Incentivizing Behind-the-Meter Storage
A Jurisdictional Review

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ICC STAKEHOLDER WORKSHOP
DECEMBER 8, 2023

Brattle

In this presentation

1. Does adding storage to rooftop solar add value to the power system?

2. What are important considerations when assessing that value?

3. What are emerging practices for leveraging customer adoption of storage?

The power system benefits of distributed generation

	System Benefits of Rooftop Solar PV
Energy	✓
Emissions	✓
Resilience	✓
Line losses	✓
Generation capacity	✓
Ancillary services	✓
Transmission capacity	TBD
Distribution capacity	TBD

As discussed in prior workshops, rooftop solar PV can provide a range of benefits to the power system

Rooftop solar PV may provide T&D benefits, but depends on system topology, solar PV location and level of penetration, and other factors

The power system benefits of distributed generation

	System Benefits of Rooftop Solar PV	Impact of Adding Storage
Energy	✓	⇧
Emissions	✓	⇧
Resilience	✓	⇧
Line losses	✓	⇧
Generation capacity	✓	⇧
Ancillary services	✓	⇧
Transmission capacity	TBD	⇧
Distribution capacity	TBD	⇧

BTM storage can increase each of the benefits provided by rooftop solar, significantly in some cases

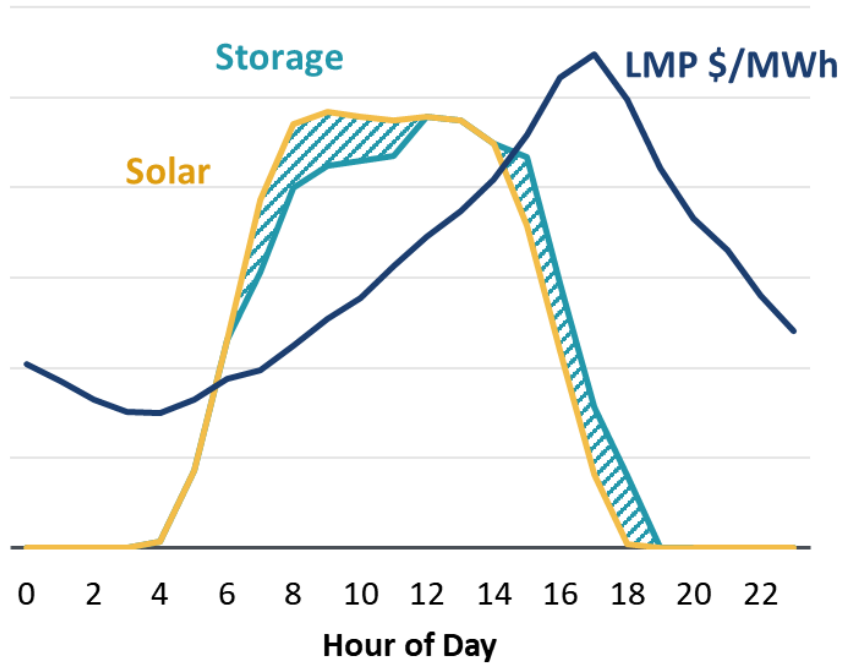
The power system benefits of distributed generation

	System Benefits of Rooftop Solar PV	Impact of Adding Storage
Energy	✓	⇧
Emissions	✓	⇧
Resilience	✓	⇧
Line losses	✓	⇧
Generation capacity	✓	⇧
Ancillary services	✓	⇧
Transmission capacity	TBD	⇧
Distribution capacity	TBD	⇧
Avoided service upgrade		TBD

BTM storage also may enable new benefits not provided by standalone solar PV

Energy value of BTM storage

Rooftop Solar Generation Profile

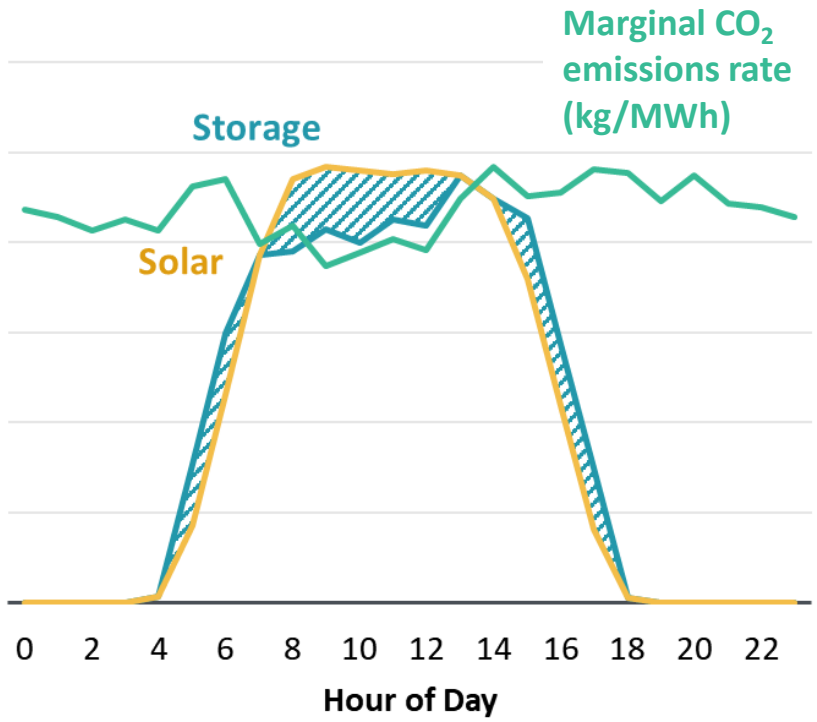


Note: Data is illustrative, but consistent with PJM generation and price trends in Illinois for summer months. Sourced from NREL Cambium, S&P Global Market Intelligence.

- Storage can shift solar output from lower-priced mid-day hours to higher-priced hours of the day.
- Energy value is amplified when dispatching storage relative to PJM energy market price spikes (potentially both day ahead and real-time).
- If DC-coupled, storage can increase the total output of solar PV by avoiding curtailments due to inverter capacity limits (though storage does incur round-trip losses).
- Value estimates need to account for degree of foresight into future market prices, implications of charging from the grid, and ability to co-optimize dispatch in day-ahead and real-time

GHG emissions value of BTM storage

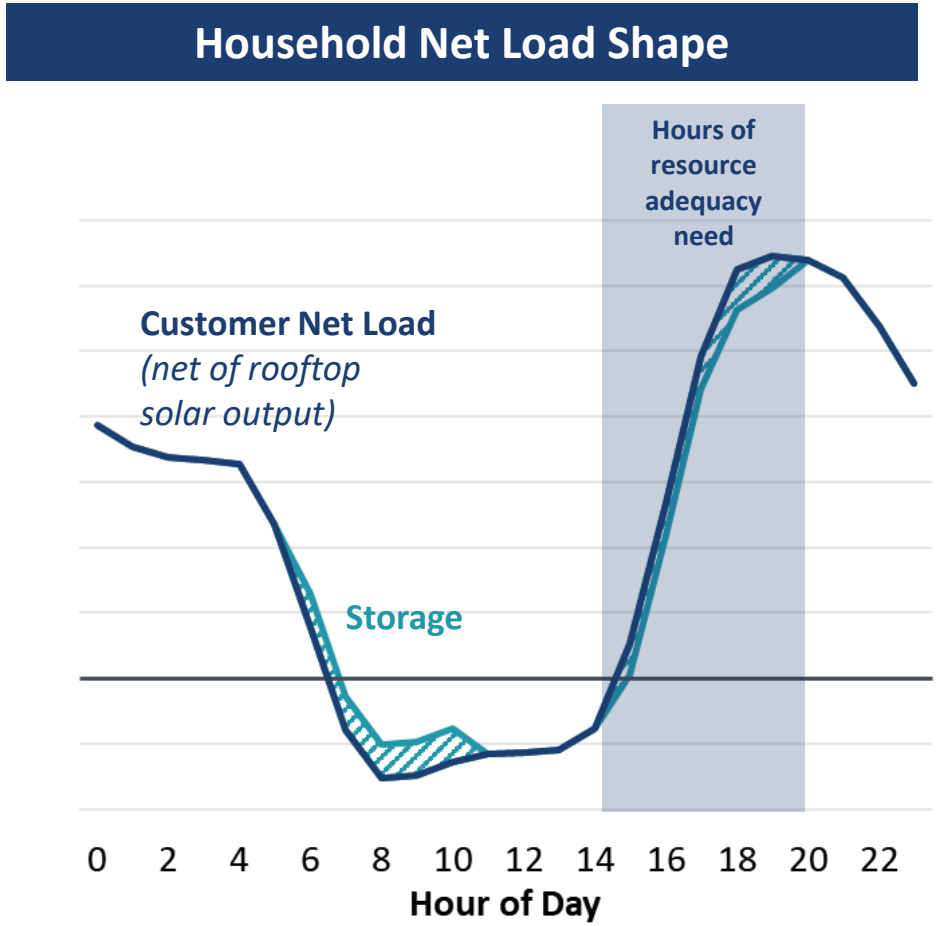
Rooftop Solar Generation Profile



Note: Data is illustrative, but consistent with PJM generation and emissions trends in the Illinois for summer months. Sourced from NREL Cambium.

- Storage can shift output to hours when higher-emitting generators are on the margin.
- If solar curtailments due to excess generation become more prominent in PJM, mid-day charging would increase load and could help to reduce those curtailments.
- High emissions hours do not perfectly correlate to hours with high energy prices, so that tradeoff should be considered when estimating this benefit.

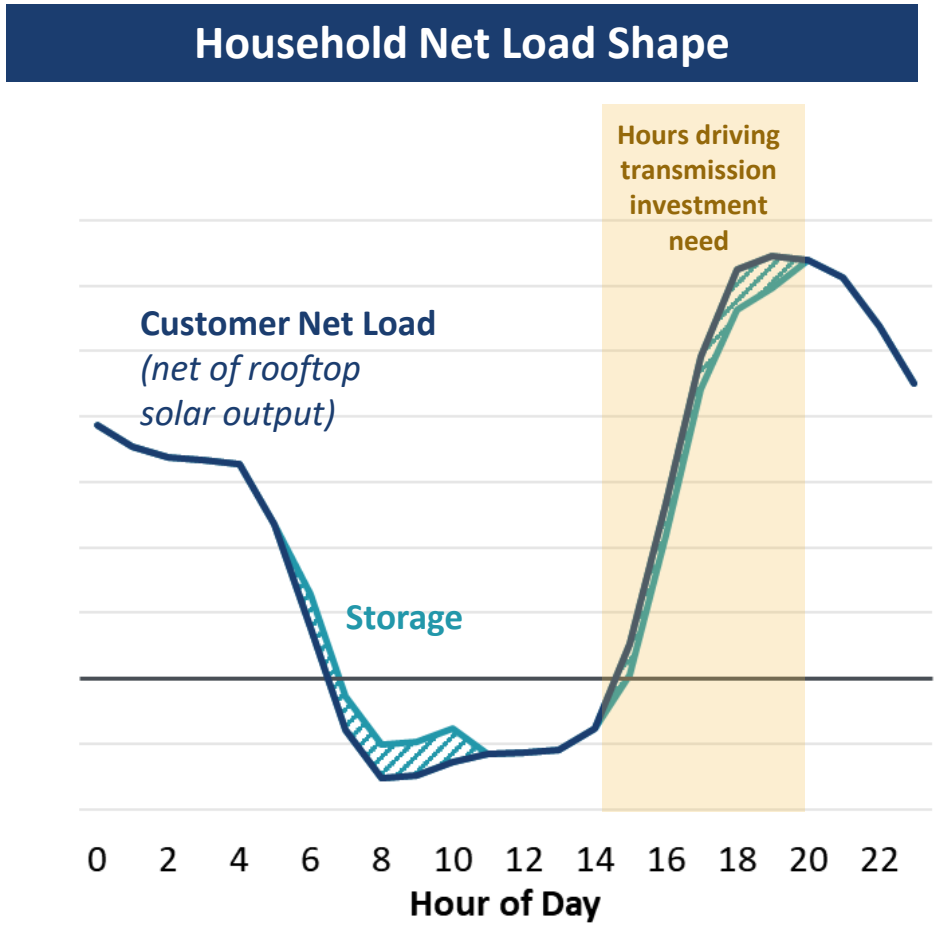
Generation capacity value of BTM storage



Note: Data is illustrative, but consistent with PJM demand trends in the COMED/Illinois region. Sourced from NREL Cambium, NREL ResStock.

- Storage converts solar PV into a dispatchable resource that can be utilized when needed for resource adequacy purposes.
- Capacity value depends on
  - Storage duration (kWh:kW ratio)
  - Frequency and duration of PJM capacity need
  - Market participation rules or method for determining utility capacity obligation

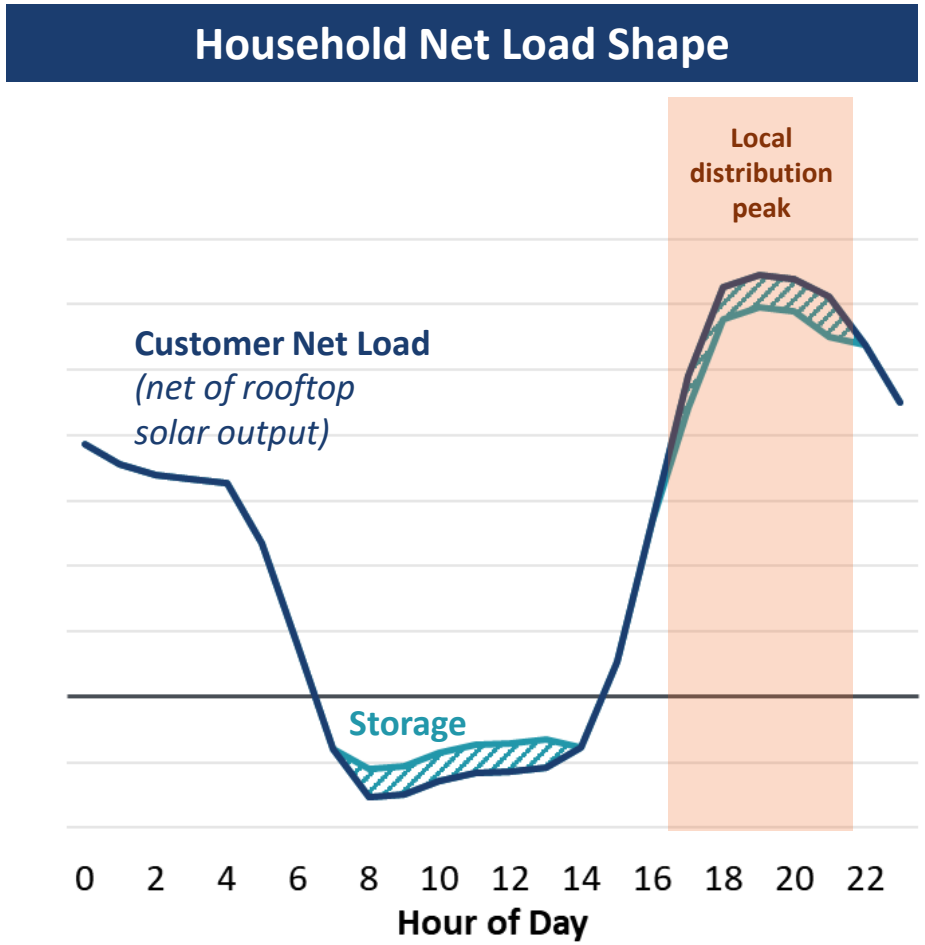
Transmission capacity value of BTM storage



Note: Data is illustrative, but consistent with PJM demand trends in the COMED/Illinois region. Sourced from NREL Cambium, NREL ResStock.

- If discharged during system peak hours, BTM storage may reduce the long-run need for peak-driven local transmission capacity investment.
- BTM storage adoption will need to reach significant levels or otherwise be coupled with other demand-side resources to reach the scale to impact transmission investment decisions.
- Transmission system expansion still will be needed for interregional connections and to connect remotely located utility-scale renewables to load.

Distribution capacity value of BTM storage



Note: Data is illustrative, but consistent with PJM demand trends in the COMED/Illinois region. Sourced from NREL Cambium, NREL ResStock.

- Similar to potential transmission capacity benefits, BTM storage could be discharged to reduce local distribution peaks and defer upgrades
- Optimizing value requires geographically targeted deployment of BTM batteries in relatively high concentrations, with a focus on avoiding specific distribution projects with applicable characteristics
- These opportunities have been limited historically, but will increase with electrification-driven load growth and when paired with other emerging flexible home energy technologies

Other power system value of BTM storage

Resilience

- BTM batteries can store daytime solar output to provide 24/7 backup generation to critical circuits during an outage
- Value depends on customer value of lost load (VOLL), duration and frequency of outages, sizing of battery relative to customer usage, and other factors.

Line losses

- BTM storage can charge during times with lower line losses and serve local load during times with higher losses
- But batteries must overcome round-trip energy losses when cycling

Ancillary services

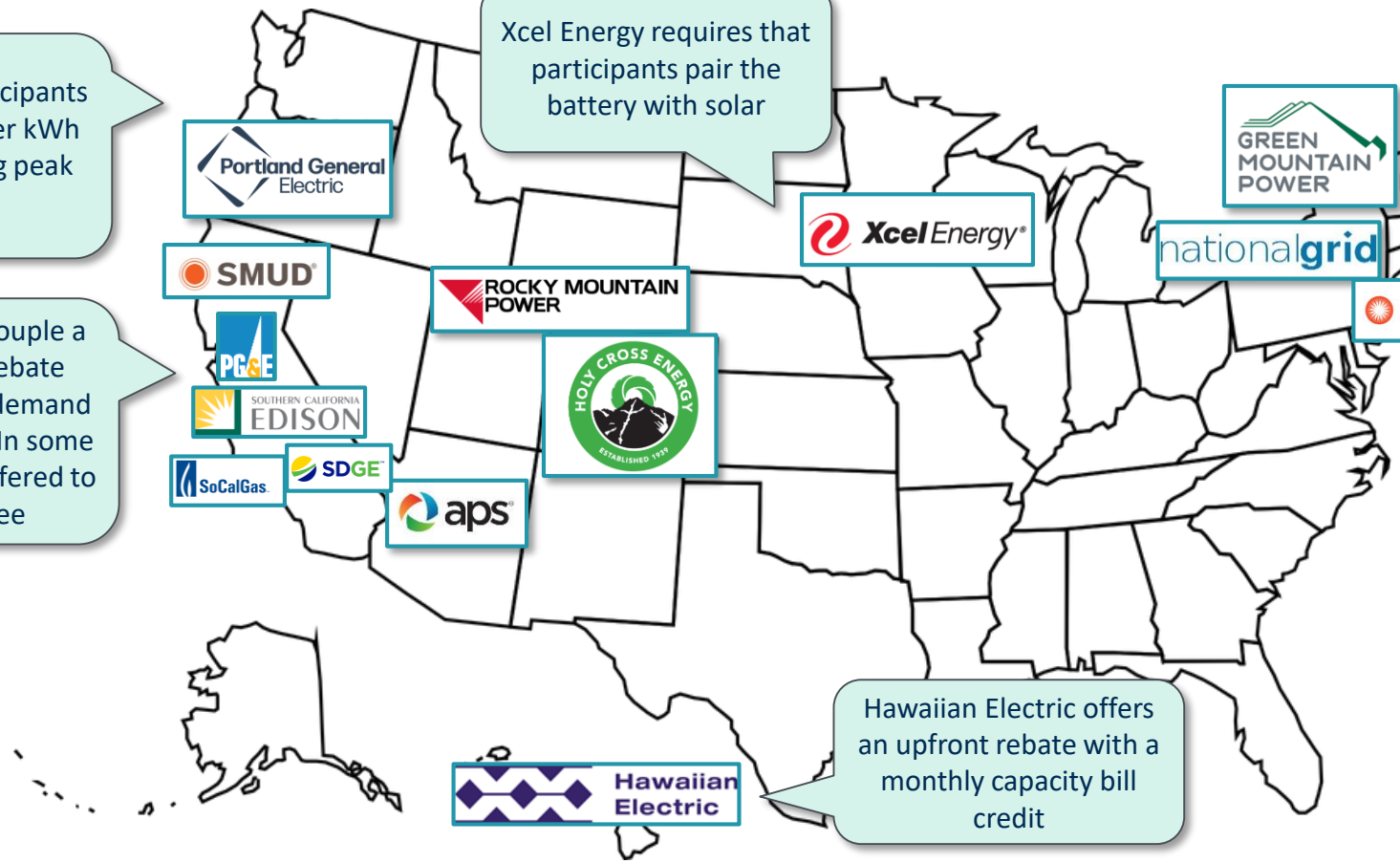
- BTM storage can provide a range of grid balancing and reliability services

Avoided service upgrade

- By absorbing solar exports and serving home charging load, BTM storage could serve as a buffer that limits the need for a service upgrades to an individual home

Utility BTM storage programs

We surveyed 15 utility BTM storage programs to understand how participants are compensated for providing grid services



PGE provides participants with bill credits per kWh discharged during peak events

Xcel Energy requires that participants pair the battery with solar

Green Mountain Power is a pioneer in home storage programs, offering a utility-owned battery at a discounted lease, as well as a bring-your-own battery option

The California IOUs couple a statewide battery rebate program (SGIP) with demand response incentives. In some cases, batteries are offered to customers for free

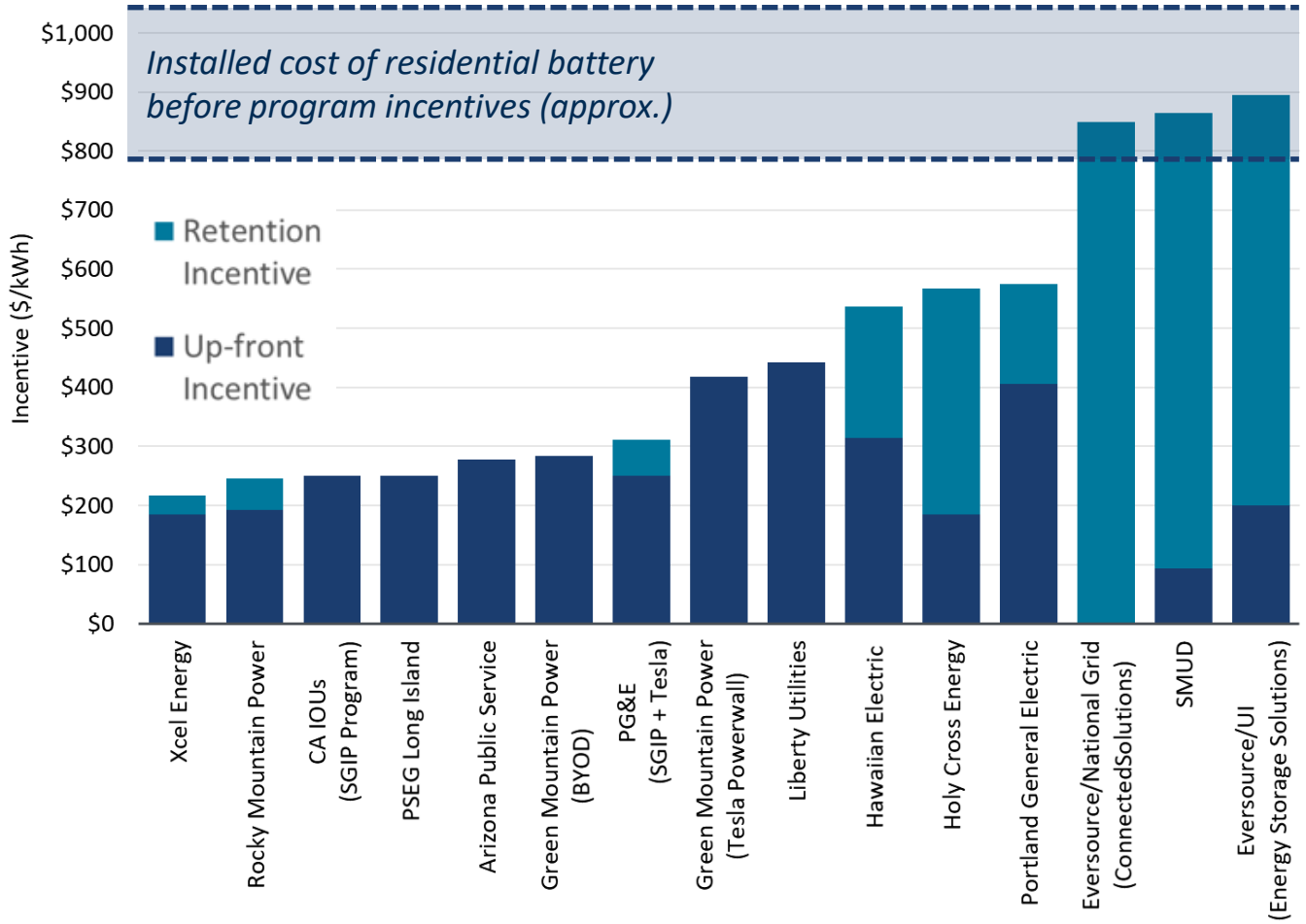
Eversource and United Illuminating offer both "active" and "passive" dispatch options to participants

Hawaiian Electric offers an upfront rebate with a monthly capacity bill credit

Incentives vary significantly in utility BTM storage programs

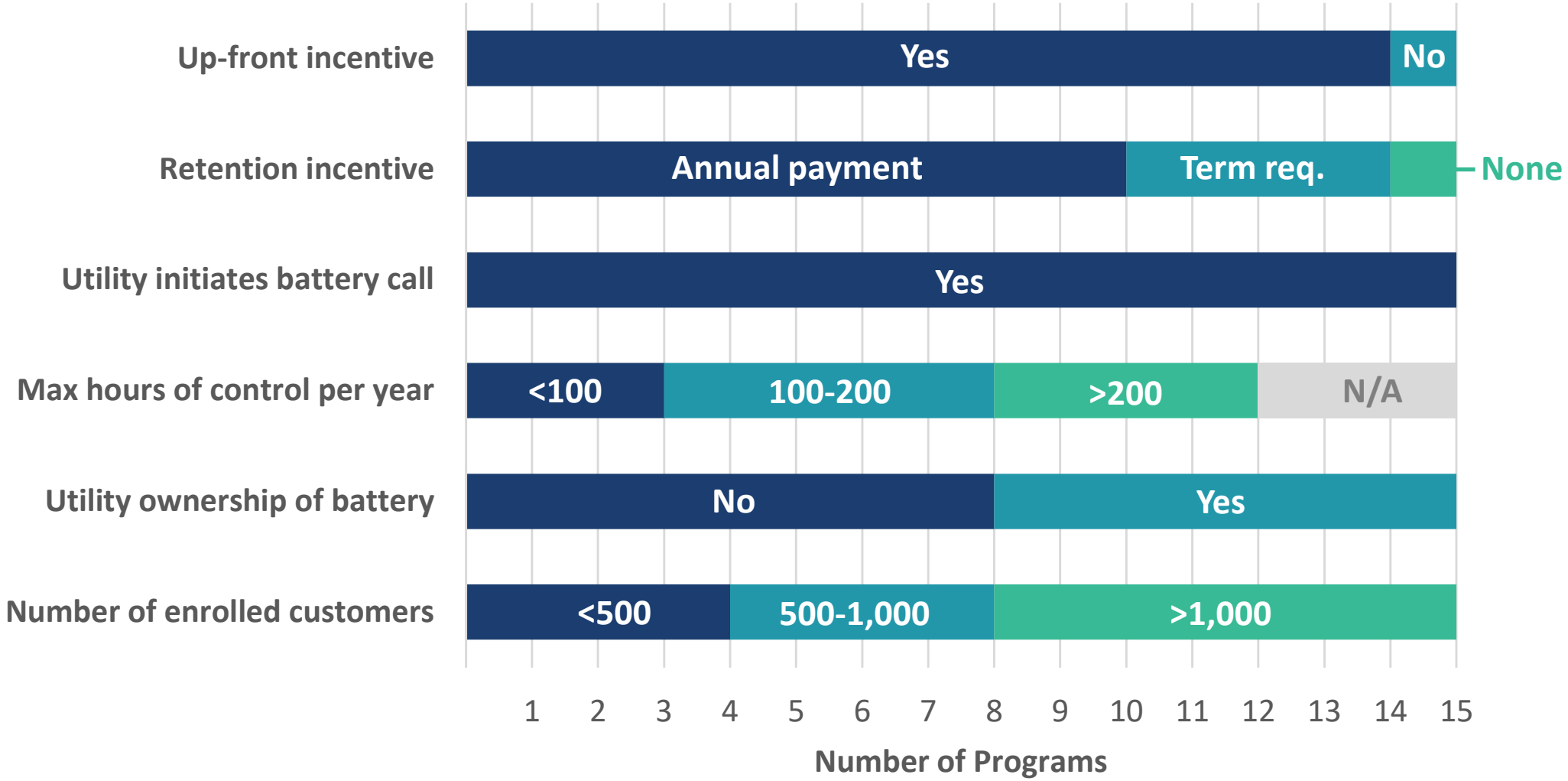
All-in Participant Incentive

Present value over assumed 10 years of participation



Notes: Assumed participant has two Tesla Powerwall batteries (10 kW / 27 kWh) unless otherwise specified in program. Assumed 10 years of participation where applicable. PGE up-front incentive is only available to customers in specific locations. When retention incentives are a function of discharge, we assume the maximum amount of discharge available. Assumed discount rate for present value calculation is based on discount rate implied in Green Mountain Power lease (i.e., difference between up-front versus monthly payment plan offerings). Estimates of incentives in leasing programs based on pre-tax incentive battery cost without installation. Shown range of costs of installed residential battery based on Tesla Powerwall with and without tax incentives.

Characteristics of 15 utility BTM battery programs



Note: For three of the programs, the reported number of enrolled customers is the program participation cap.

Takeaways

BTM storage can add significant value when attached to rooftop solar PV.

Emerging programs operationalize the value of BTM storage and share the resulting benefits with participants.

An effective incentive structure typically consists of two parts:

- **Up-front incentive** to reduce the cost of the technology to the consumer and encourage adoption. Can be structured as rebate or discounted lease of the battery.
- **Retention incentive** to "pay for performance" and ensure that customers remain enrolled and engaged. Can be structured an annual payment or a required term for earning the full up-front incentive.

The level of the incentive varies significantly by jurisdiction. Further analysis is needed to establish a BTM storage incentive in Illinois.