NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Energy Storage Overview

Emma Elgqvist, NREL

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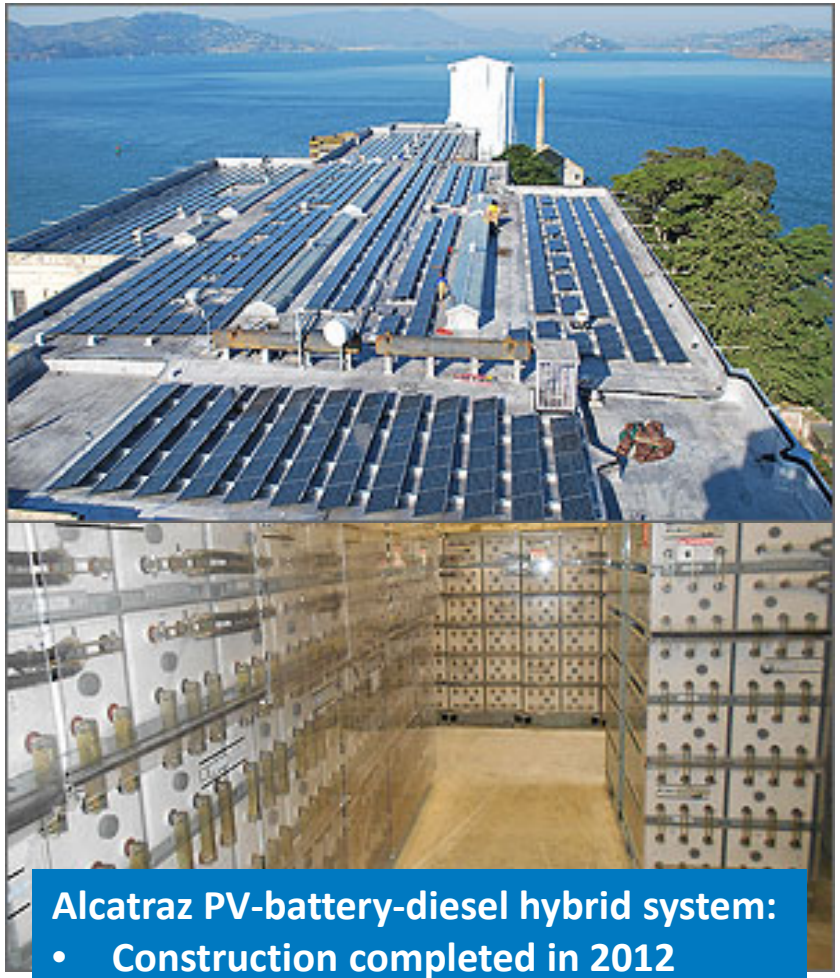
Agenda

1. **Background**
2. **Batteries 101**
3. **Will storage work at my site?**

Background

Long History of Storage and RE at Federal Sites… for Off-Grid Applications

- Federal agencies have a long history of implementing storage systems in conjunction with renewables, primarily at remote sites with high diesel costs
- Off-grid hybrid RE + storage systems lower costs and provide a sustainable alternative to diesel generators
- Recent reductions in li-ion battery costs are making storage systems economically attractive in grid-connected applications



Alcatraz PV-battery-diesel hybrid system:

- **Construction completed in 2012**
- **Two 220 kW diesel engine generators**
- **305 kW-DC of solar photovoltaics (PV)**
- **1,920 kWh of lead acid batteries**

Why Storage Now?

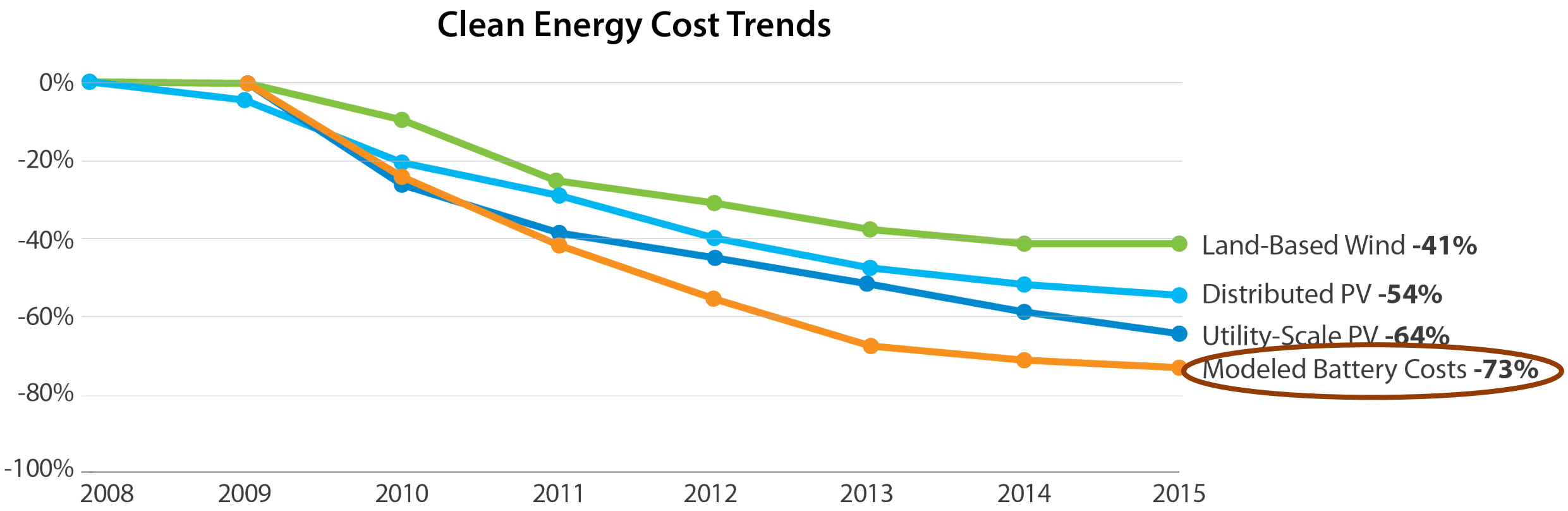


Image credit: energy.gov/revolution-now

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Revolution Now – Accelerating Clean Energy Deployment.* DOE/EE-1478, September 2016. https://energy.gov/eere/downloads/revolutionnow-2016-update.

Battery Storage 101

PV vs. Batteries

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

- Batteries are more complicated
  - Don’t generate electricity
  - Shifts energy from one time period to another
  - Put one in the basement or in a shed, nothing happens

- Batteries can usually only do one thing at a time
  - Cost of energy at the time it’s stored must be cheaper than cost of energy when it is used
  - To maximize return on investment, must determine what application battery should serve and when

Types of Energy Storage

Application

Transmission

Distribution

Behind-the-Meter (BTM)

Technology

Bulk Storage: Pumped hydro, compressed air

Pros: low cost, large capacity
Cons: long lead-time, very site specific

Distributed Storage: Fly-wheels, batteries (Flow, Lead, Acid, Sodium Beta, Lithium-Ion)

Pros: Siting, short lead time, use case
Cons: Cost

Lithium-ion batteries made up 98.8% of batteries installed in Q4 2017

Power vs. Energy Capacity

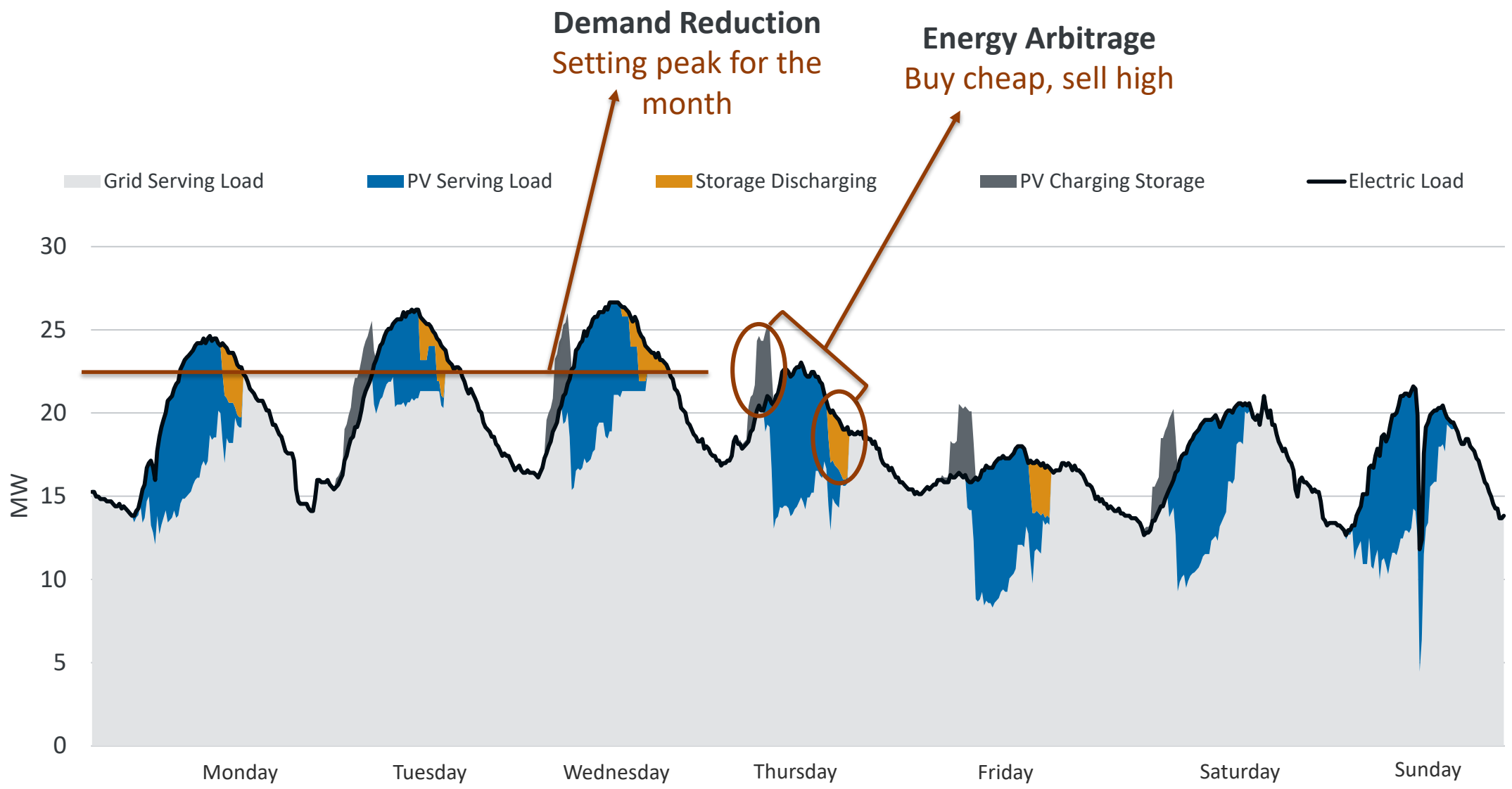
Power	• How fast you can charge or discharge the battery • Measured in kW or MW
Energy	• How much energy you have available • Measured in kWh or MWh
Power:Energy Ratio	• Ratio of power vs. energy; need to specify both • Typical configurations include 1 MW: 2 MWh, equivalent to a 2 hour battery

The purpose of the battery impacts the system size and ratio

Value Streams for Storage

	Service	Description	Grid	Commercial	Residential
Driven by Utility Rate Structure	**Demand charge reduction**	Use stored energy to reduce demand charges on utility bills		✓	✓
	Energy arbitrage	Buying energy in off-peak hours, consuming during peak hours		✓	✓
Utility/Regional Programs	**Demand response**	Utility programs that pay customers to lower demand during system peaks		✓	✓
	Capacity markets	Supply spinning, non-spinning reserves (ISO/RTO)	✓	✓	
	Frequency regulation	Stabilize frequency on moment-to-moment basis	✓	✓	
Not applicable for BTM storage	**Voltage support**	Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system	✓		
	T&D Upgrade Deferral	Deferring the need for transmission or distribution system upgrades, e.g. via system peak shaving	✓		
Value varies	**Resiliency / Back-up power**	Using battery to sustain a critical load during grid outages	✓	✓	✓

Example of Demand Reduction and Energy Arbitrage



Drivers of Cost Effective Storage Systems

Will Storage Work for Your Site?

Storage Costs

Incentives & Policies

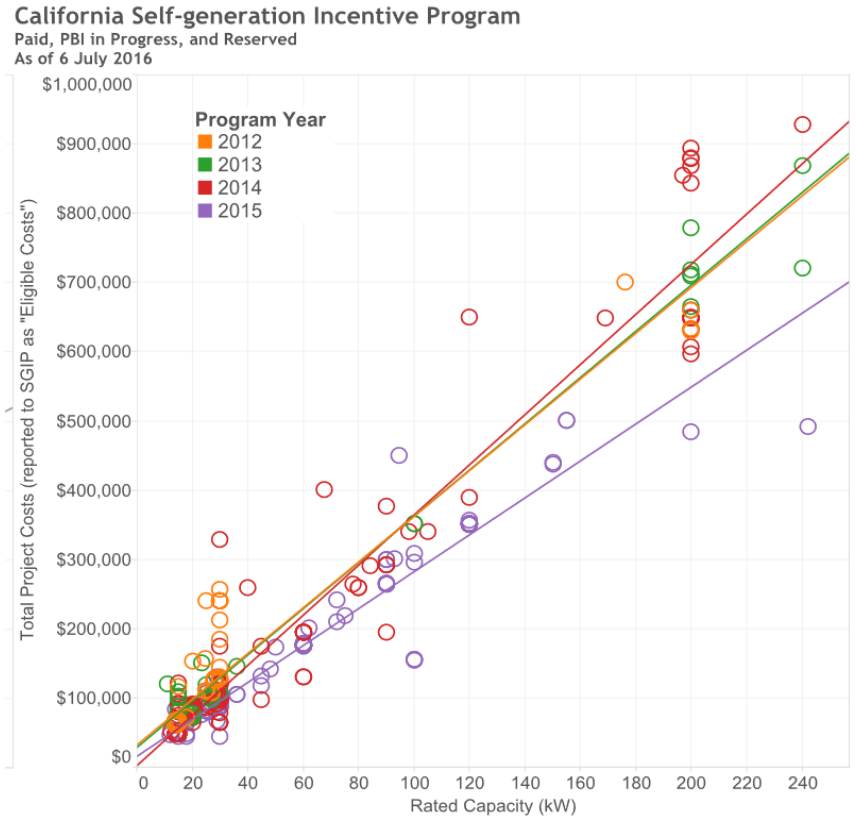
Utility Cost & Consumption

Ancillary Services Markets

Resilience Goals

Current Battery Cost Trends and Estimates

- Wide range of storage costs reported due to rapid cost reduction in a relatively new technology
- Some costs are reported for battery cell-only (not accounting for pack or total installed cost)
- Normalizing to $/kW or $/kWh can be misleading when power:energy ratio is not considered

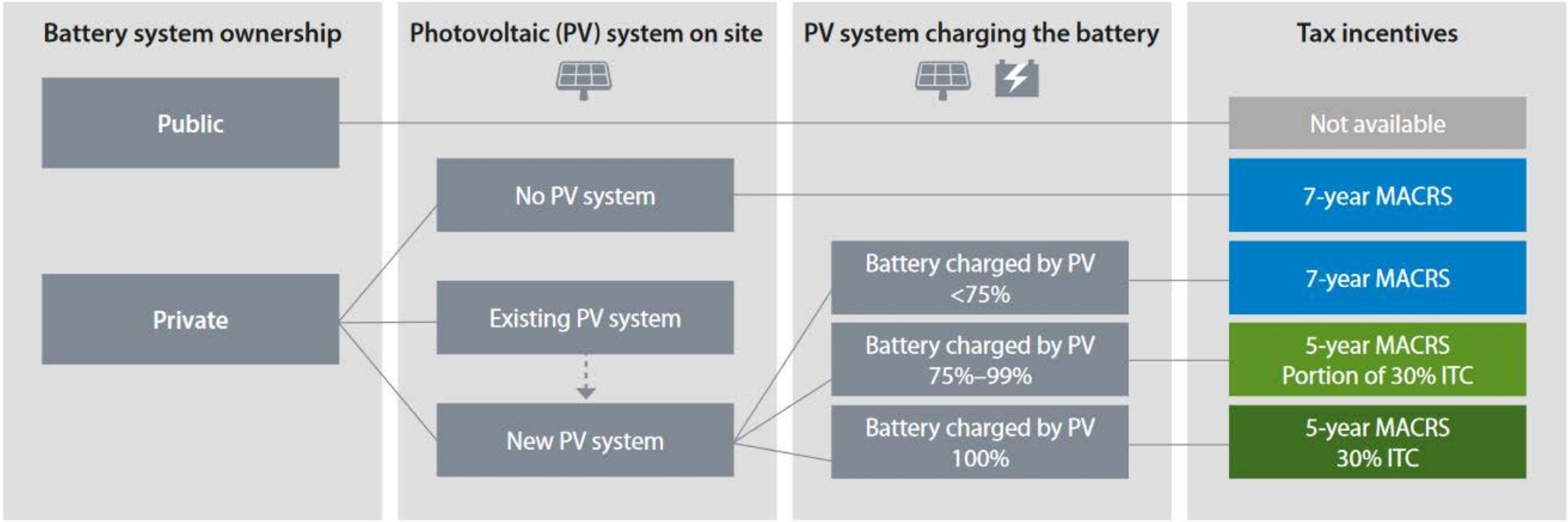


Reported costs from SGIP show range & decline

Battery Energy Storage Market: Commercial Scale, Lithium-ion Projects in the U.S. https://www.nrel.gov/docs/fy17osti/67235.pdf

Incentives for Storage

Federal Investment Tax Credit (ITC) for storage: Lowers the cost of storage when coupled with RE



State incentives for storage: state incentives, like the CA SGIP, can significantly accelerate the deployment of storage

State net metering policies: in states with net metering policies, storage can be less impactful

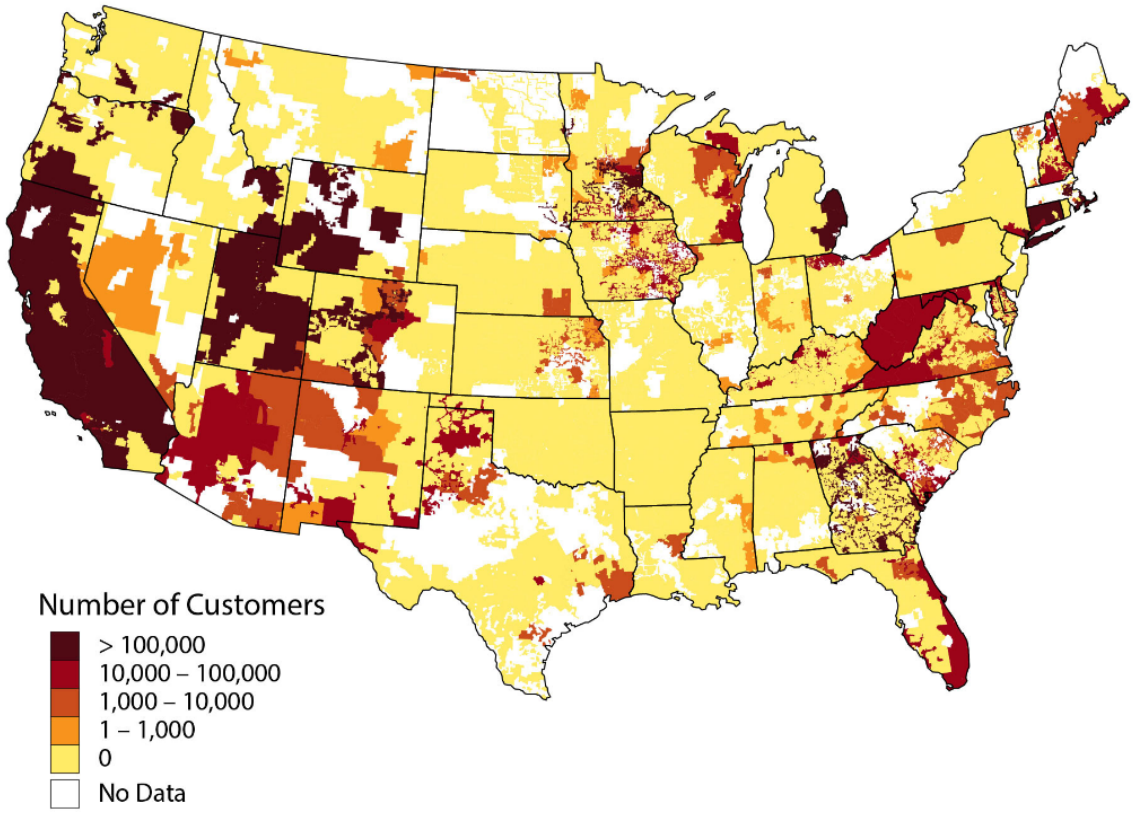
https://www.nrel.gov/docs/fy18osti/70384.pdf

Electricity Bill Structure

Electricity Bill Component	How It's Billed	How Storage Can Help
Energy Charges	Amount of kWh consumed (can vary by time of use [TOU])	Shift usage from high TOU periods to low TOU period
Demand Charges	Based on highest demand (kW) of the month	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

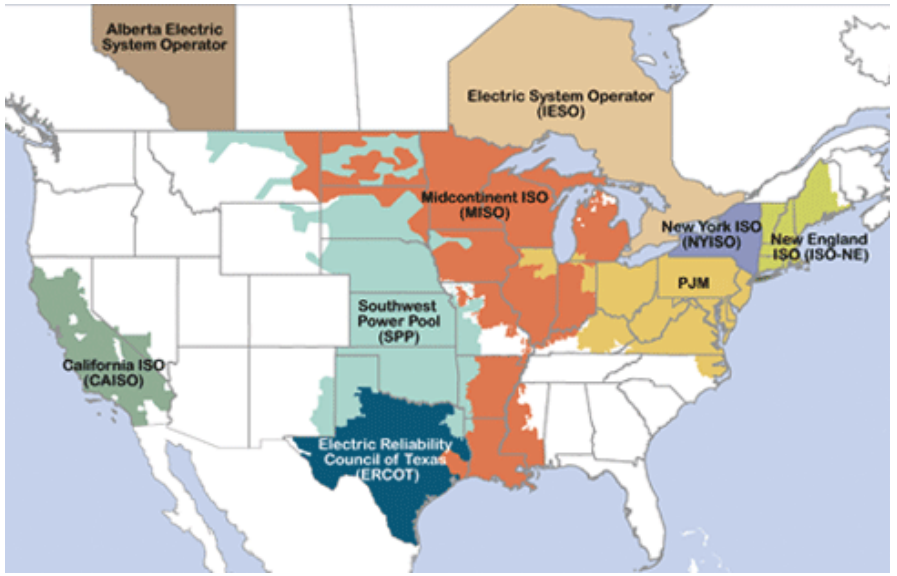


Number of commercial customers who can subscribe to tariffs with demand charges over $15/kW

Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges https://www.nrel.gov/docs/fy17osti/68963.pdf

Demand Response & 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 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 (RTO/ISO) compensate battery systems for delivering energy when dispatched
  - **Frequency Regulation Markets** (regulation-up and regulation-down) compensate battery system owners for responding to automatic control signals

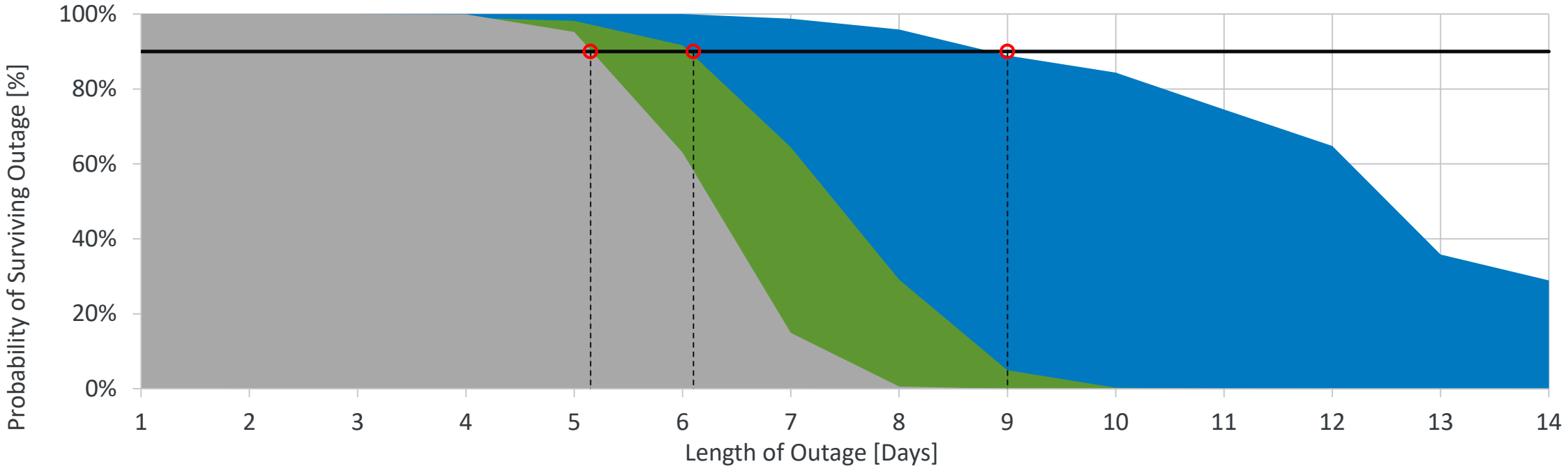


Participation in these programs doesn't always align with utility bill reduction opportunities

Incorporating Storage and RE for Resilience

In some cases, RE + storage can contribute to resilience goals *and* provide cost savings

	Generator	Solar PV	Storage	Lifecycle 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



K. Anderson et al., "Increasing Resiliency Through Renewable Energy Microgrids". SCTE Journal of Energy Management Vol.2 (2) August 2017 pp.22-38. https://www.nrel.gov/docs/fy17osti/69034.pdf

Thank You!

Emma Elgqvist, NREL

emma.elgqvist@nrel.gov

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