energy at a later time.

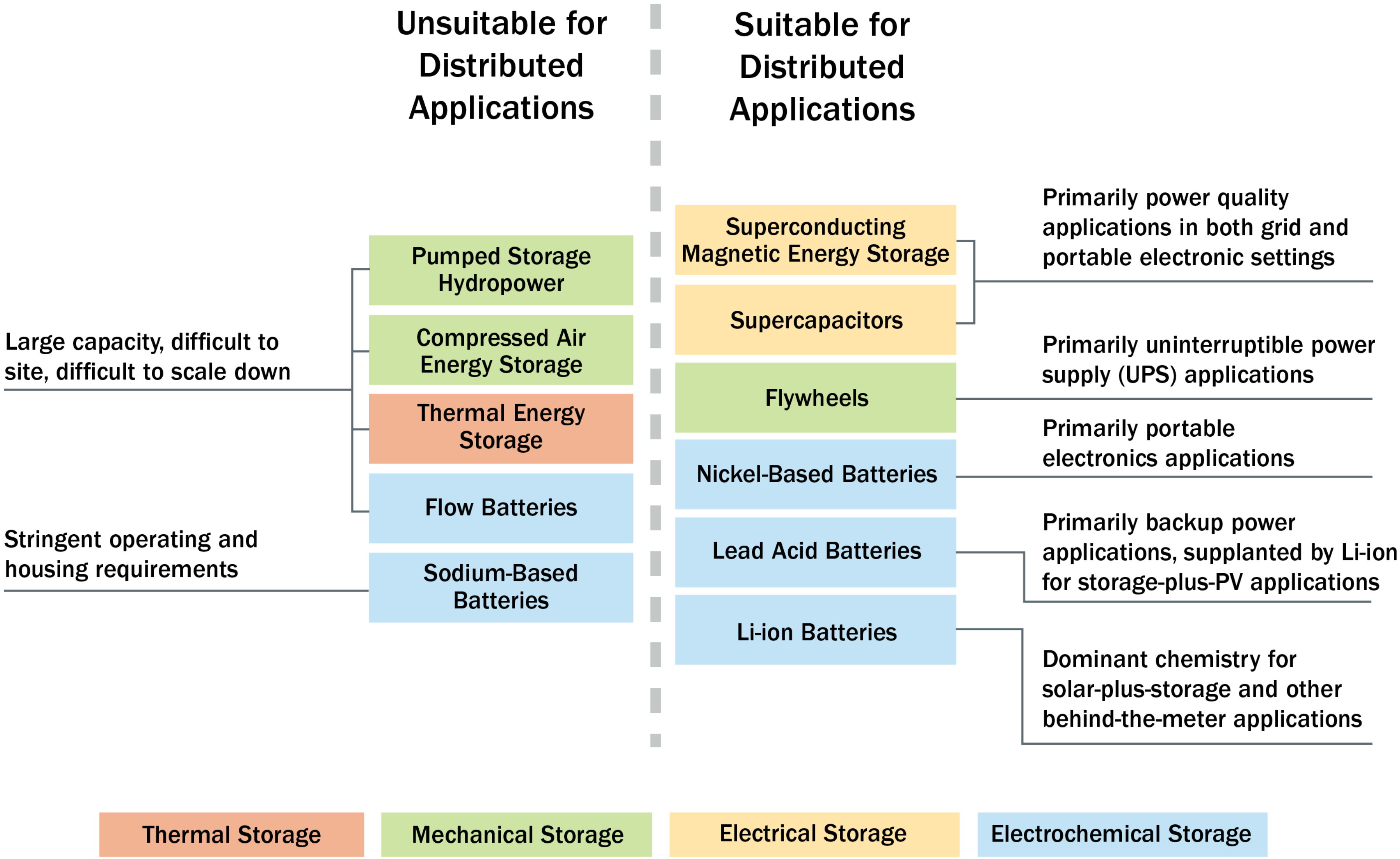
Credit: Byron Stafford, NREL

Credit: [Wikipedia Commons]

Credit: Dennis Schroeder, NREL

Credit: Dennis Schroeder, NREL

Why Batteries?



Source: Zinaman, Bowen, and Aznar 2020

Why Lithium Ion Batteries?

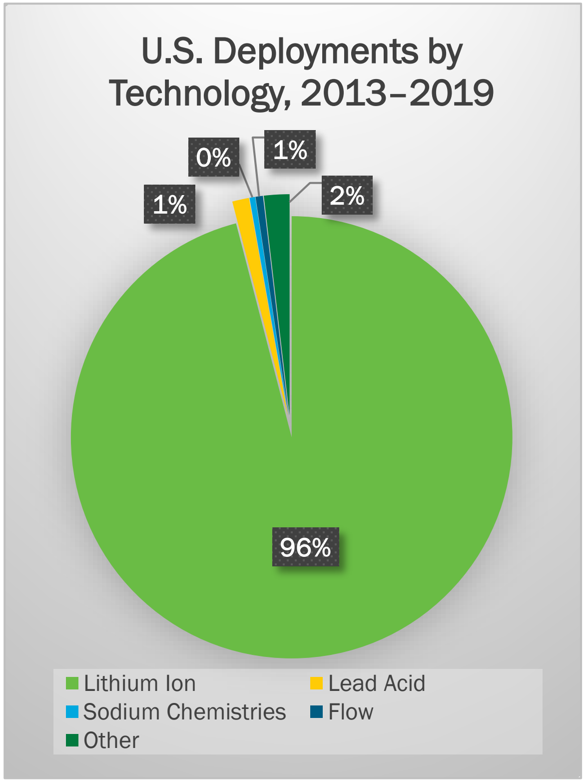
Best combination of price, operational characteristics, safety, and feasibility

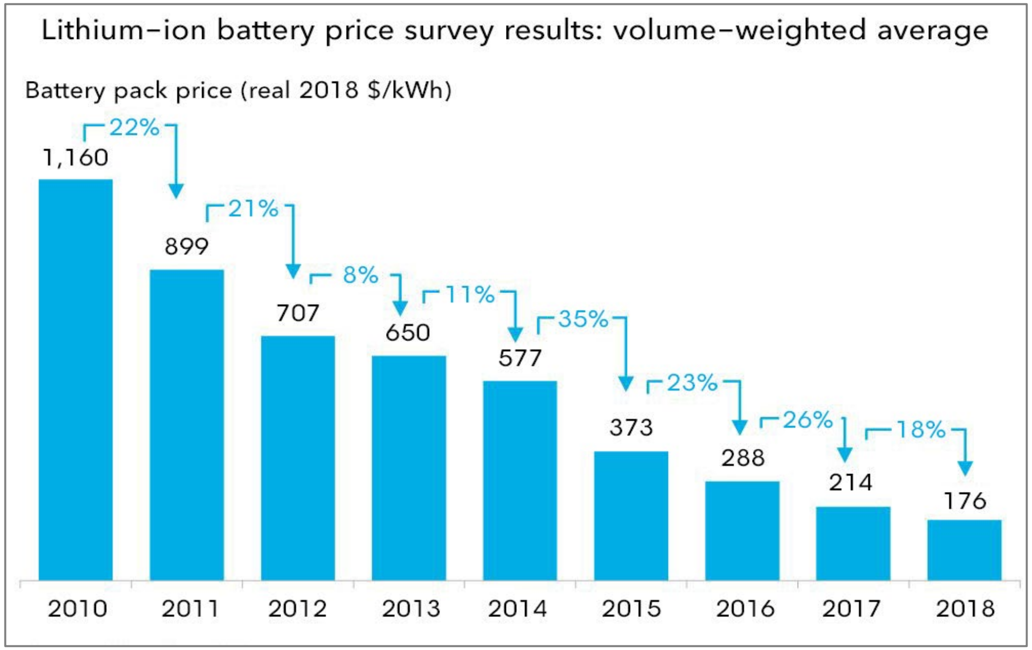
	Energy density (kW/kg)	Round Trip Efficiency (%)	Life Span (years)	Eco-friendliness
Li-ion	1st 150–250	1st 95	1st 10–15	1st Yes
NaS	2nd 125–150	2nd 75–85	2nd 10–15	2nd No
Flow	3rd 60–80	3rd 70–75	4th 5–10	4th No
Ni-Cd	4th 40–60	4th 60–80	3rd 10–15	3rd No
Lead Acid	5th 30–50	5th 60–70	5th 3–6	5th No

Li-ion = lithium-ion, Na-S = sodium-sulfur, Ni-Cd = nickel-cadmium.

Source: Kim et al. 2018

Why Lithium Ion Batteries?

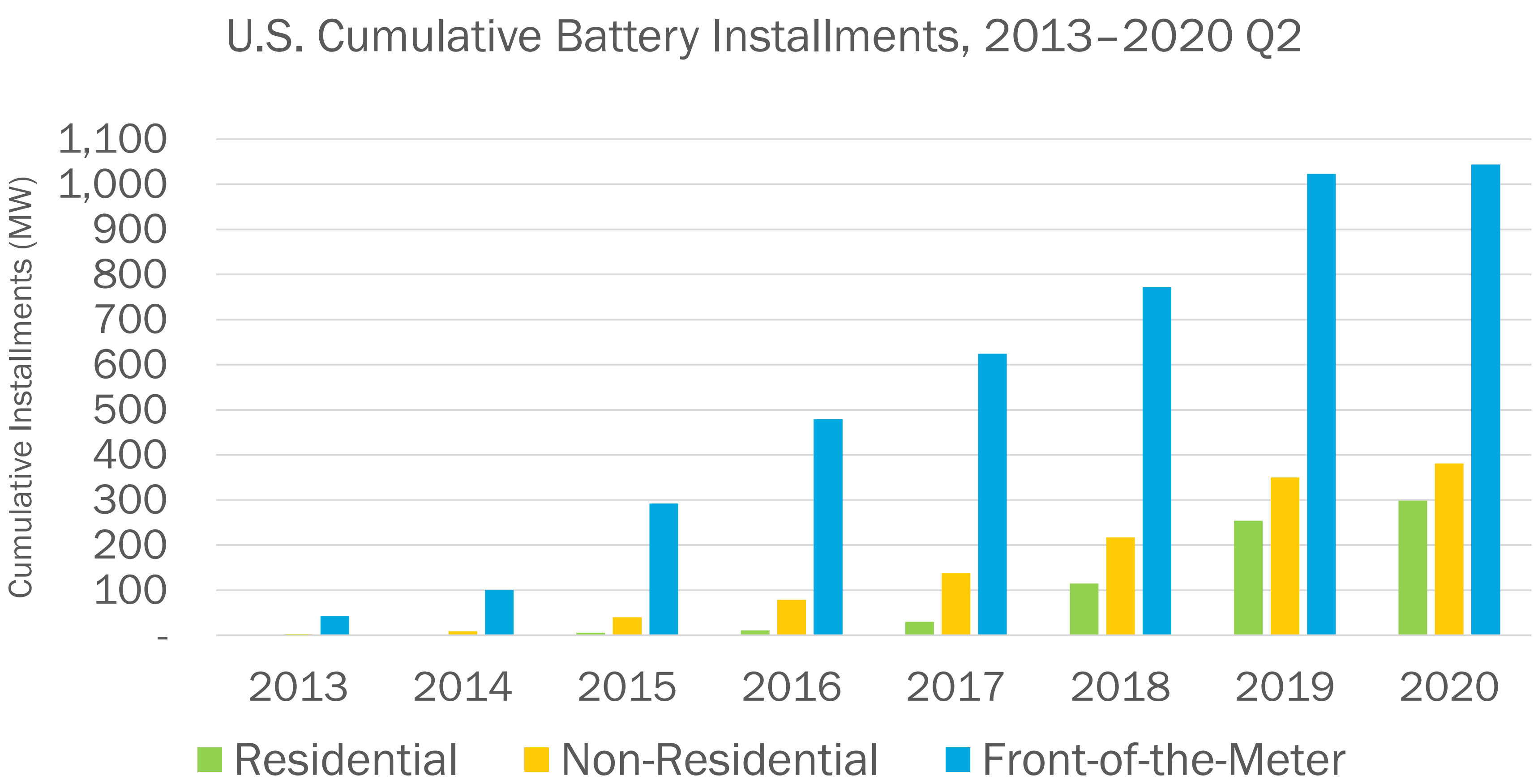




Source: Bloomberg New Energy Finance

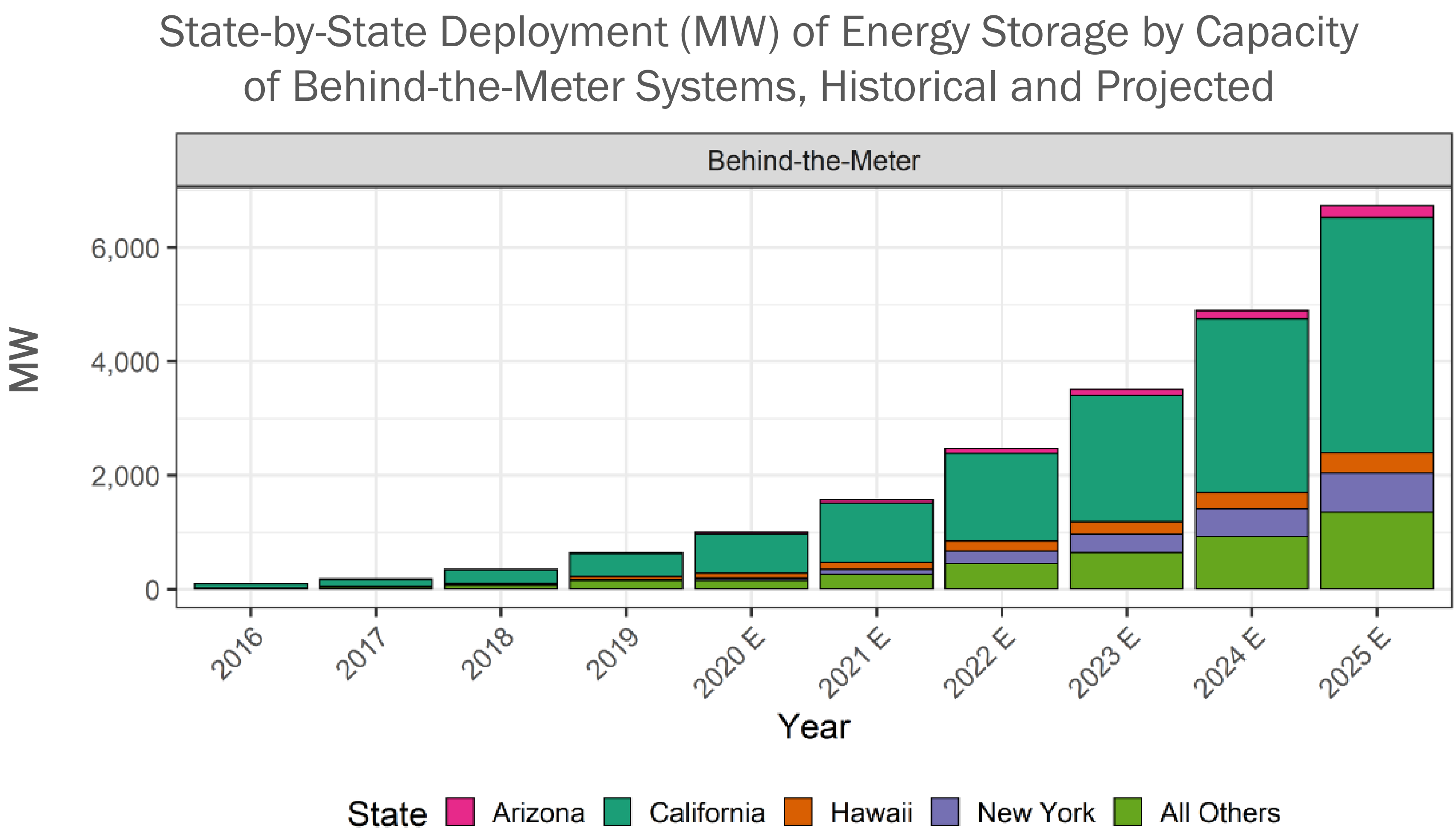
Source: GTM Research and Energy Storage Association 2019. U.S. Energy Storage Monitor: Q2 2019 Full Report

Battery Storage Deployment in the United States



Source: GTM Research and Energy Storage Association 2020. [U.S. Energy Storage Monitor: Q2 2020 Full Report]

Battery Deployment: Select U.S. Markets



Source: GTM Research and Energy Storage Association 2020. U.S. Energy Storage Monitor: Q2 2020 Full Report

Battery Storage Components

Credit: Dennis Schroeder, NREL

Battery Storage Terminology Explained

- **Battery storage:** Technology that stores electrical energy in a reversible chemical reaction. Li-ion batteries are the most common technology for distributed (behind-the-meter) energy storage applications due to their performance characteristics and cost
- **Dispatch:** The way that the battery is operated, including the times at which it is charged and discharged, and the depth of charge or discharge
- **Degradation:** The decrease in the battery's capacity over time and through use
- **State of charge:** The battery capacity as a percentage of its maximum capacity at a given time
- **Depth of discharge:** The battery capacity that has been discharged as a percentage of its maximum capacity.

Power versus Energy Capacity

Power	• How fast you can charge or discharge the battery • Measured in kW or MW
Energy	• How much energy you have available • Measured in kWh or MWh
Power: Energy Ratio (Duration)	• Ratio of power to energy; need to specify both • Typical configurations include 1 MW: 2 MWh, equivalent to a two-hour battery

The purpose of the battery impacts the recommended system size and duration.

PV + Batteries

PV versus Batteries

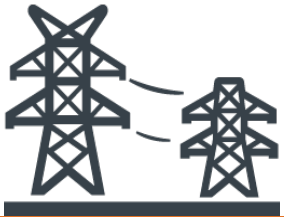
- **PV is simple**
  - Put it on the roof
  - The sun shines
  - Electricity is produced
  - Your utility bill is lowered.

- **Batteries are more complicated**
  - Do not generate electricity
  - Shift energy from one time period to another
  - Need controller to specify how they should be operated.
- **Batteries can usually only do one thing at a time**
  - To maximize return on investment, must determine what application the battery should serve and when.

PV + Storage: Use Cases for Federal Sites

	Off-Grid PV + Storage	Grid-Connected PV + Storage	Islandable PV + Storage	Large-Scale PV + Storage
Purpose	Provide continuous power in lieu of utility	Lower cost of utility purchases	Lower cost of utility purchases and provide power during grid outage	Large-scale generation for off-site sale
Why and Where it Works	• Remote sites with high fuel costs • Low grid reliability	• High demand charges • Time-of-use (TOU) rates • Ancillary service markets	• High demand charges • TOU rates • Ancillary service markets • Resilience requirements	• Interested offtaker • Large land availability • Deregulated market
Primary Power Supply	Distributed energy resources (DERs), typically including generators	Grid + DERs	Grid + DERs	Grid only
Provides Back-up Power?	No	No	Yes	Maybe

Energy Storage Operational Modes



Grid-Tied Mode | **Versus** | **Island Mode**

- Operated to provide cost savings/ancillary services
- Can operate at any power setting.

Island Mode

- "Diesel-off" mode to reduce fuel
- Store excess renewables
- Power must balance between sources/loads.

Other Considerations

- Can provide seamless transfer into island
- Can operate in parallel with generators
- Capabilities limited by power (kW) while duration is limited by energy (kWh).

PV + Storage: Use Cases for Federal Sites

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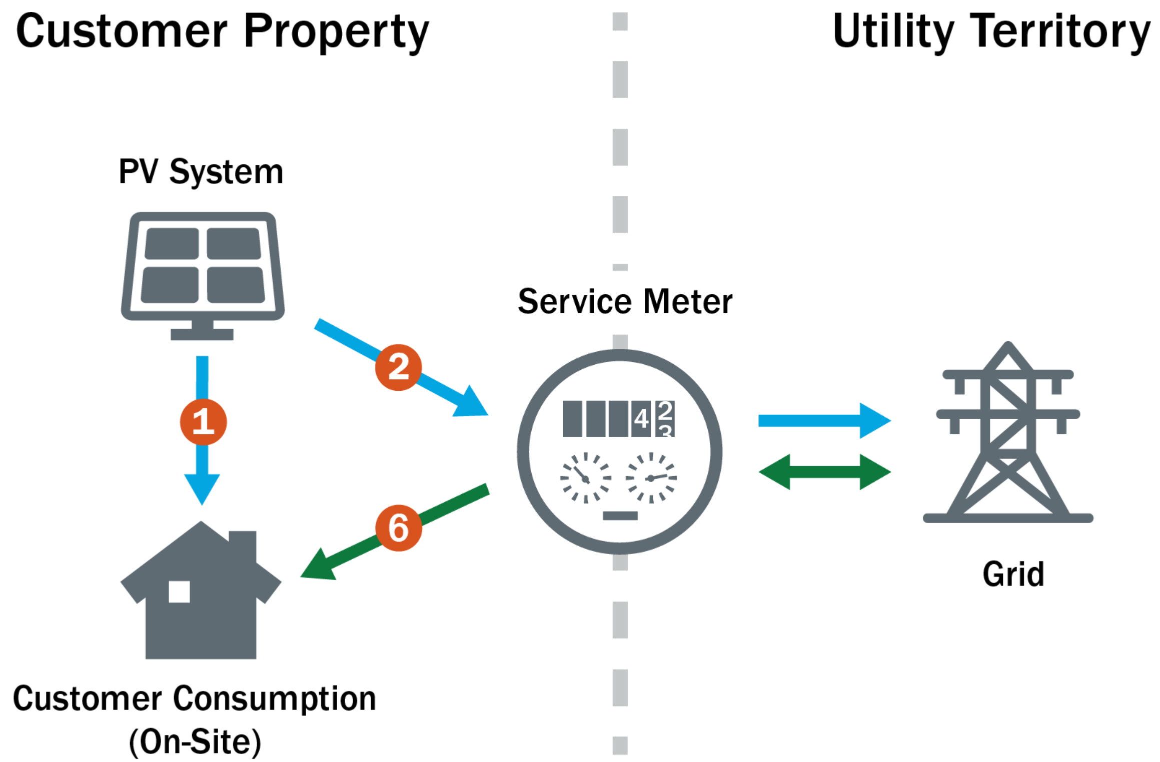
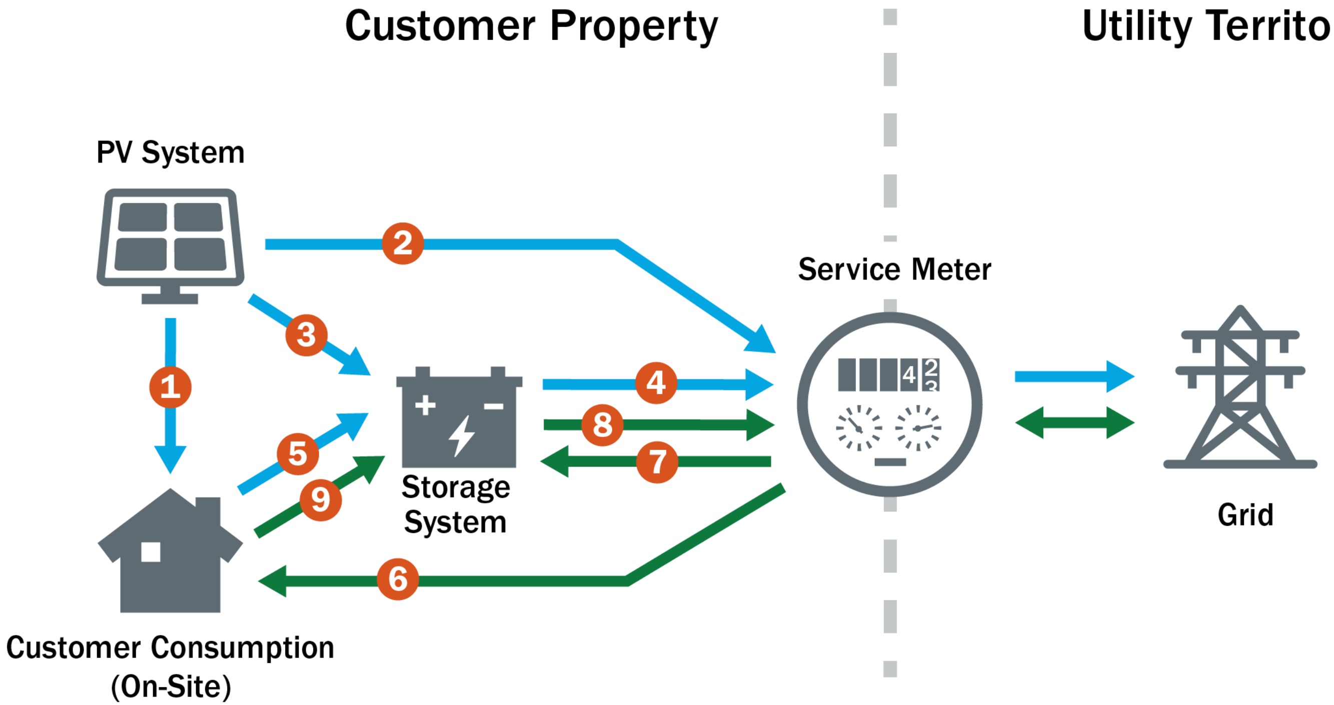
Provides Back-up Power?	No	No	Yes	Maybe

Grid-Tied PV System



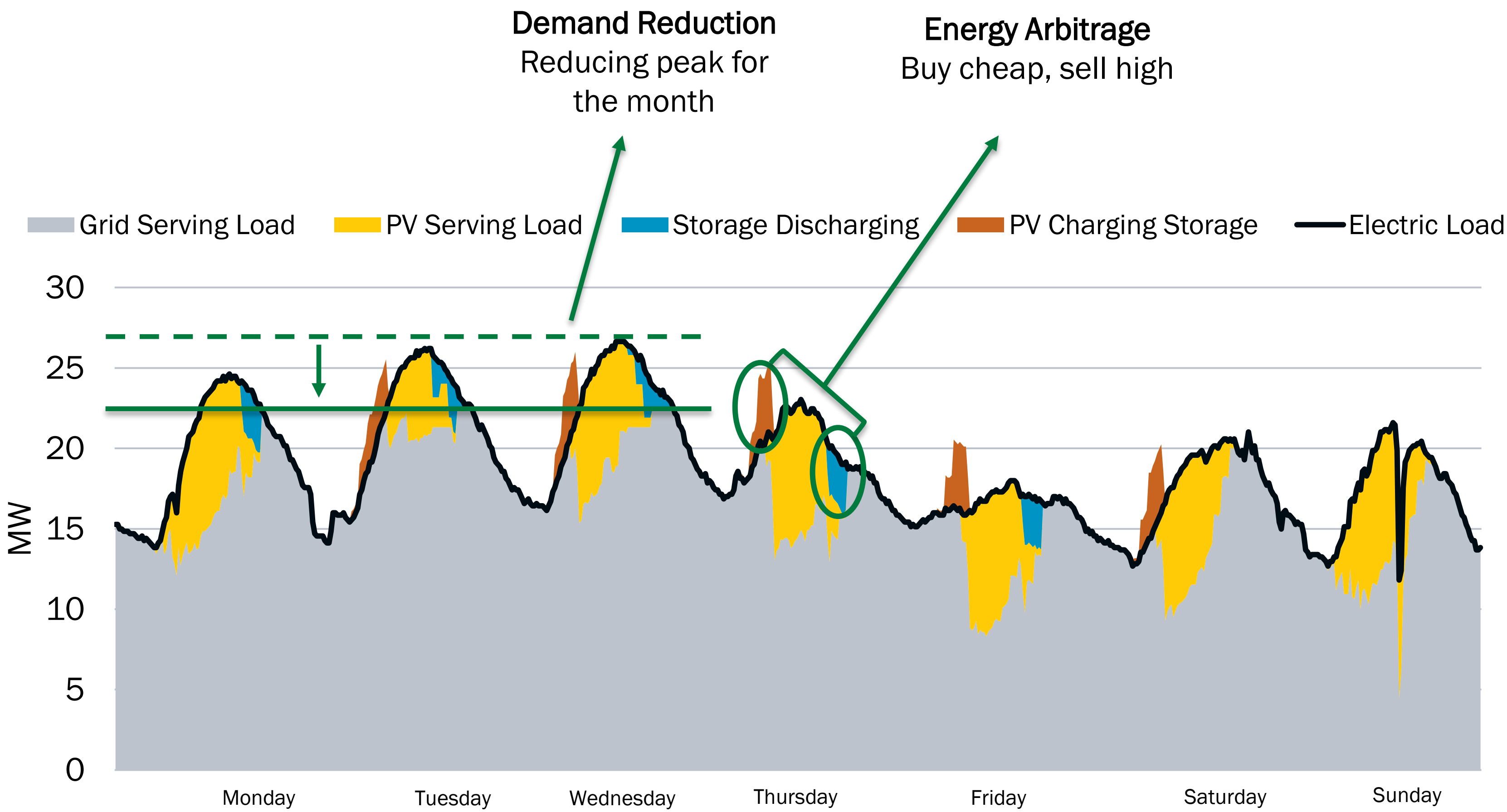
1. PV kWh consumed directly on-site
2. PV kWh exported directly to grid
6. Grid kWh consumed directly on-site

Grid-Tied Storage-Plus-PV System



1. PV kWh consumed directly on-site
2. PV kWh exported directly to grid
3. PV kWh exported to battery
4. PV kWh discharged from battery to grid
5. PV kWh discharged from battery, consumed on-site
6. Grid kWh consumed directly on-site
7. Grid kWh exported to battery
8. PV kWh exported to battery
9. Grid kWh discharged from battery, consumed on-site

Example of Demand Reduction and Energy Arbitrage



Battery Technical Considerations

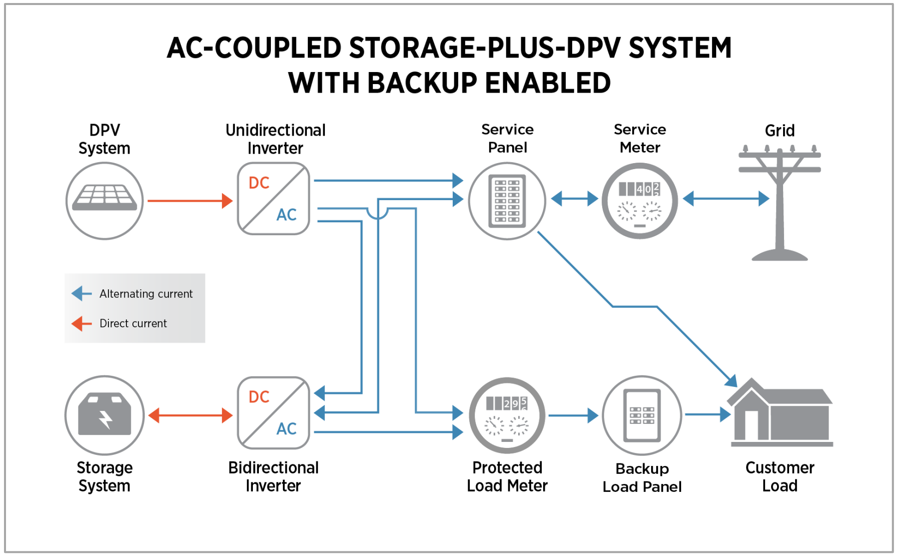
Configurations

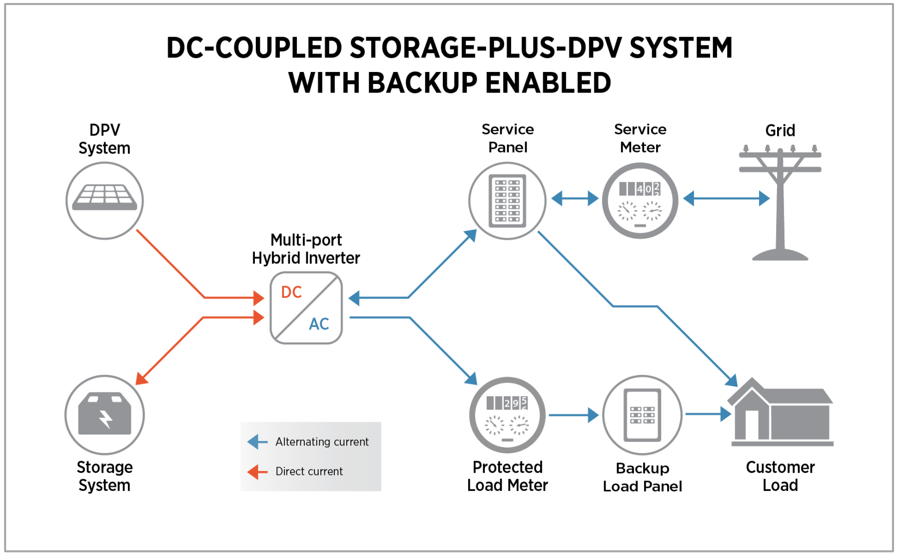
Degradation

Controls

Configurations

- Alternating Current (AC) vs. DC
- Depends on system size, desired use case, new or retrofit, with or without renewable energy





Source: Zinaman, Bowen, and Aznar 2020

Layers of Controls within an Energy Storage Unit

Battery Controller

- Prevent under/overcharging
- Balance multiple stacks
- Regulate state of charge (SoC) and monitor temperature.

Energy Storage System Controller

- Transient stability
  - Voltage control
  - Frequency control
- Island operation
- Renewable smoothing.

Microgrid Controller

- Demand response
- Peak shaving
- Time shifting
- Ancillary services.

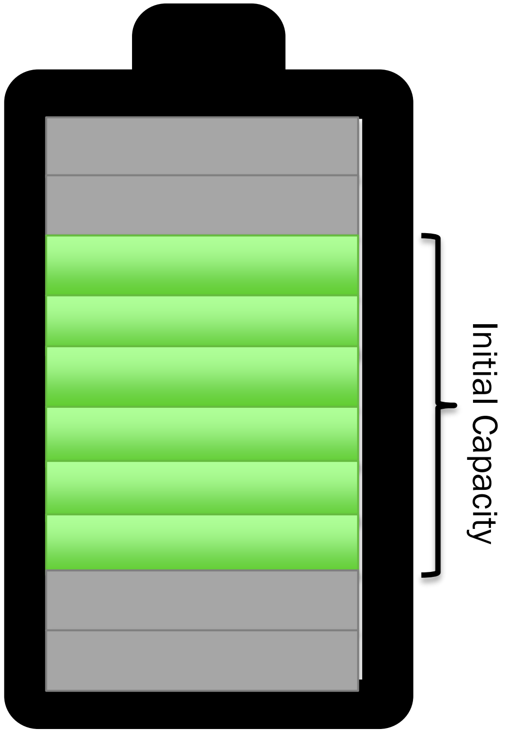
Battery Degradation

- **Battery capacity degrades at different rates over time, depending on the use case**
  – This degradation may eventually prevent the energy storage system from delivering on its intended use case, at which point augmentation of the battery capacity may be necessary
- **Augmentation—repowering an energy storage system by partially or fully replacing its existing batteries and potentially its balance of plant**
  – Planning for battery augmentation is important. This could include leaving extra space for new battery racks and anticipating where new cabling and trays may need to go in the container.

Strategies for Addressing Battery Degradation

There are multiple approaches to address battery degradation:

- **Oversizing:** Install more batteries than what is needed up-front, to account for future degradation
- **Capacity Maintenance Agreements:** Include augmentation to ensure that a minimum capacity is maintained (partial or full replacement of the existing batteries)
- **Reduced Service:** Contract should specify expected battery degradation and penalties for exceeding the specified degradation
- **Replacement:** Plan for complete battery replacement after approximately 10 years.



Oversizing Example

Types of Warranties

- **Typically a storage project will include a guarantee that a specified percentage of a battery's initial capacity will remain after a certain number of years**
  - For example: 80% of capacity at 10 years or 7,000 cycles
- **Common warranties**
  - Battery pack
  - Power conversion system
  - Full turnkey
- **Make sure that the battery management system measures all of the battery characteristics needed to meet warranty requirements**
  - Average daily temperature
  - Peak and average DC charge/discharge rates.

Will Battery Storage Work For Your Site?

Storage Costs

Incentives & Policies

Utility Cost & Consumption

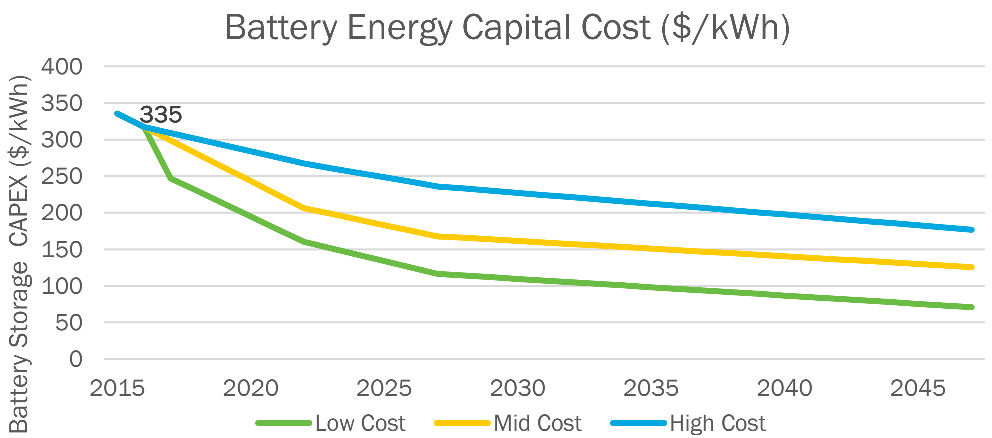
Value Streams

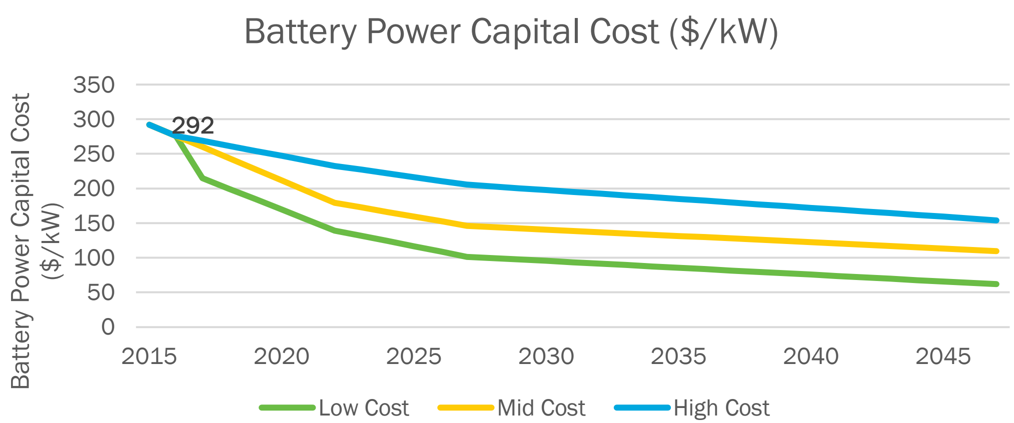
Site Goals

Battery Storage Costs

Battery Cost Estimates and Projections

Total battery system cost ($) = battery energy capital costs ($/kWh) * battery energy size (kWh) + battery power capital cost ($/kW) * battery power size (kW)





Costs are expected to decline over time.

Source: National Renewable Energy Laboratory (NREL) 2020

Utility Cost and Consumption

Electricity Bill Structure

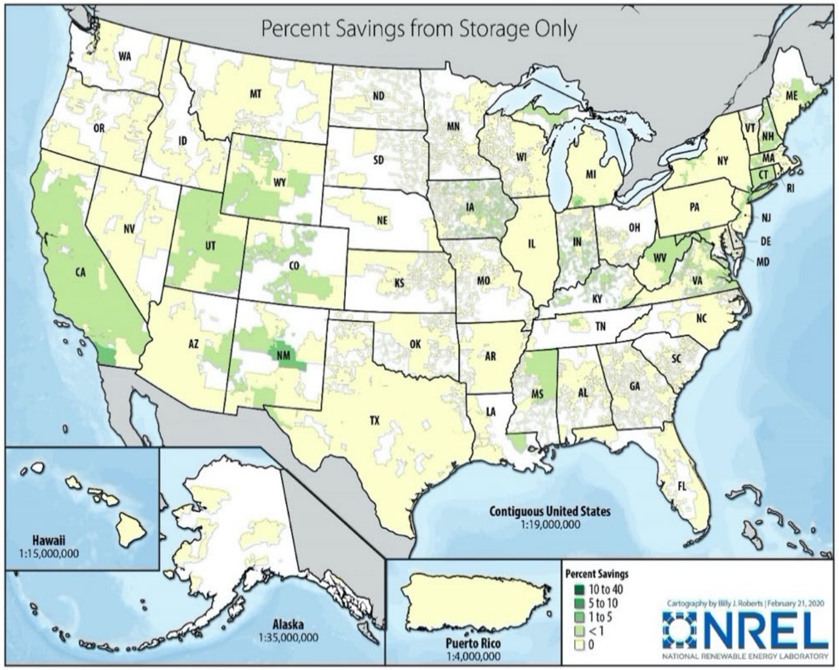
Electricity Bill Component	How It's Billed	How Storage Can Help
Energy Charges	Amount of kWh consumed (can vary by TOU)	Shift usage from high-TOU periods to low-TOU period
Demand Charges	Based on highest demand (kW)	Reduce peak demand when dispatched during peak period
Fixed Charges	Fixed cost per month	Storage cannot offset these

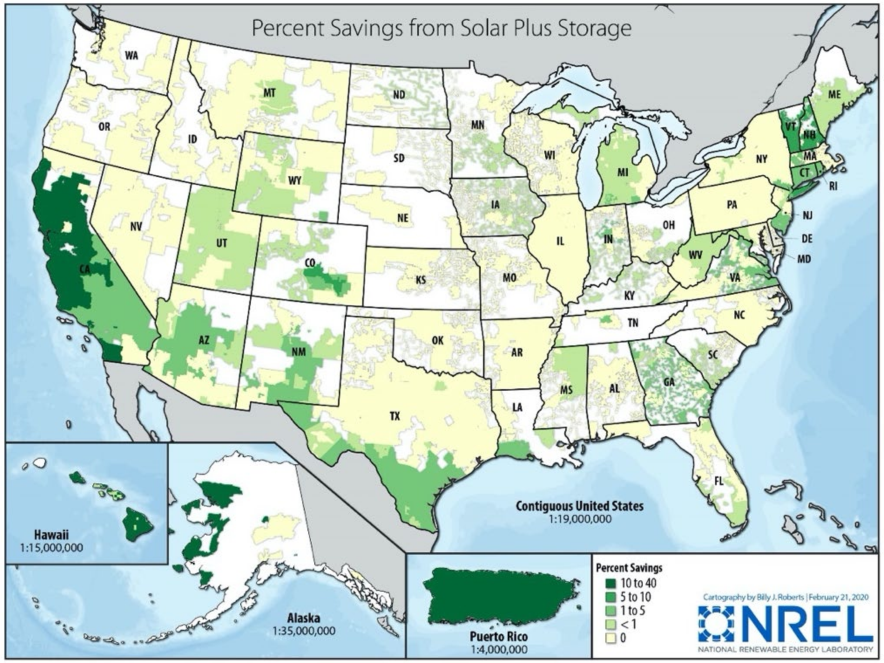
Other types of charges include:

- Minimum charge
- Departing load charge
- Standby charge.

Battery Storage Opportunities across the U.S.

Solar paired with storage can provide deeper savings (dark green) for commercial customers than standalone storage throughout the U.S.





Storage Incentives and Policies

Federal

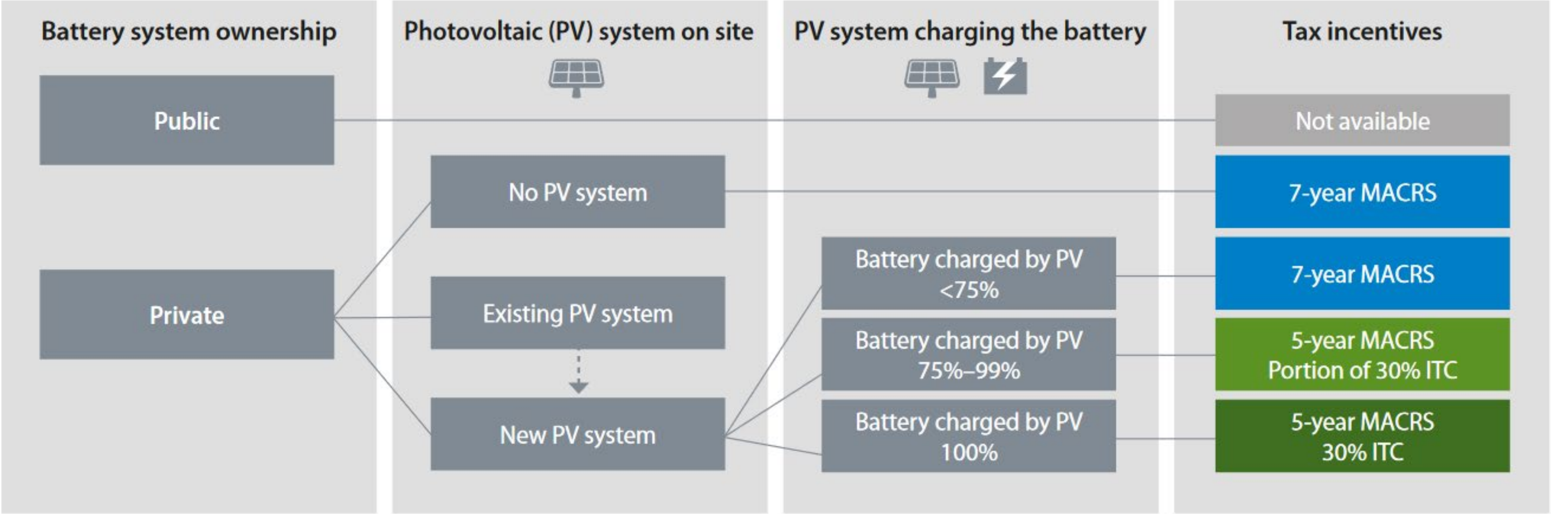
State

Utility

Federal Financial Incentives for Storage

Federal Investment Tax Credit (ITC) for storage: Lowers the taxes for taxable business entities if the storage is charged by certain types of renewable energy

Modified Accelerated Cost Recovery System (MACRS): Allows for accelerated depreciation of renewable energy

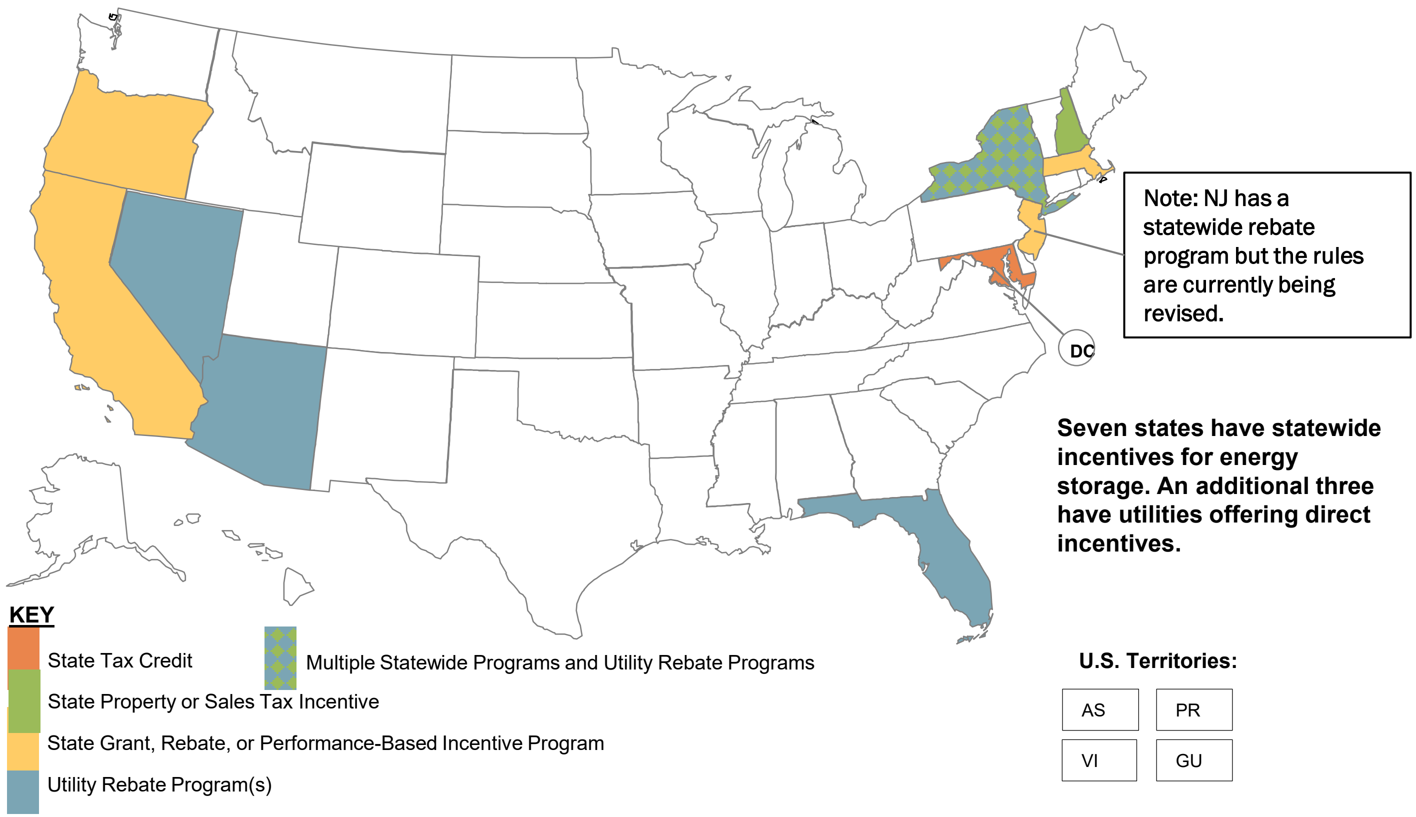


Source: NREL 2018

Storage systems are eligible (to varying degrees) for federal financial incentives.

State Financial Incentives for Storage

Energy Storage Financial Incentives



Seven states have statewide incentives for energy storage. An additional three have utilities offering direct incentives.

Source: Database of State Incentives for Renewables & Efficiency, April 2020

Net Metering Versus Net Billing

Net Metering	Net Billing
Most common compensation mechanism in the U.S.	Growing popularity in the U.S.
Energy generation in excess of on-site consumption credited, typically at retail rate	All energy exports from the system credited at a sell rate typically *below* the retail rate of electricity. All imports debited at the retail rate
Grid operates as "financial storage," allowing consumers to bank their PV generation to use later	Weaker incentive for standalone PV
Typically not an effective incentive for pairing storage with PV	Stronger incentive for storage-plus-PV rates as it encourages self-consumption of PV generation

Source: Zinaman et al. 2017

Time-Variant Sell Rate Design

- **Can encourage storage deployment**
- **Can align customer behavior with system needs**
- **Hawaii: Smart Export**
  - Encourage pairing of storage and PV
  - Encourage afternoon exports.

Island	12 A.M.–9 A.M. (₵/kWh)	9 A.M.–4 P.M. (₵/kWh)	4 P.M.–12 A.M. (₵/kWh)
Oahu	14.97	0	14.97
Maui	14.41	0	14.41
Lanai	20.79	0	20.79
Molokai	16.64	0	16.64
Hawaii	11.00	0	11.00

Source: Hawaiian Electric Company 2019

Interconnection

- **Utilities and regulators are revising interconnection rules for storage. Common approaches include:**
  - Clarifying that *existing* interconnection rules for small-scale distributed energy resources apply to storage
  - Developing *separate* interconnection rules for distributed photovoltaic (DPV) + storage systems
    - Depending on export/non-export features
    - Customization technical requirements.
- **It is important to understand local utility requirements, processes, and restrictions.**

Value Streams

Value Streams for Battery Storage

Driven by Utility Rate Structure

Utility/Regional Programs

Transmission and Distribution

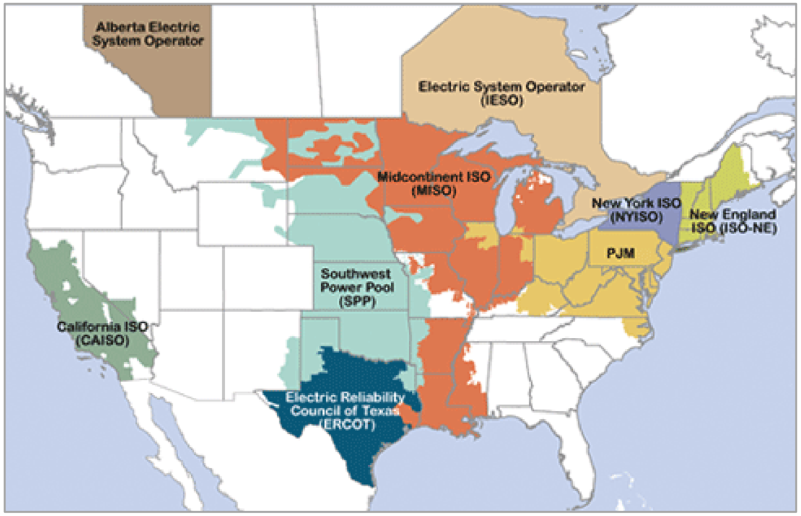
Service	Description	Grid	Commercial	Residential
Demand Charge Reduction	Use stored energy to reduce demand charges on utility bills		✓	✓
Energy Arbitrage	Behind the meter: Energy TOU shift (from on-peak to off-peak hours)		✓	✓
	Wholesale: Buy during off-peak hours; sell during on-peak hours	✓	✓	
Demand Response	Utility programs that pay customers to lower demand during system peaks		✓	✓
Frequency Regulation and Capacity Markets	Stabilize frequency on moment-to-moment basis or supply spinning, non-spinning reserves (Independent System Operators [ISO]/Regional Transmission Operators [RTO])	✓	✓	
Voltage Support	Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system	✓		
Transmission and Distribution Upgrade Deferral	Deferring the need for transmission or distribution system upgrades, e.g., via system peak shaving	✓	✓	✓

✓ Emerging

Demand Response and Ancillary Service Markets

In addition to directly lowering their utility bill through peak shaving and energy arbitrage, battery storage system owners can be compensated through utility or regional programs (such as ISO/RTO) for providing a service:

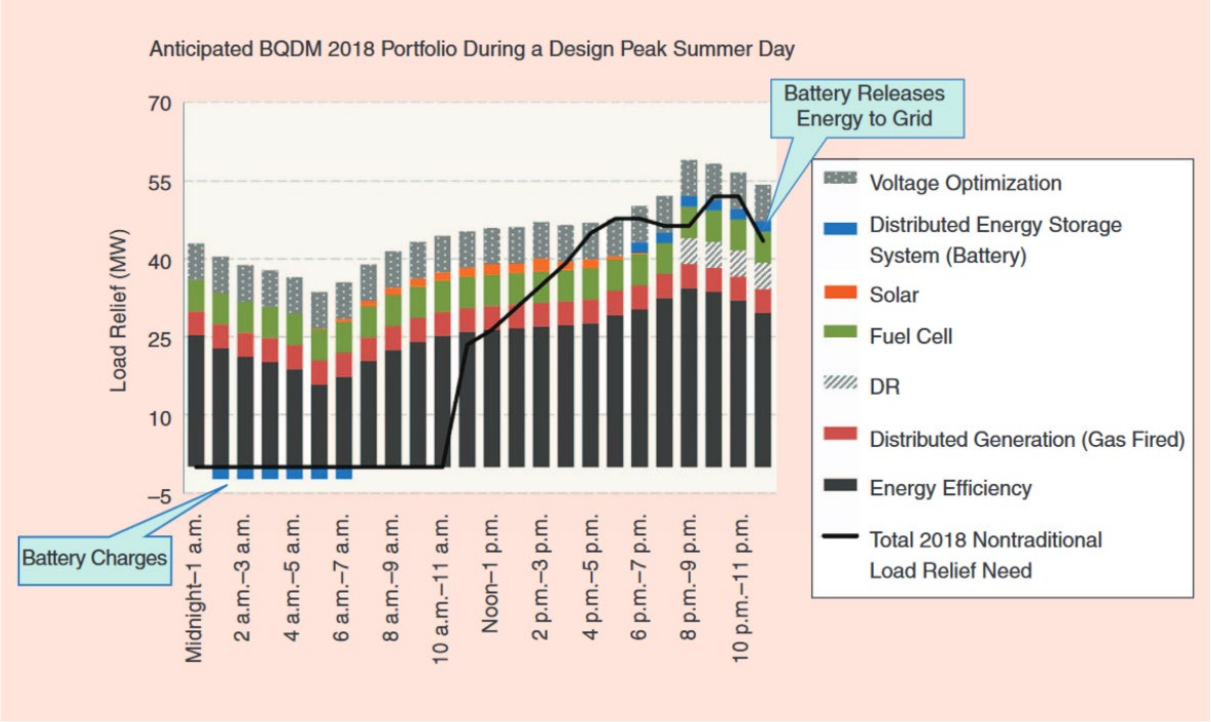
- Demand response programs offered by certain utility providers compensate customers for lowering demand (by discharging battery systems) at certain times
- Capacity markets regional programs compensate battery systems for delivering energy when notified
- Frequency regulation markets (regulation-up and regulation-down) compensate battery system owners for responding to automatic control signals.



Participation in these programs may conflict with utility bill reduction opportunities.

Alternative to Distribution Upgrades

Battery storage can have additional value for utilities in deferring distribution system upgrades and can be part of a larger package of *nonwires alternative* solutions.



Anticipated portfolio of Con Edison's Brooklyn Queens Demand Management (BQDM) Program during a design peak summer day

Source: NREL 2018

Meeting Site Goals

Using Batteries for Back-Up Power

Incorporating Grid-Tied Storage and Renewable Energy for Back-up Power

Critical Loads | Outage Duration | Value of Resilience | Cost of Islanding PV + Storage

- There are additional considerations for using battery storage and other distributed energy technologies (including renewables) to provide back-up power in the event of a grid outage
- Different technology solutions have different costs and provide different levels of back-up.

Critical Loads

- **Load served during a grid outage**
- **Usually different from typical load**
- **Will impact technology selection and size of back-up solution**
- **There may be different levels of critical loads**
  - Some that are critical and need to be met immediately and constantly
  - Some that are nice to have and can be met when there is excess generation
- **Sites may not be known during initial assessments and may need to be estimated.**

Estimating Critical Load

Percent of Typical Load Estimate

- Can be larger or smaller than typical load
- Easy to estimate if typical load is known
- Same shape as typical load

Metered Critical Load

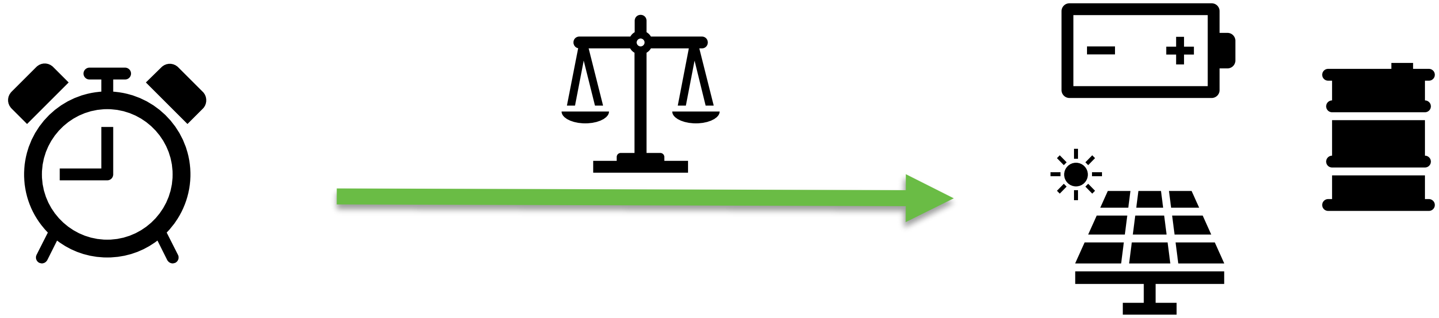
- Most accurate
- Could be obtained from sub-meters of critical facilities or critical load panel(s)
- May have different shape (and time of peak)

Modeled Loads

- Works well if critical load is only comprised of a few components

Outage Duration

- **Length of outage can drive the technology selection**



Seconds or Minutes

- Battery UPS may be sufficient

Days

- Battery supplemented by RE and traditional backup

Weeks

- On-site fuel supply may not be sufficient

Length of outage (shorter to longer)

Quantifying, Valuing, and Monetizing Back-Up Power Solutions

Quantifying

Performance-based metrics quantify the consequences that could be avoided as a result of the back-up power solution:

- Customer outage time
- Load not served
- # or % of customers experiencing outage
- # of critical services without power
- Time to recovery.

Valuing

The value of a back-up solution can be measured by the direct or indirect costs incurred:

- Loss of revenue
- Cost of recovery
- Avoided outage cost
- Loss of assets and perishables
- Business interruption costs.

Monetizing

Monetizing back-up solutions turn the value into cash flows:

- Reduced insurance rates
- Reduced mortgage rates
- Government incentives
- Grid services value
- Resilience payment from site host.

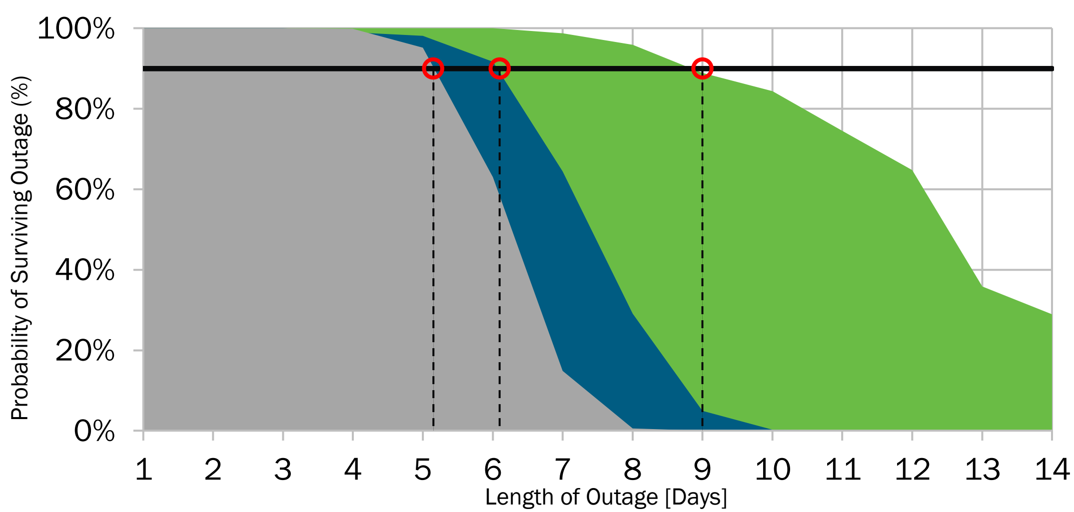
Source: NREL 2019

Incorporating Grid-Tied Storage and Renewable Energy for Back-up Power

- **The probability of surviving an outage of a certain length from different technology combinations is shown**
- **Increased system sizes provide added days of survivability but increase life cycle costs.**

	Generator	Solar PV	Storage	Life Cycle Cost	Outage
1. Base Case	2.5 MW	-	-	$20 million	5 days
2. Lowest Cost Solution	2.5 MW	625 kW	175 kWh	$19.5 million	6 days
3. Proposed System	2.5 MW	2 MW	500 kWh	$20.1 million	9 days

Battery duration: 1 hour

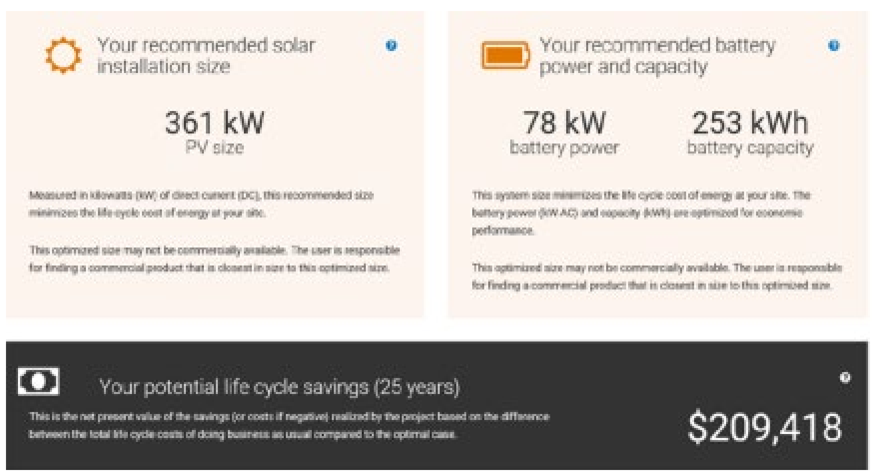


Source: Anderson et al. 2017

Ready for Batteries?
Next Steps

1. Conduct an Initial Screening in REopt Lite

- **This no-cost web tool allows users to:**
  - Evaluate the economic viability of grid-connected battery storage (as well as PV and wind) at a site
  - Identify system sizes and battery dispatch strategies to minimize energy costs
  - Estimate how long a system can sustain critical load during a grid outage
- **To get started, visit https://reopt.nrel.gov/tool.**



Illustrative output: REopt Lite outputs include optimal system sizes and life cycle cost savings.

2. Explore Considerations for Implementing Battery Storage at Federal Sites

Numerous resources and tools are available for federal agencies to learn more:

- Considerations for Implementing PV plus Storage Systems at Federal Buildings and Campuses
- FEMP Federal Distributed Energy and Energy Procurement
- Request FEMP Technical Assistance for Distributed Energy Projects through an online portal: https://www7.eere.energy.gov/femp/assistance/node/add/application-combined
- Contact FEMP through the website contact: https://www.energy.gov/eere/femp/federal-energy-management-program-website-contact.

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Considerations for Implementing PV plus Storage Systems at Federal Buildings and Campuses

Federal agencies have a long history of using solar photovoltaics and battery storage (PV plus storage) systems at remote sites where the technologies can offset costly diesel fuel. However, recent declines[1] in lithium-ion battery costs, along with changes in net metering policies and utility rate structures, are opening up opportunities for PV plus storage to be deployed cost-effectively at grid-connected sites.

When grid connected, storage systems can be deployed along with PV to maximize the economic value of the PV system and to support critical operations during grid outages (if configured and controlled appropriately). However, there are several reasons why PV plus storage systems are more complicated than PV alone, which this fact sheet aims to clarify.

Figure 1. Fort Hunter Liggett installed a lithium-ion battery to help mitigate demand charges and reduce PV curtailment. The battery was purchased with funding from the Army's Energy Resilience & Conservation Investment Program. *Photo by Lars Lisell, NREL.*

Table 1. Value Provided by Distributed PV plus Storage

Use	Value
Utility bill cost reduction	Reduced demand charges, energy arbitrage
Revenue generation	Demand response, ancillary services
Resilience	Back-up power during grid outage

Estimating the Value of PV plus Storage

In general, PV plus storage systems can provide value by reducing costs, generating revenue, or providing resilience (Table 1). Cost reduction is achieved through utility bill management; for example, by increasing PV self-consumption, reducing demand charges, or using energy arbitrage. Revenue can be generated by dispatching the PV plus storage system during a demand response event or participating in ancillary services. Finally, these systems can provide back-up power to support critical operations during grid disturbances. PV plus storage systems are typically deployed for one of these purposes, but combining multiple value streams, or "value stacking," can increase the economics of PV plus storage systems.

Identifying a federal site's utility rate structure is an important step in evaluating the economics of a PV plus storage project, as utility bill cost reduction is typically a primary driver of behind-the-meter PV plus storage economics. PV plus storage systems are more likely to provide positive returns at sites with time-varying rates and/or high demand charges. Dynamic rate structures reward customers with flexible load profiles, allowing the PV plus storage system to maximize the value it generates. Other factors include the building's load profile and net metering policies.

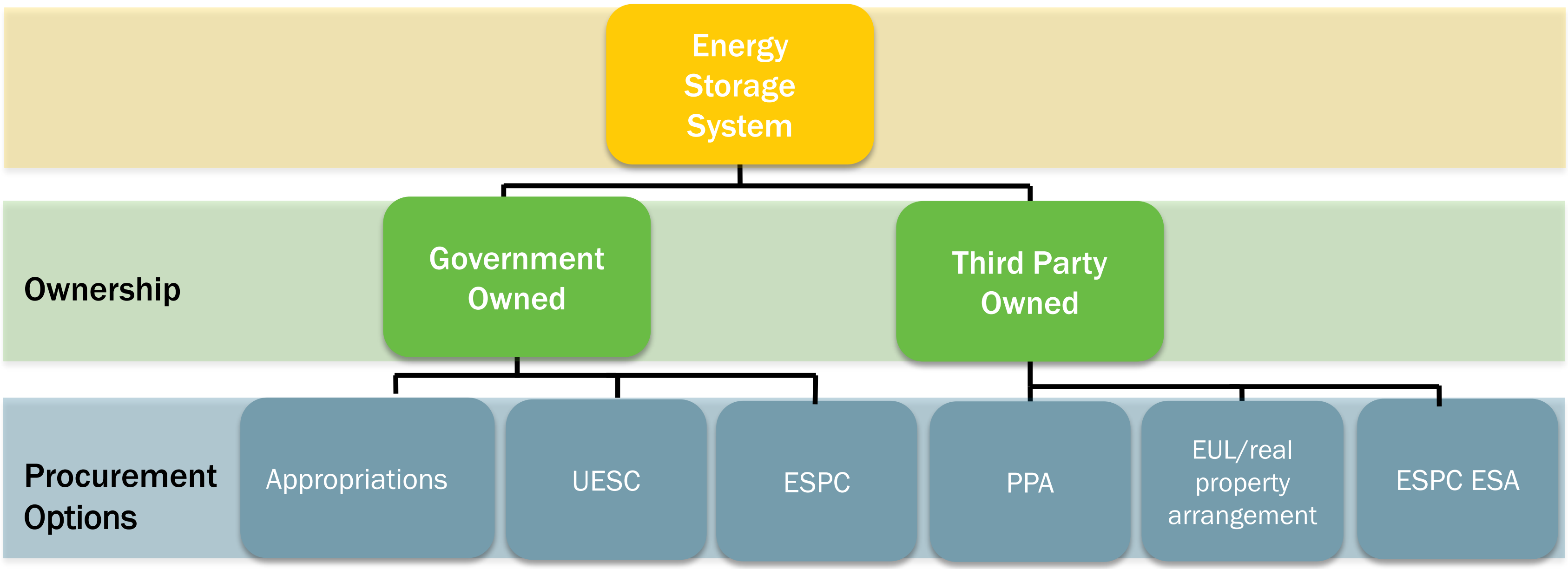
Identifying the combination of value streams can be a complicated process. Additionally, access to grid service value streams may be constrained by access to wholesale markets. Participating in wholesale markets in regulated utility territories requires engaging with the utility. Projects may need to be coordinated through an aggregator who bundles many small distributed systems to form a network that meets market participation requirements. Federal sites can also face cybersecurity challenges when connecting to energy markets.

If the system's primary purpose is to provide resilience, utility rates and value stacking may be less important; instead, maintaining service through an electric service interruption would be the primary source of value provided by the system. The value of this resilience benefit can sometimes be hard to quantify and depends on the value of the load that is lost during the outage. A system installed for resilience also needs the ability to island (disconnect) from the grid. This requires additional equipment such as electrical isolation switches and multimode PV inverters, which can increase expenses by between 10% to 50% compared to the nonislandable system's cost.[2]

Sizing and Dispatching PV plus Storage

The primary purpose of the PV plus storage system dictates the system design, configuration, and cost. For instance, a battery intended to provide resilience may be required to maintain a minimum state of charge at any given time, limiting the

3. Understand Procurement Options and Considerations



Abbreviations

UESC	Utility Energy Service Contract	PPA	Power Purchase Agreement
ESPC	Energy Savings Performance Contract	EUL	Enhanced Use Lease
		ESPC ESA	ESPC Energy Sales Agreement

3. Understand Procurement Options and Considerations

- **If government-owned, consider contracting for operations and maintenance and ensuring performance during the system's lifetime, including:**
  - Performance guarantees (e.g., minimum demand reduction guarantees)
  - Require battery management system performance monitoring and augmentation (or replacement) to ensure safety, performance, and longevity
  - Capacity maintenance agreements
- **If the energy storage system is intended to provide power during an outage:**
  - Clearly specify the intended sequence of operations for startup of the backup system and battery operating requirements for the duration of the outage
  - Consider whether the storage system must maintain a minimum state of charge during grid-tied operations to have sufficient charge at the start of an outage.

4. Consider Siting, Permits, and Safety

- **Siting: National Fire Protection Association (NFPA) 855 "Standard for the Installation of Stationary Energy Storage Systems" should be considered:**
  - Fire protection requirements for indoors, outdoors within 100' of building and greater than 100' from building (remote, less stringent)
  - Separation of 3' between every 50-kWh group of battery energy storage systems (BESS) (not required for remote siting)
- **Local Permitting may be required:**
  - Important features called out in building and fire codes include spacing, security (e.g., fencing for outdoor systems), placement of electrical disconnects and emergency stops, construction building or encasement material (e.g., noncombustible), fire suppression systems, and ventilation and exhaust systems.
- **Safety Requirements:**
  - Provide Battery Management System (BMS)
  - Cooling and ventilation systems that remain operational during grid outage
  - Training requirements including response procedures that incorporate system monitoring, detection of gases, ventilation practices, extinguishing methods, and information prior to entry of BESS
  - BESS commissioned per the Electric Power Research Institute (EPRI) "Energy Storage Integration Council (ESIC) Energy Storage Commissioning Guide"
    - Require the provision of a detailed commissioning report.

5. Codes and Standards

Component		Applicable Codes and Standards
Battery	Cell	• Underwriters Laboratories (UL) 1642 "Standard for Lithium Batteries" • International Electrotechnical Commission (IEC) 62619
	Module	• UL 1973 "Batteries for Use in Light Electric Rail Applications and Stationary Applications" • IEC 62619
	Rack/Bay	• IEC 61508 (BMS)
System		• UL 9540 Standard for Energy Storage Systems and Equipment • NFPA 70 (including NFPA 70E Arc flash) • UL Subject 508 "Standard for Industrial Control Panels" • United Nations (UN) 38.3 • IEC 60529, 60990-1, 62040-1 • National Electric Code 2017 • Institute of Electrical and Electronics Engineers (IEEE) 693
Grid Interconnection		• IEEE 1547 • UL 1741, "Standard for Static Inverters and Charge, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources"

Batteries that meet nationally-recognized codes and standards ensure safety and reliability.

Summary

Key Takeaways

- Li-ion battery **costs reductions and operational characteristics are making battery storage systems economically attractive** in grid-connected applications for federal agencies and other end users.
- There are **different use cases** (e.g., off-grid, grid-connected, islandable) for PV + battery storage systems that federal agencies can consider to meet their needs, but systems must be designed and operated to meet specific requirements.
- **There are many factors that determine if battery storage makes economic sense for a site; utility rate structures and cost strongly affect battery economics**.
- **Federal and state policies** influence the overall cost of purchasing and operating a battery, in addition to the time and expense it takes to interconnect the battery to the grid.
- **Batteries have multiple value streams** (e.g., demand charge reduction, resilience, demand response) but different opportunities for value might not align. For a behind-the-meter application, demand charge reduction and energy arbitrage for TOU rates are the most common.
- If configured accordingly, RE + battery storage can contribute provide cost savings, and provide back-up power in the event of a grid outage.
- **Preliminary screenings, understanding procurement options, and considering siting, permits, and safety are critical steps** prior to deploying battery storage at a federal site.

Knowledge Check

Question #1

What is the predominant battery chemistry used in recently deployed behind-the-meter battery storage systems?

a) Lead-acid

b) Lithium-ion

c) Nickel

d) Sodium

Question #2

Power is a measure of how much energy you have available in a battery, measured in kWh or MWh.

a) True

b) False

Question #3

When calculating the full cost of a battery, both the capacity in terms of power and energy must be considered.

a) True

b) False

Question #4

Utilities and regulators are revising interconnection rules for storage. Common approaches include:

a) Clarifying that existing interconnection rules for small-scale distributed energy resources apply to storage

b) Developing separate interconnection rules for PV + storage systems

c) All of the above

Question #5

Distributed battery storage may provide value to the customer because of:

a) Demand charge reduction

b) Resiliency/back up

c) Energy arbitrage

d) All of the above

Question #6

Battery storage systems can be connected to a PV installation on either the AC or DC side of an inverter.

a) True

b) False

Question #7

Fixed charges on an electricity bill can typically be offset by battery energy storage or any other distributed energy technologies.

a) True

b) False

Question #8

When the battery energy storage system is in an islanded mode:

a) It can sell and purchase power from the grid
b) It provides power during a grid outage
c) It can operate at any kW and kVAR settings
d) It provides power directly to loads
e) B and D
f) A and B

Question #9

Under what conditions are battery storage systems most financially attractive for the customer?

a) High demand charges, time-of-use rates
b) Net metering, high fixed charges
c) Net metering, low demand charges
d) Low demand charges, high battery capital costs

Question #10

All **battery system owners can participate in and derive additional value from participating in demand response programs and ancillary services markets.**

a) True

b) False

Question #11

Battery storage systems can be used both when the grid is operating as well as if the utility grid goes down (if configured accordingly).

a) True

b) False

Question #12

Ways of estimating a critical load include:

a) Percent of Typical Load
b) Metered Critical Load
c) Modeled Loads
d) All of the above