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ENERGY RESEARCH

Pacific Northwest Storage Roadmap

Prepared for Renewable Northwest

August 2026

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PNW grid transition is increasing need for core services that storage provides: capacity, energy shifting, and ancillary services

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Impact of PNW grid transition on need for storage-provided services

		Effect on requirement for storage services		
		Capacity	Energy shifting	Ancillary services
PNW grid transition drivers	**Load growth** *Driven by population growth, electrification, data center deployment*	**Increased need for firm capacity** given load growth's impact on peak load	**Increased need to shift energy from off-peak to peak periods** as load shapes evolve	**Increased procurement** of ancillary services is necessary as the grid scales, exacerbated by volatile loads like data centers for AI training
	Shrinking thermal fleet *Driven by aging fleet, Clean Energy Standards*	**Reduces supply of firm capacity**	**Increases need for flexible resources** to replace lost load-following capabilities	**Reduces supply of ancillary services** from thermal units, increasing need for alternative providers
	Renewable deployment *Support for variable renewables capacity under CETA, HB2021*	**Diminished security of supply** despite rise in nameplate capacity addition	**Increased need to shift energy** from periods of excess renewable generation to periods of low output	**Increased need for ramping support and frequency regulation** driven by variable generation
	Transmission constraints *Driven by BPA transmission queue delays*	**Reduction in firm capacity** due to IXQ[1] delays slowing pace of new additions to replace retirements	**Increases need to shift energy across** constrained periods to mitigate congestion and curtailment	**Limits access to system-wide balancing resources,** increasing need for local ancillary services

1) IXQ or interconnection queue refers to the pipeline of energy projects awaiting approval to connect to the grid

Sources: Aurora Energy Research

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Executive Summary

The Pacific Northwest's power system is entering a period of rapid transition

- After decades of flat demand and hydro-driven stability, **load growth is accelerating** just as the **thermal fleet ages out**
- The pace of renewable deployment is constrained by the transmission system, particularly by BPA's **interconnection queue delays**

Storage solves all three sides of the energy trilemma

- This shift brings the energy trilemma to the forefront: how to keep the system **reliable, affordable, and aligned with clean energy goals** while it also **expands at an unprecedented rate**
- **Storage is uniquely positioned to support all three objectives** in the Pacific Northwest. Among its many grid benefits, storage can be **deployed faster than thermal or hydro**. It can **shift low-cost renewable generation** to when it's needed. Storage can also **ease grid congestion** and help avoid costly transmission upgrades, and it can deliver ancillary services more cheaply than thermal plants
- Together, these capabilities **can meaningfully reduce system costs** for ratepayers, as utilities face pressure to expand the grid without triggering rate increases

Current markets and planning frameworks undervalue storage

- New regional day-ahead markets bring **more transparent energy and capacity pricing**, but still **lack an ancillary services** market, leaving a significant portion of storage's value unpriced
- Storage deployment will continue to be shaped more by utility IRPs than by market signals, and current planning practices remain centered on **capacity mandates that miss storage's full capabilities**
- Outdated **interconnection processes systematically undervalue storage** and lock in decades of thermal dependence

Targeted reforms can unlock storage at scale

- Closing this value gap calls for reform on three fronts -
  - **Updating planning frameworks to recognize storage's full value**: IRP reform, performance-based ratemaking, revised ELCC methodology
  - **Creating new revenue streams that reflect it**: ancillary services markets, stronger resource adequacy frameworks
  - **Removing development bottlenecks**: interconnection queue reform, fewer transmission rights barriers, streamlined siting
- Together, these reforms would **enable the Pacific Northwest to deploy storage at scale** and take a step toward resolving its energy trilemma

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Storage provides three core services: capacity, energy shifting, and ancillary services

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Response time: Years → Hours → Minutes → Seconds → Delivery

Service	Capacity	Energy shifting	Ancillary services
Overview	▪ Provides firm, dispatchable capacity to meet peak demand and reliability needs ▪ Can be reliably dispatched during system stress events, reducing reliance on peaking generation ▪ Contributes to resource adequacy by delivering energy during critical hours, even if derated ▪ Enables flexible, scalable capacity additions without the siting and fuel constraints of thermal resources	▪ Stores excess low-cost or surplus generation (e.g., midday renewables) and discharges during high-demand periods ▪ Reduces curtailment of renewable energy and improves overall system utilization ▪ Supports load balancing across hours and intra-day periods, smoothing net load variability	▪ Provides dispatchable balancing energy to manage forecast errors and intra-day variability ▪ Maintains operational grid requirements and provides fast-acting power injection to arrest changes in system frequency, through sub-second to minutes long response

Other ancillary services and benefits

- Can also provide ancillary services to maintain grid operability such as inertia
- Supports distribution-level reliability and can be used as a transmission asset to defer upgrades
- Integrates with grid programs (e.g., DER[1] aggregation, VPPs[2]) to deliver system-wide value

1) **Distributed Energy Resource** 2) Virtual power plant

Sources: Aurora Energy Research

Ongoing transition in the PNW increases the need for the services storage provides

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Impact of PNW grid transition on need for storage services

		Effect on requirement for storage services		
		Capacity	Energy shifting	Ancillary services
PNW grid transition drivers	**Load growth** *Driven by population growth, electrification, data center deployment*	**Increased need for firm capacity** given load growth's impact on peak load	**Increased need to shift energy from off-peak to peak periods** as load shapes evolve	**Increased procurement** of ancillary services is necessary as the grid scales, exacerbated by volatile loads like data centers for AI training
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Sources: Aurora Energy Research

Capacity | Faster to deploy than thermal or hydro, storage is well-positioned to meet the PNW's near-term capacity needs

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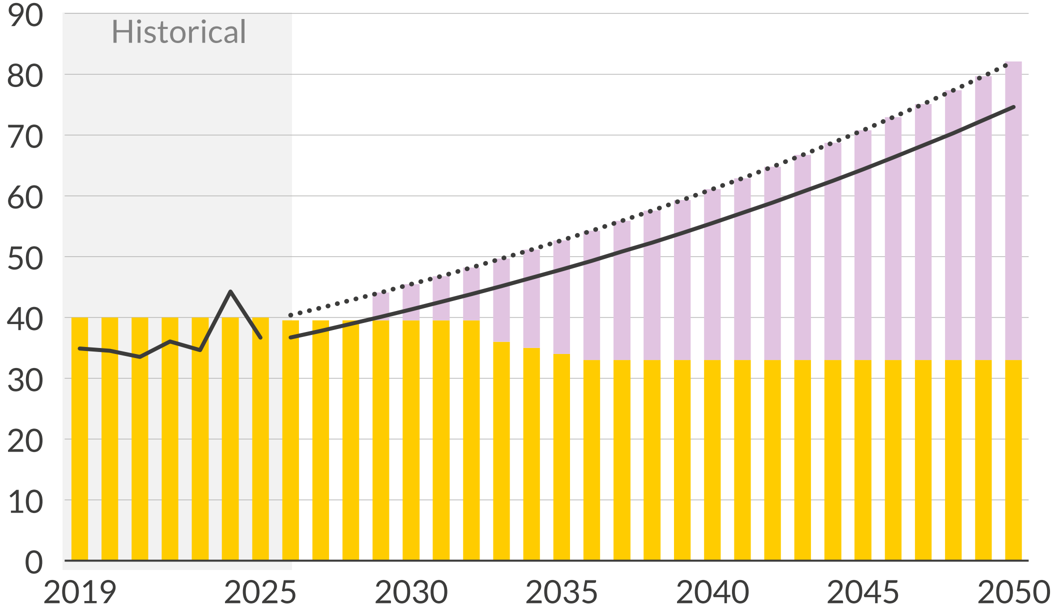
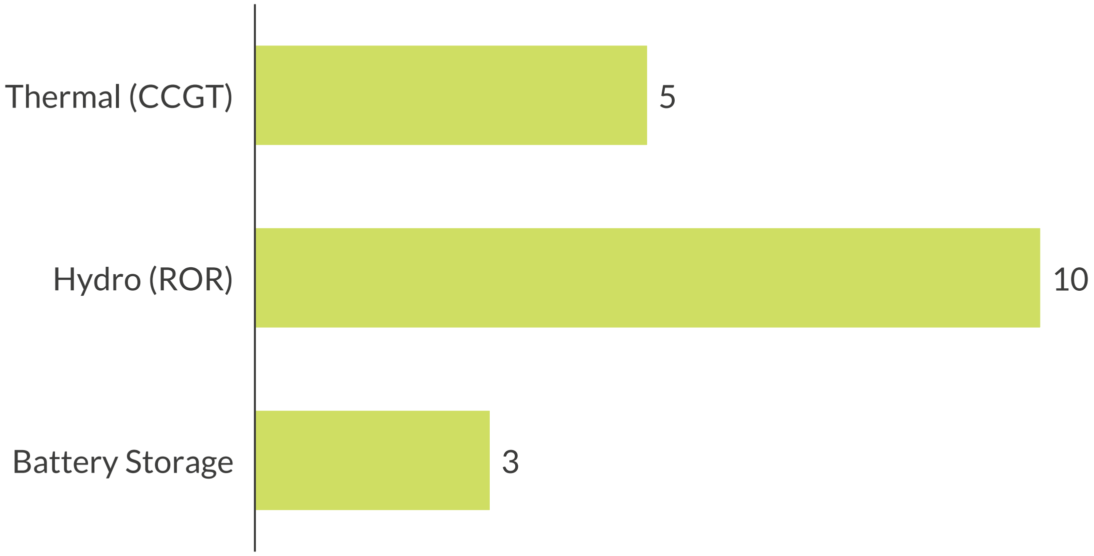
PNW peak total demand[1]
GW



Average construction time [3]
Years



- Sustained load growth is anticipated for the first time in decades, driven by electrification, economic development, population growth, and data centers
- Load growth and thermal retirements are tightening Resource Adequacy in the PNW, creating a growing need for firm capacity to come online quickly
- Storage can provide firm, dispatchable capacity to meet peak demand and reliability needs

- Storage can be deployed faster than thermal or hydro resources because projects are modular, require less infrastructure, face fewer permitting hurdles, and have shorter construction timelines
- This speed makes storage well-suited to address the PNW's near-term capacity gap amid rapid load growth

Peak total demand[2] ···· Planning reserve margin ■ Resource Adequacy shortfall (illustrative) ■ Existing resources (illustrative)

1) Net (less the demand met by behind-the-meter generation). Forecasts primarily based on utility/balancing authority Integrated Resource Plans 2) Forecast applies a 2.6% CAGR to the 2026 base value, consistent with the PNUCC 2025 Northwest Regional Forecast winter peak growth rate used in E3's PNW Resource Adequacy study (April 2026). 3) An estimation based on IEA data

Sources: Aurora Energy Research, NREL, IEA

Capacity | Given its relatively high accreditation among non-emitters, storage can support reliability and clean energy goals

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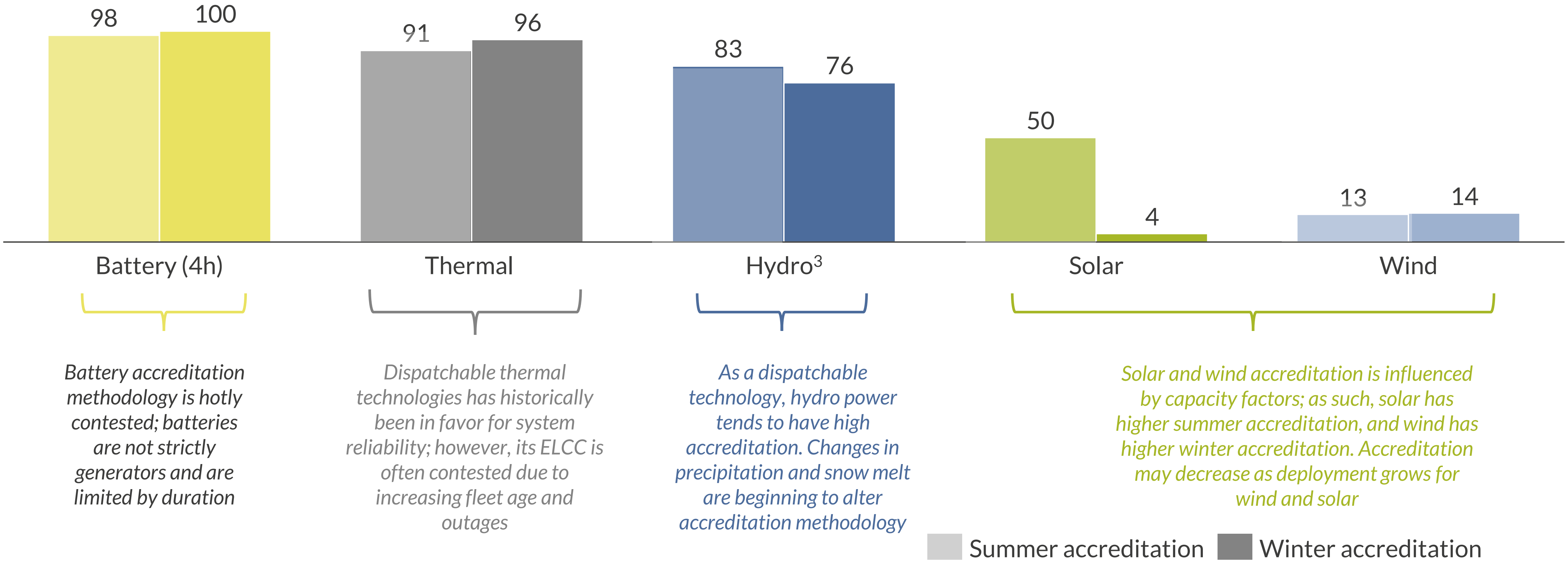
Not all MWs are created equal from a reliability perspective; resource accreditation attempts to compare MWs like-for-like by considering a technology's reliability, thus discounting the capacity a project can contribute to a bilateral contract's capacity obligation. The measure of reliability varies across BAs, though the following criteria may be considered: dispatchability, production levels during peak load hours, and risk of outages. This "de-rating" creates a difference between a project's nameplate capacity (maximum production potential) and accredited capacity (nameplate capacity * accreditation).

Western Resource Adequacy Program (WRAP) ELCC[1,2] %



Battery accreditation methodology is hotly contested; batteries are not strictly generators and are limited by duration

Dispatchable thermal technologies has historically been in favor for system reliability; however, its ELCC is often contested due to increasing fleet age and outages

As a dispatchable technology, hydro power tends to have high accreditation. Changes in precipitation and snow melt are beginning to alter accreditation methodology

Solar and wind accreditation is influenced by capacity factors; as such, solar has higher summer accreditation, and wind has higher winter accreditation. Accreditation may decrease as deployment grows for wind and solar

1) Effective load carrying capacity 2) The ELCC values illustrated is winter ELCC for the MIDC region in WRAP accreditation area 3) WRAP metrics for winter 2026-2027 and Metrics for Summer 2027 is used to calculate hydro ELCC that's averaged across the summer and winter months

Sources: Aurora Energy Research, WPP, SPP

Capacity | Declining CAPEX, ITC, and elevated gas turbine prices make storage an increasingly cost-competitive capacity option

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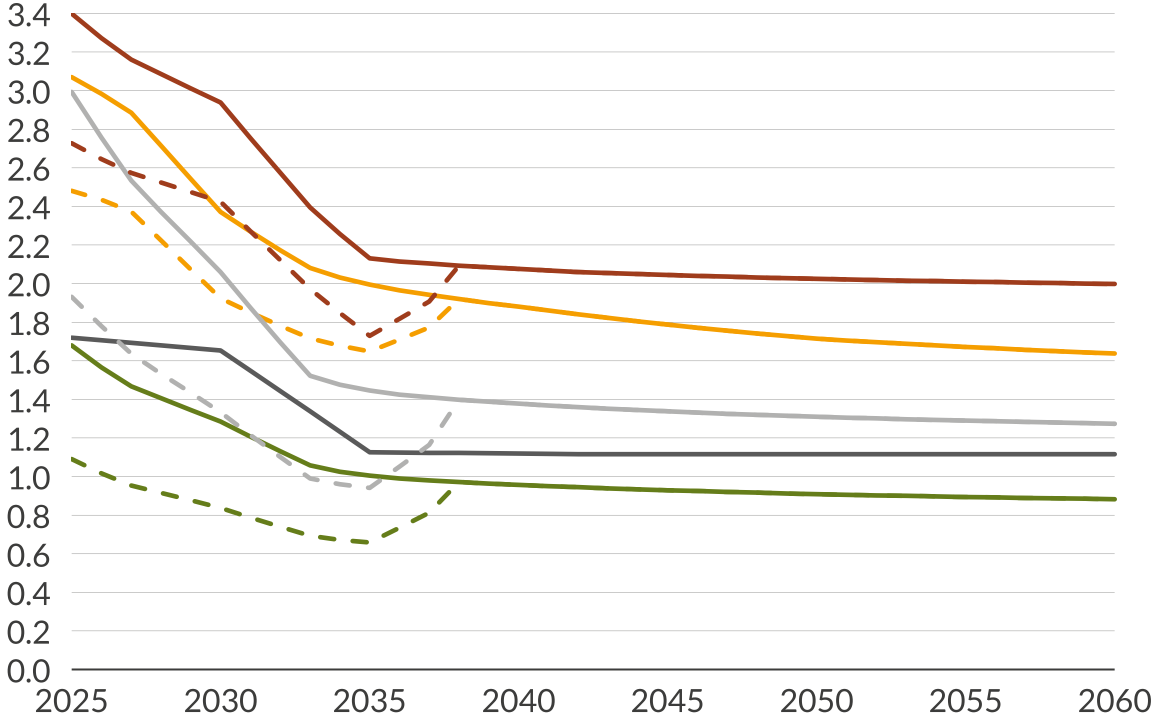
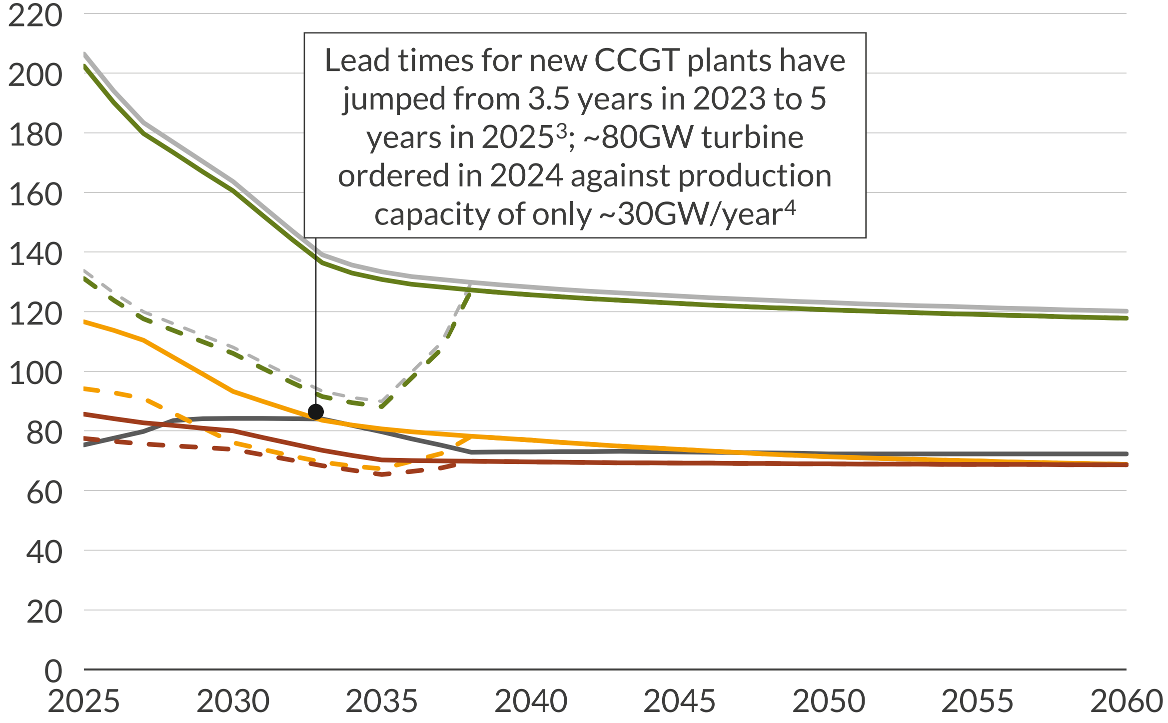
CAPEX trajectory, PNW
M$/MW, real 2024



LCOE[1] trajectory, PNW
$/MWh, real 2024



- BESS costs have declined sharply due to falling cell prices
- Storage is still eligible for the Investment Tax Credit, which steps down incrementally through 2032 before phasing out

- Uptick in the LCOE for Gas CCGT plants is driven by recent turbine shortage and backlog driving up CAPEX
- LCOE for utility-scale solar paired with storage is competitive with or lower than that of gas CCGT

Gas CCGT | 4h BESS + PV[2] | 8h BESS | 4h BESS | BESS + CCGT | With PTC

1) The LCOE considers the PTC and ITC tax credit phase out defined by terms in the OBBBA 2) Assumes 20-year technical lifetime for both PV and BESS 3.) Assumes 20-year technical lifetime 3) BloombergNEF 4) IEEFA Asia

Sources: Aurora Energy Research, Bloomberg, IEEFA

Energy | As more renewables come online, storage can provide energy shifting to enable their integration

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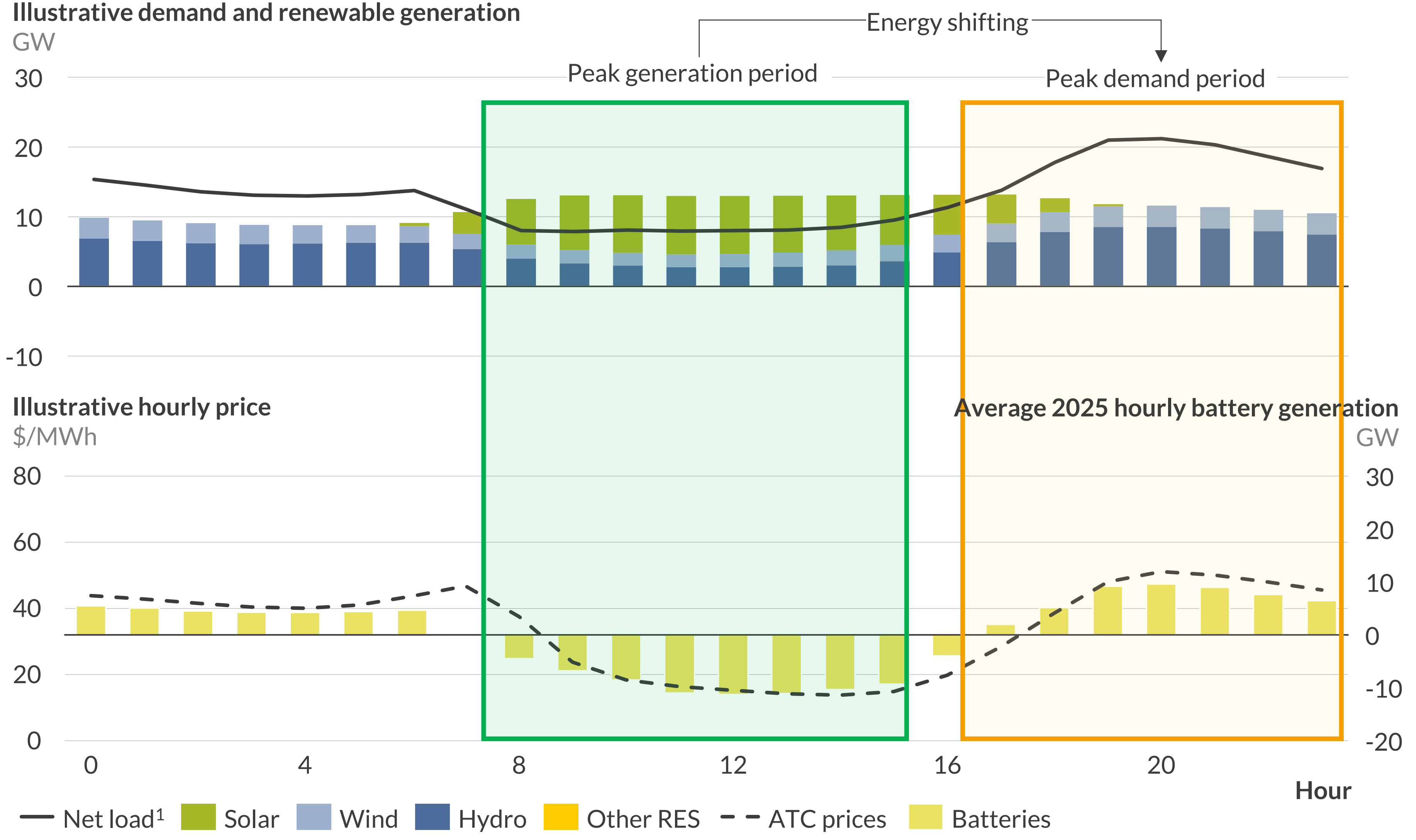

1) Net load = Demand – Installed solar and wind capacity – Imports.

Sources: Aurora Energy Research, CAISO

- Oregon's HB2021 and Washington's CETA mandate full electricity decarbonization by 2040 and 2045 respectively with carbon neutrality in 2030
- These targets drive increased deployment of variable renewable generation, creating a need to shift energy from periods of excess supply to periods of high demand and low output
- Battery storage enables this shift by absorbing excess low marginal cost renewable generation and dispatching when needed
- In regionalized markets, electricity prices will reflect supply-demand conditions, creating arbitrage opportunities that incentivize storage to charge during oversupply and discharge during scarcity

Energy | Storage's energy shifting capabilities can also ease PNW transmission congestion, lowering overall system cost

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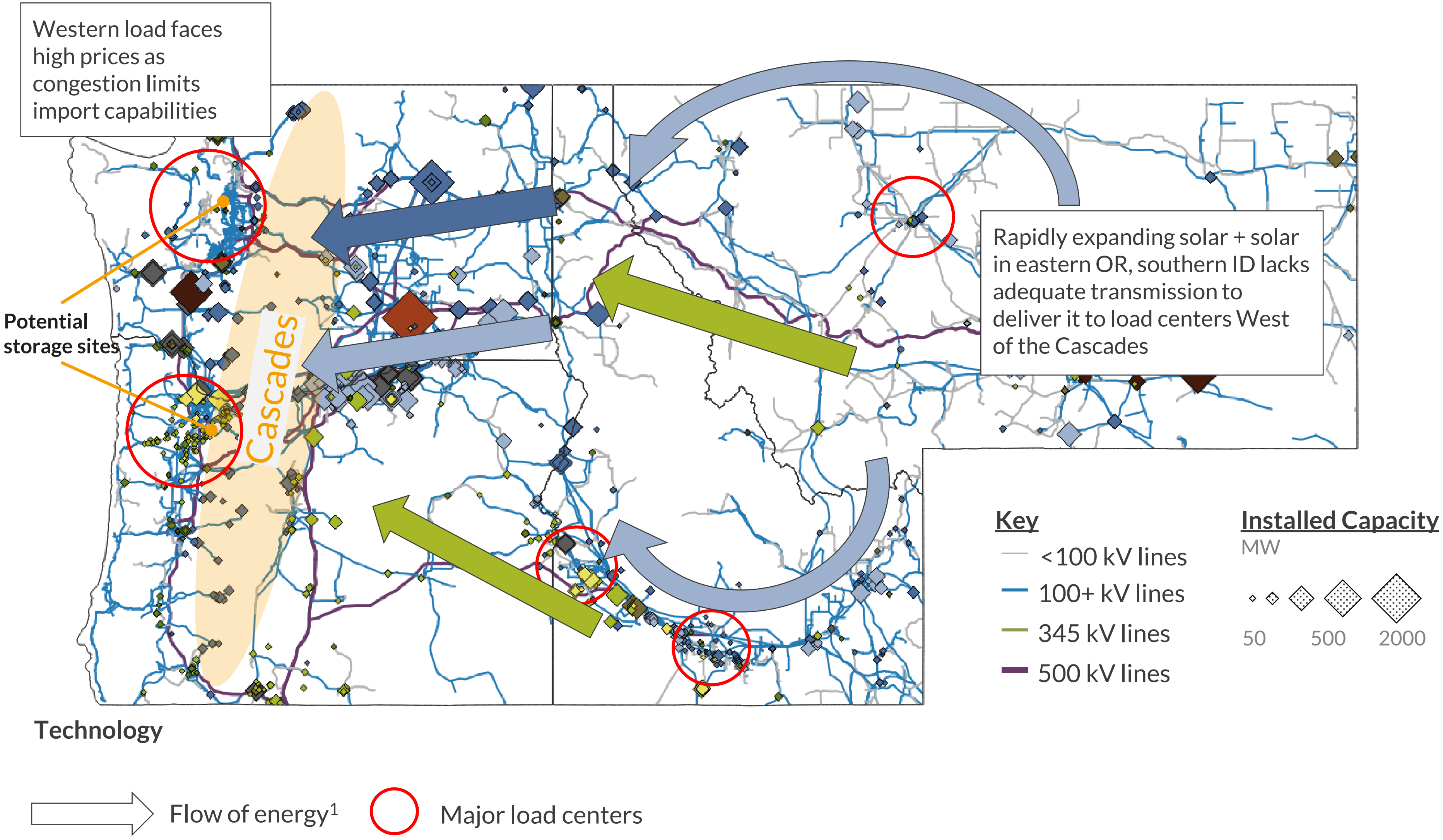

- Cascades transmission constraints limit the flow of low-cost eastern generation to high-demand western load centers, creating persistent congestion
- This results in periods of excess low-cost supply in the east and scarcity in the west, increasing the need to shift energy across constrained interfaces
- Siting storage close to the constraint allows it to directly absorb excess generation or serve nearby load, reducing power flows across the bottleneck and alleviating congestion
- As nodal pricing is introduced under EDAM and Markets+, these congestion-driven price signals will become more explicit, further incentivizing storage to operate in ways that relieve transmission constraints

1) For illustrative purpose

Sources: Aurora Energy Research, EIA, WECC, Northwest Power and Conservation Council

Energy | By dispatching during peak hours, storage can clip the high-cost end of the merit order, lowering system marginal cost of energy

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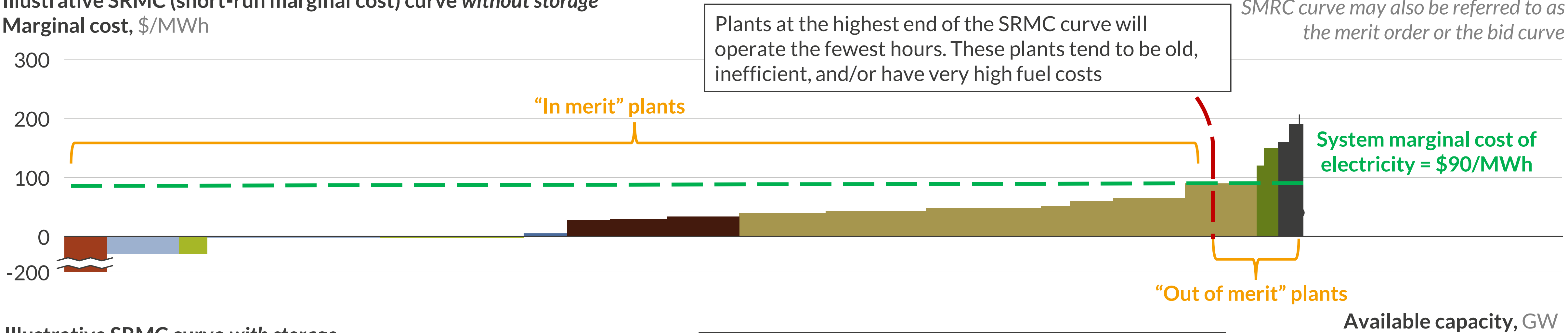
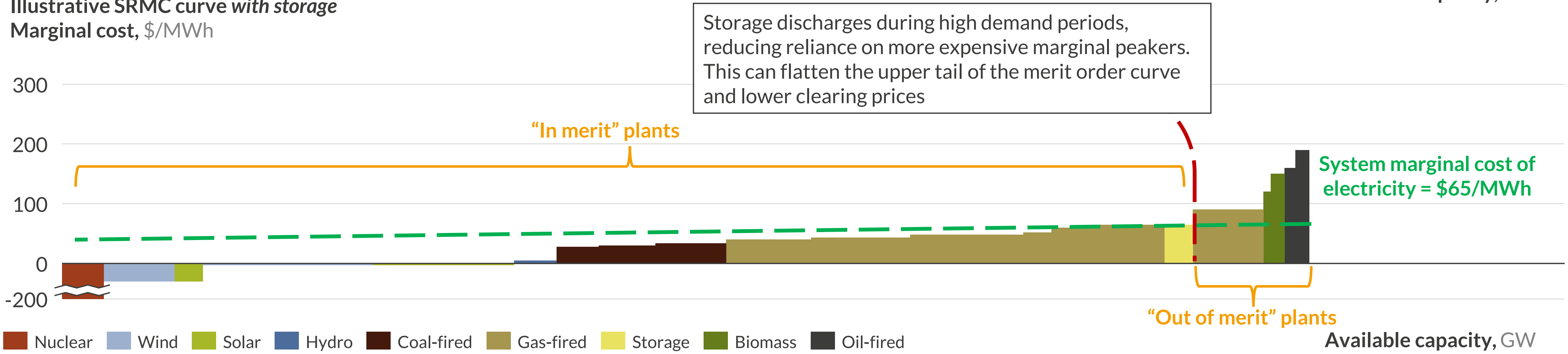
SMRC curve may also be referred to as the merit order or the bid curve

Illustrative SRMC (short-run marginal cost) curve *without storage*
Marginal cost, $/MWh



Illustrative SRMC curve *with storage*
Marginal cost, $/MWh



Sources: Aurora Energy Research

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Ancillary services | Storage is well suited to meet growing need for ancillary services in PNW at lower cost than thermal generators

Ancillary services technologies and their characteristics

		Pumped Storage	Lithium-ion battery storage	Reciprocating Engines	CCGT
Characteristics	CAPEX, $/kW	2,700-3,400	740-1,680[2]	1,300-1,400	1000-1500
	Efficiency, %	70 - 80	85 - 90	35 – 45	55-60
	Response time	≈ 60 secs	≈ 0.001 secs	≈ 5 minutes	≈ 10 minutes
	Avg. construction time	10	3	5	5
Ancillary Services	Frequency (Response)	◕	●	◑	◑
	Inertia (Stability)[1]	●	◕	●	●
	Energy Balancing (Reserve)	◑	◑	◕	●
	Congestion and constraint resolution	◔	◕	◕	◑
	Voltage	◕	◕	●	◕
	Restoration / Black start	◑	◑	●	●
	Cost to provide AS	↓	↓	↑	↑

↓ Low cost ↑ High cost ● More applicable ○ Less applicable

- Ancillary service requirements in PNW will increase as renewable penetration and electricity demand grow and thermal resources retire
- Battery storage is well positioned to meet these needs due to its rapid response capabilities, operational flexibility, and relatively low lead-time compared to hydro and thermal
- Because batteries provide ancillary services without fuel consumption, they can often deliver these services more cost-effectively than thermal generators

Sources: Aurora Energy Research

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Market and planning frameworks that undervalue storage are the primary barriers to its deployment

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Storage deployment barriers

Type	Barrier
Market design	1 **Limited monetization of storage value.** Regionalized markets don't include ancillary service markets, which leaves a major portion of storage value unquantified
Planning frameworks	2 **Utility procurement centered on simple capacity mandates and cost-of-service incentives.** Capacity mandates miss storage contributions to congestion relief, transmission and distribution upgrade deferrals, etc. Furthermore, ELCC[1] assumptions often result in conservative capacity accreditation to storage. Cost-of-service incentives bias investment toward capital-intensive assets and fail to compensate grid services
	3 **Outdated IXQ planning processes.** Even where storage is selected in utility planning, IXQ planning processes in the PNW are not fit for rapid renewable and storage deployment, constraining market access and dampening the wholesale volatility and ancillary service demand that would otherwise emerge with increased renewable buildout
	4 **Planning frameworks that exclude clean energy goals.** When planning frameworks exclude clean energy goals, they are more likely to select new thermal assets that can displace storage for decades

1) Effective Load Carrying Capacity

Sources: Aurora Energy Research

1 Regionalized markets still fail to quantify the ancillary services value that storage provides

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Typical commercialization frameworks for front-of-meter storage in the PNW before and after the launch of regionalized Day-ahead Markets

	Pre-regionalization	*Regionalized Day-ahead Markets*	
Energy products	**Non-ISO**	**EDAM**	**Markets+**
Energy	Bundled PPA	Day-ahead & real-time market	Day-ahead & real-time market
Capacity	Bundled PPA	Voluntary RA program[1]	WRAP
Ancillary services[2]	No ancillary service market	**No ancillary service market**	**No ancillary service market**

- While energy and capacity markets are a step in the right direction for the compensation of storage, the lack of ancillary services markets is a key barrier for storage deployment
- Without transparent ancillary services markets, many storage benefits remain uncompensated and difficult to quantify
- Profitability of ancillary services has been a key driver of storage deployment in other markets, where ancillaries can account for over half of storage project revenues. For example, at the outset of battery deployment at scale in CAISO in 2019-2020, ancillary services made up around 60-90% of battery revenues

Key revenue streams impacted by regionalization

Limited near-term liquidity in regionalized markets maintains reliance on utility offtake...

1) A voluntary RA program governed by the Regional Organization for Wester Energy and build on the framework of WEIM is currently in development. 2) EDAM will introduce a Flexible Ramping Product and Imbalance Reserves.

Sources: Aurora Energy Research, CAISO, WPP, SPP

2 Capacity-focused resource planning and cost-of-service incentives can limit storage procurement, slowing deployment

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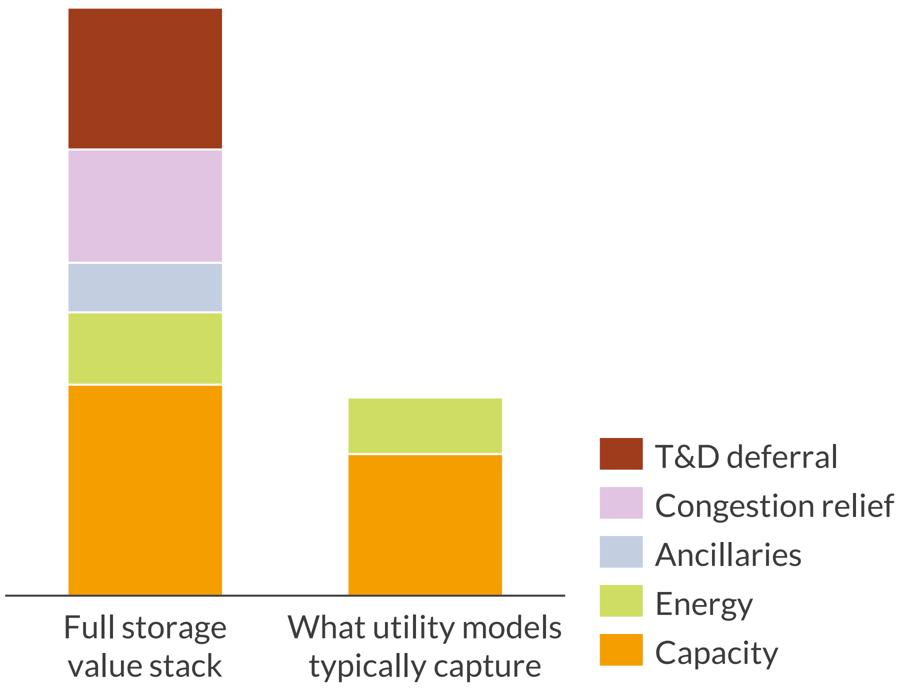
- Simplifying assumptions in IRP capacity expansion modeling obscure the full value-stack of storage and can lead to decreased storage procurement
- Cost-of-service regulation biases investment toward capital-intensive assets, which can disincentivize utilities from procuring storage

Drivers of utility procurement

	Details	Impact on storage deployment
Integrated resource planning	▪ Utilities use capacity expansion models to select-least cost portfolios that meet capacity needs ▪ Capacity expansion models are typically zonal with limited representation of congestion and location-specific constraints ▪ Capacity valuation is based on peak-hour capacity contribution (ELCC)	▪ Incomplete valuation of storage: planning models miss transmission deferral, congestion relief, ancillary service value ▪ Hydro-substitutability assumption: planning models don't capture advantages of storage over hydro including geographic flexibility and insensitivity to environmental conditions and constraints ▪ Conservative capacity accreditation: methodologies used to calculate ELCCs can undervalue storage
Incentive structure	▪ Utility returns are tied to capital deployment ▪ Limited financial incentives to minimize system-wide costs	▪ Preference for capital-intensive, lower-risk assets over emerging storage use cases (e.g., BTM, storage-as-transmission) ▪ Limited incentive for utilities to procure storage for non-capacity value streams (e.g., ancillary services, congestion relief)

Storage value stack (illustrative)



Even when utilities do procure storage, ongoing IXQ delays may prevent projects from coming online…

1) Typical Utility Integrated Resource planning – some utilities use more detailed approach.

Sources: Aurora Energy Research

3 Outdated IXQ planning process slows renewable and storage deployment, limiting storage's market access and value

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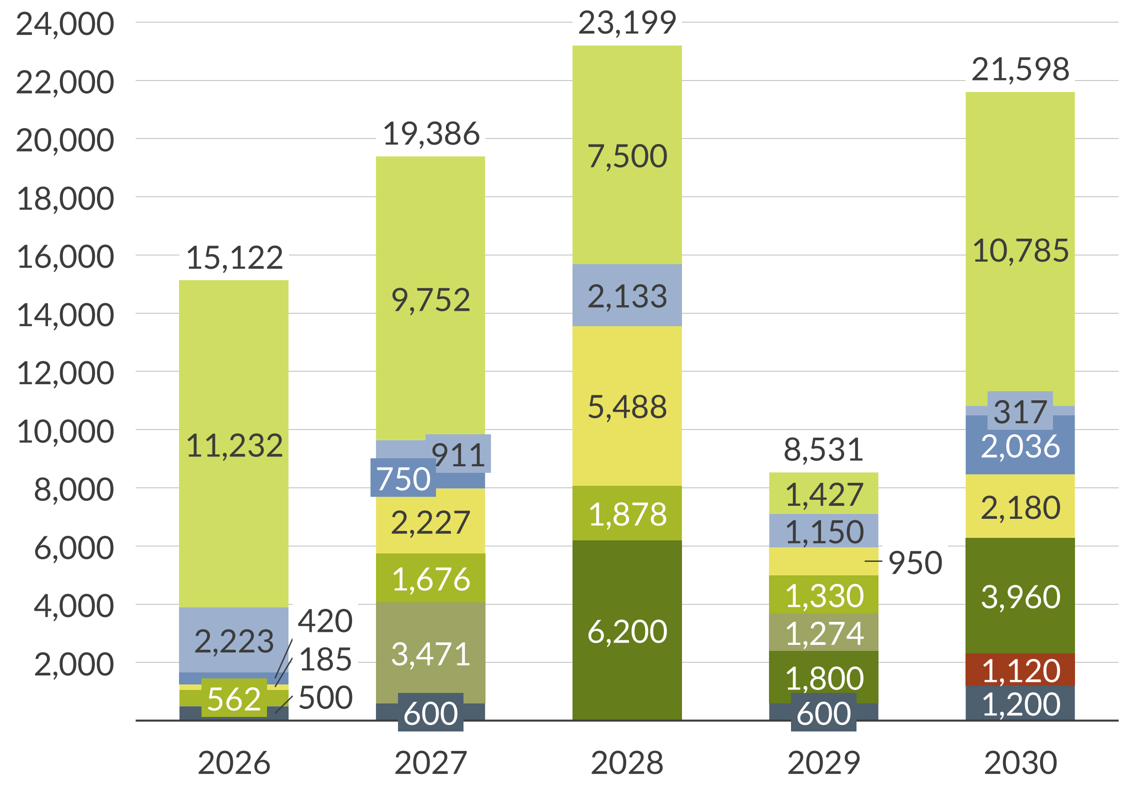
BPA's interconnection queue by requested in-service date and technology[1]

MW



Count of queued projects

2026	2027	2028	2029	2030
34	44	37	22	36

Solar + BESS | Wind | Wind + BESS | Battery storage | Solar | Wind + Solar + BESS | Other RES | Nuclear | Pumped storage hydro

Queue Summary

- Bonneville Power Administration (BPA) owns about 75% of transmission in the PNW
- BPA's planning framework was designed for incremental thermal addition. As a result, it's not equipped to handle the volume of renewable and storage interconnection required for states to meet their reliability needs while also adhering to clean energy goals
- So, despite over 87GW of storage and renewable capacity currently in the interconnection queue, that capacity may not actually materialize

Storage Impact

- IXQ constraints limit renewable buildout, preventing the electricity price volatility and ancillary service demand that underpins storage value
- ***Constrained interconnection capacity also pushes utilities to prioritize natural gas over storage and renewables…***

1) As of February 12th, 2026. Includes projects in phase one study, phase two study, active contract negotiations, or under construction.

Sources: Aurora Energy Research, BPA

4 Planning frameworks that don't incorporate clean energy targets tend to favor new thermal, which displaces storage for decades

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Rapid load growth combined with interconnection queue delays is putting near-term reliability pressure on utilities. In response, utilities are increasingly turning to thermal generators as a readily deployable resource, even in OR and WA, where clean energy targets exist, at the expense of long-term decarbonization goals and storage deployment.

State Renewable Policy Landscape

Montana

No state-level renewable target

Idaho

No state-level renewable target

Oregon

100% clean energy by 2040 but concerns regarding to its ability to meet the target

Washington

CETA 100% clean energy by 2045, but utilities still planning new gas/thermal addition

Near-term PNW thermal capacity additions[1]

Name	COD	State	Size (MW)
South hills Power Plant	Mid-2029	ID	222
Peregrine Power Plant	Mid-2030	ID	430
Centralia Unit 2 coal-to-gas conversion	Late-2028	WA	700
PSE peaker turbines (IRP planned)	2026-2030	WA	237

New-build thermal results in long-term displacement of storage because it:

- Suppresses price volatility
- Provides ancillary services
- Provides Resource Adequacy
- Stays online for decades

1) List of most notable examples and is not a complete list.

Sources: Aurora Energy Research, PacifiCorp, Idaho Power, PSE

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Long-duration storage technology is maturing and could provide reliability over multi-hour and multi-day events in PNW

Near-term long-duration energy storage projects

Iron-air

Form energy, Google, Xcel Energy

300MW/30GWh

COD: 2028+

Location: MISO Minnesota

Feb 2026: Google and Xcel Energy signed an agreement for 1,600MW of clean generation and a 300MW iron-air LDES[1] asset, which will provide "similar benefits to a natural gas peaking plant"

- Iron-air batteries can help to firm a renewables portfolio by providing multi-day storage capabilities, maintaining reliability during low-renewables periods.

Flow (zinc-bromine)

MN8, eos

20MW/200MWh

COD: TBD

Location: U.S.

Oct 2025: Eos Energy signed a supply agreement with MN8 Energy for up to 750MWh of zinc-bromine storage energy storage systems; commercial operation dates have not yet been announced.

- Eos Energy's current order backlog totals 2.8GWh. Eos Energy is scaling U.S. manufacturing to reach up to 8GWh of annual capacity by 2027.

A-CAES[1]

Hydrostor, California Community Power

500MW/4GWh

COD: 2030

Location: CAISO California

Feb 2026: Hydrostor signed an offtake agreement with California Community Power for an A-CAES[2] system serving six California Community Choice Aggregators.

- A-CAES's benefits over traditional CAES include its ability to re-use heat generated during the compression process and improved site flexibility

- In 2025, 6% of global energy storage additions (~15GWh) were LDES. The U.S. has yet to see operational grid-scale LDES deployment, however multiple policies are in place to encourage near-term projects
- Long-duration storage could help provide firm capacity during winter peaks and regional stress events in the PNW
- PacifiCorp has sought gigawatt-scale multi-day (100-hour) storage in its IRP but has not yet acted on this through actual procurement. In its 2025 IRP preferred portfolio, 511MW of 100-hour iron-air storage system is called for by 2030, increasing to ~3GW by 2045

Opportunity: LDES technologies are maturing and are well-suited provide firm capacity during the PNW winter stress periods where multi-day outages are seen

Barrier: Modeling challenges and a lack of mechanisms that value storage duration lead to limited market exposure

1) Long duration energy storage 2) Adiabatic compressed air energy storage technology

Sources: Aurora Energy Research, Xcel Energy, Eos Energy, Hydrostor

Storage as a transmission asset can defer costly and lengthy transmission upgrades

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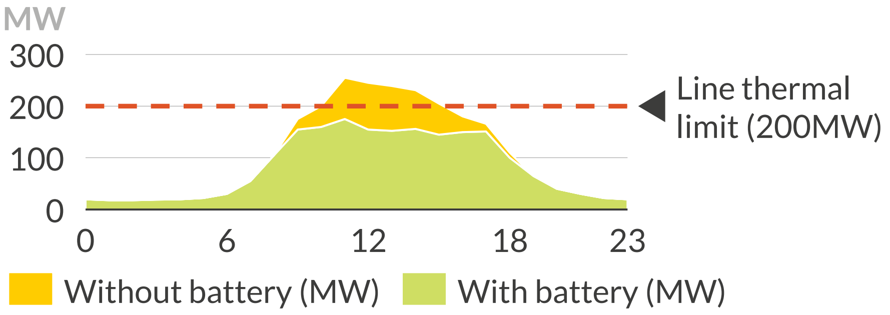
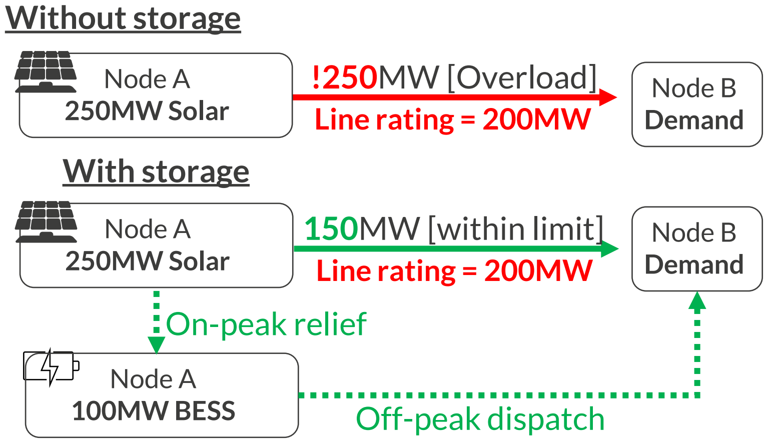
Overview of storage-as-a-transmission asset

Net-flow on constrained line





Existing SATA examples

Nantucket SATA

6MW/48MWh SATA on Nantucket

- Implemented in 2019 to defer investment in transmission upgrade by 13 years
- Deferral alone valued at $122M in present-value savings
- Total benefits of $158M against $94M cost yielding a 1.68x return on investment

First RTO SATA Policy Endorsement

PJM Operating Committee endorsed a SATA proposal on June 4, 2026

- Requiring SATA units to auto-discharge during contingency to address reliability violations
- The framework positions SATA as rate-based and utility-owned which is first on the RTO-level in the US

Opportunity: SATA can defer expensive transmission upgrades for years, making it a valuable tool in the PNW where transmission planning and development timelines are often lengthy.

Barrier: Under cost-of-service regulation, utilities generally earn returns on capital investments, which can make traditional transmission infrastructure more financially attractive than SATA solutions despite their lower system cost

- Storage as a transmission asset (SATA) refers to storage that is connected and operated as part of the transmission system
- FERC's 2017 policy statement (PL17-2) enables utilities to treat storage as a viable, rate-recoverable alternative to conventional transmission upgrades
- SATA can be deployed faster and often cheaper than traditional transmission upgrades, helping accelerate deployment of lower marginal cost variable renewables in the PNW, affordably
- Limited uptake of SATA in PNW. PSE issued a non-wires transmission solution RFP, though it ultimately did not select SATA as a solution
- PJM Operation Committee endorsement (June 2024) is the first major RTO to formally advance a SATA framework

Sources: Aurora Energy Research, PSE, PJM

Storage co-location with data centers can help support affordability amidst expected load growth

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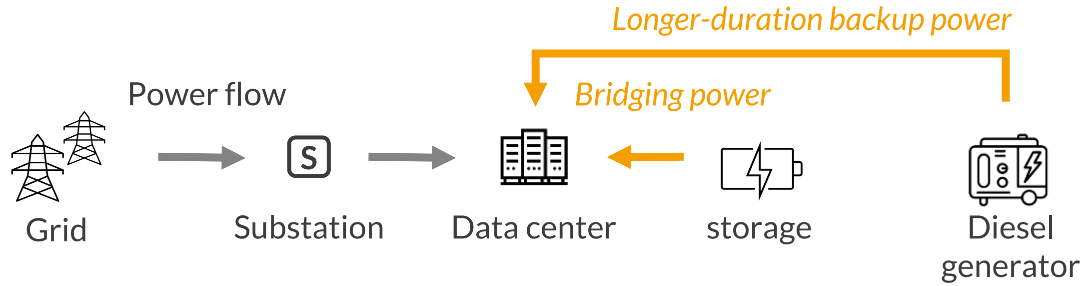
Example configurations of storage co-location with data centers

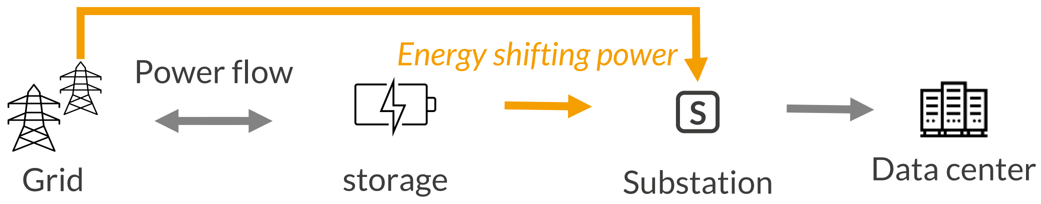
1 Behind-the-meter storage + thermal with data center



Benefits

- **For ratepayers:** BTM storage reduces peak demand on the utility substation, deferring costly upgrades required for the additional data center load that could otherwise be passed to rate-payers, depending on tariff design
- **For data center developers (interconnection):** BTM storage can accelerate data center interconnection timelines, allowing projects to come online faster
- **For data center developers (operating costs):** BTM storage can displace on-site thermal generation, materially reducing fuel consumption and reduce the overall data center operation cost

2 Front-of-the-meter storage with data center



Benefits

- **For ratepayers (grid stability):** FTM storage absorbs data center load spikes and provides grid stability; this can reduce the amount of ancillary services a utility would need to procure, potentially reducing overall system cost
- **For data center developers (interconnection):** Strategically placed batteries can increase hosting capacity available to data centers, as determined in utility interconnection studies. This can provide data center developers a cheaper and faster route to interconnection by allowing them to avoid paying for costly and lengthy transmission network upgrades

Opportunity: To the extent that data center-driven load growth is accelerating interconnection demand in the PNW, there are strong incentives for both BTM and FTM storage

Barrier: Interconnection queue delays still impede deployment of front-of-meter storage co-located with data centers

Sources: Aurora Energy Research, EIA, UtilityDive, Stanford, Tesla

BTM storage can bypass IXQ bottlenecks and reduce capacity needs. Incentive programs led by PSE, PGE, Pacificorp

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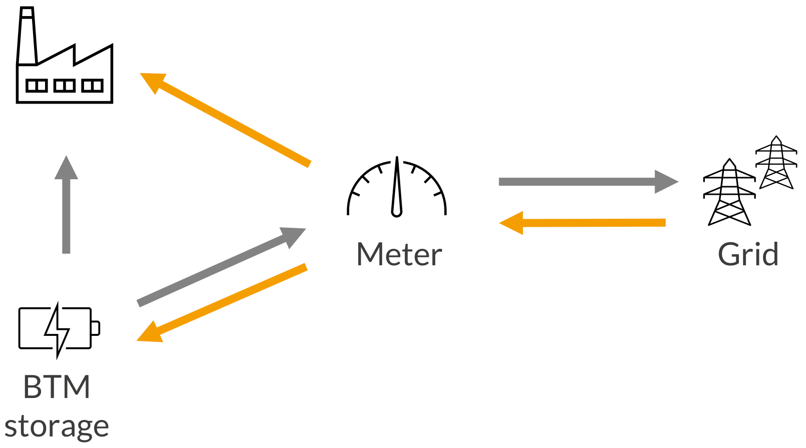
BTM storage cuts peak demand deploys faster than utility-scale, helping address delays and near-term capacity gaps in the PNW

BTM configuration schematic



- BTM storage charge during off-peak hours and discharge during peak events
- Reduces coincident system peak, lowering required capacity
- BTM systems installed in weeks–months vs. years for new generation (permitting, siting, interconnection)

BTM storage incentives in the PNW are led by PSE, PGE, and PacifiCorp

Summary of existing BTM storage programs across PNW

	Puget Sound Energy (WA)	Portland General Electric (OR)	PacifiCorp / Pacific Power (OR/WA/ID)
Program	Flex Batteries	Smart Battery Pilot	Wattsmart Battery
Incentives	• Up to ~$1,000 • Up to ~$500/year • Up to ~$10k equity	• ~$1.70/kWh during events • Monthly credits • Upfront rebates (Energy Trust)	• ~$600/kW upfront (up to ~$3k) • Ongoing bill credits
Dispatch / control	Utility dispatch during peak "Flex events"	Utility dispatch ~10–15 peak events/year	Utility dispatch during grid stress events
Maturity	High	Medium (pilot)	High

Opportunity: BTM storage can typically be deployed in less than a year, enabling a rapid response to grid needs and avoiding transmission interconnection queue bottlenecks that can delay utility-scale projects

Barrier: Limited deployment incentives across the PNW

Sources: Aurora Energy Research, PGE, PSE, PacifiCorp, Pacific Power

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Storage deployment in the U.S. is concentrated in CAISO and ERCOT due to stronger revenue opportunities

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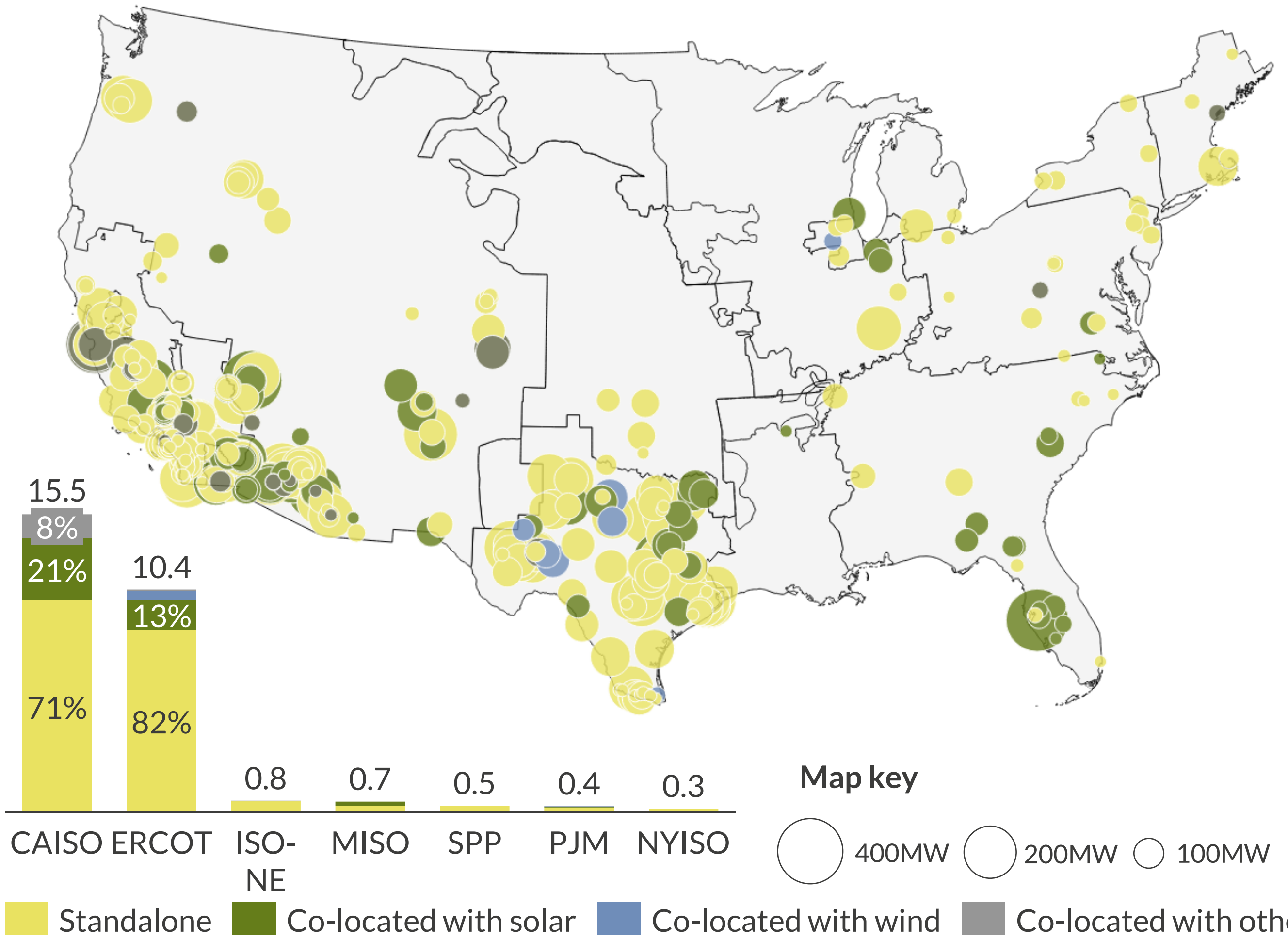
Installed battery capacity in the U.S. as of 2025[1]
MW



Key drivers of storage deployment in CAISO and ERCOT

CAISO - Capacity market + rapid decarbonization

- Midday solar oversupply drives solid energy arbitrage opportunities
- State-led procurement mandates provide stable, contracted revenue streams for storage

ERCOT - Volatile energy-only wholesale market

- Rapid renewables growth and high price caps drive high price volatility, creating profitable arbitrage opportunities for storage

Lessons for PNW

- Storage projects typically require at least one stable revenue stream to support deployment
- In the PNW, limited wholesale and underdeveloped ancillary services markets currently constrain the extent to which storage can receive compensation for its value
- More opportunities for storage to secure long-term offtake could support broader deployment

1) Only showing grid-scale assets on the map for quality of visualization.

Sources: Aurora Energy Research, EIA, Energy Storage News, ERCOT

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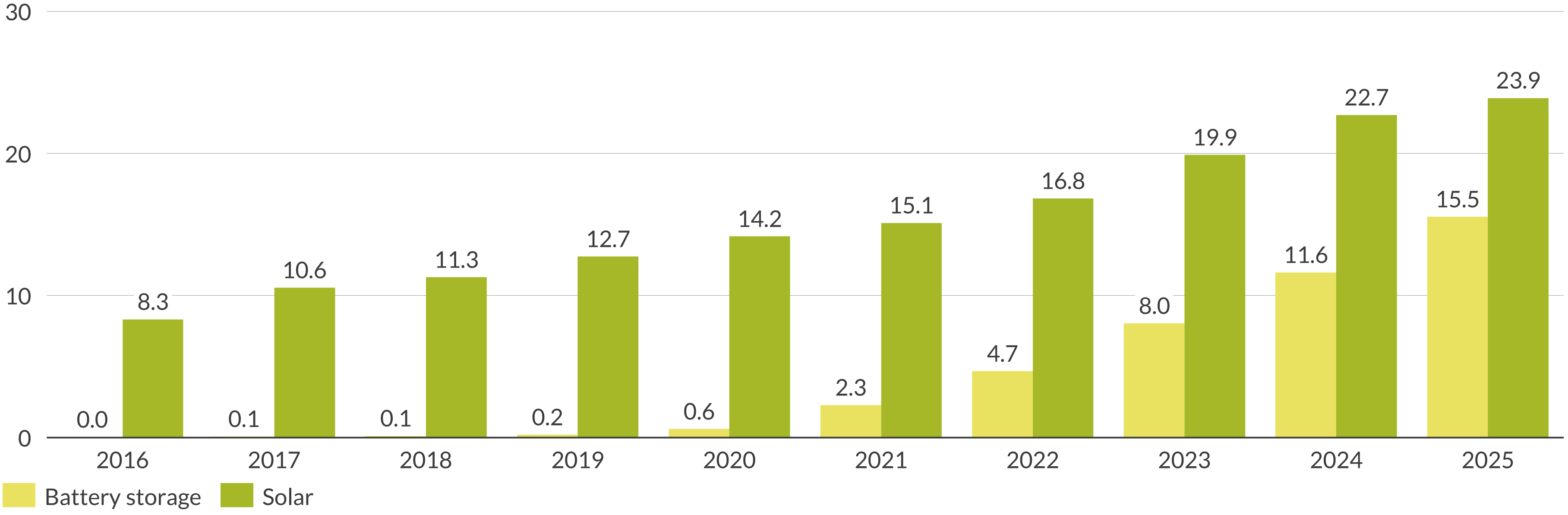
Storage deployment in CAISO is driven by favorable solar conditions and state-led procurement

CAISO historical solar and battery installed capacity (GW)



CPUC Procurement Mandates

2013 — **Oct 2013:** 1.3GW IOU storage mandate by 2030

2019 — **Nov 2019:** 3.3GW energy storage capacity by 2023

2021 — **Jun 2021:** 11.5GW net qualifying capacity by 2026

2023 — **Feb 2023:** 4,000MW NQC supplemental procurement ordered on top of 2021 mandate

1) SB350 states that all retail sellers must offer contracts of at least 10 years or more when procuring RPS-eligible renewable resources.

Drivers of storage deployment in CAISO

Solar buildout

- Between 2016 and 2025, grid-scale solar capacity doubled, driven by strong solar availability, federal tax credit support, technological advances, and availability of PPAs brought upon by SB350[1]
- Midday generation surpluses and steep evening ramps drive demand for storage to shift energy and balance the grid

State-led procurement

- CPUC's procurement mandates require LSEs to procure firm, clean flexibly capacity, directly driving large-scale battery deployment
- This creates a clear contracting pathway for storage, enabling long-term agreements that support stable, predictable project revenues

California's storage buildout has contributed to falling ancillary services prices and decreased reliance on imports

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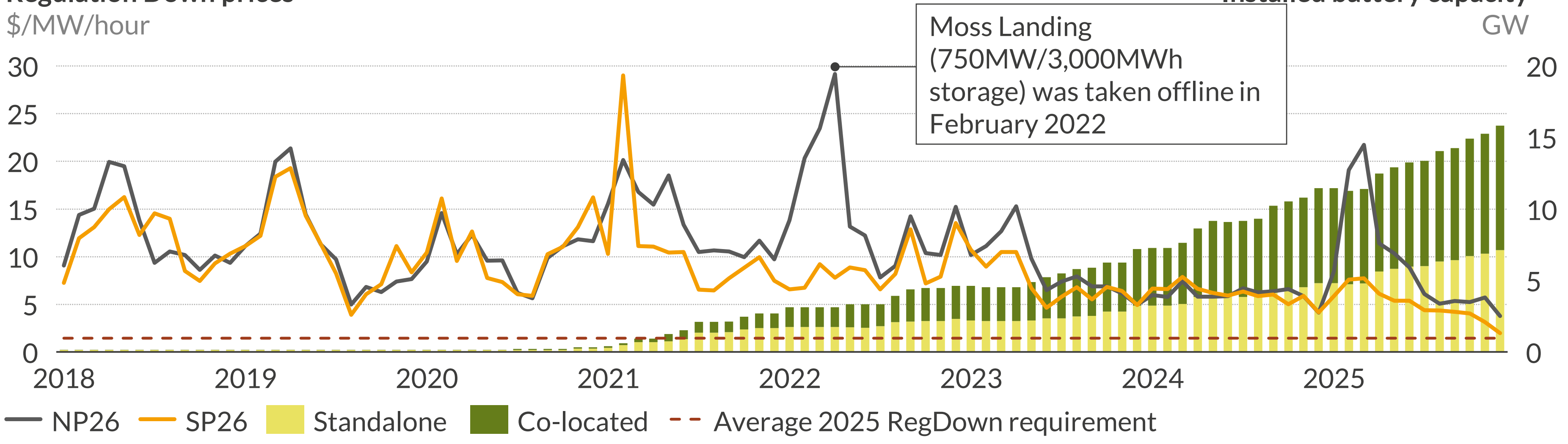
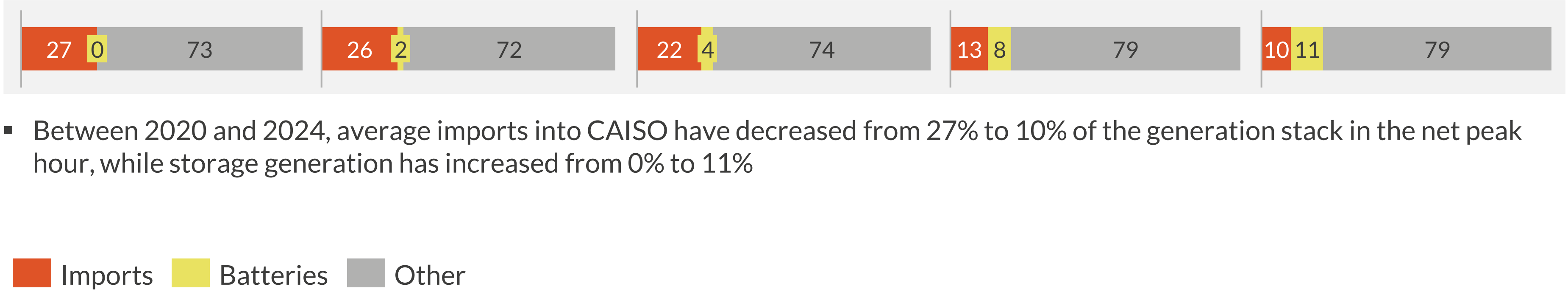
Regulation Down prices
$/MW/hour

Installed battery capacity
GW



Generation share by technology in HE19[1] from 2020 to 2024
%



- Between 2020 and 2024, average imports into CAISO have decreased from 27% to 10% of the generation stack in the net peak hour, while storage generation has increased from 0% to 11%

- Installed battery capacity has increased to over 15GW by 2025 from near zero in 2018 while the regulation down prices have trended downward significantly
- Traditional thermal units that provided ancillary services are increasingly getting replaced by battery storage which is setting the marginal price and driving costs down
- As battery penetration has increased, CAISO historical generation data shows a declining reliance on imports during peak hours

1) HE19 refers to the hour ending at 7pm local time representing the peak evening demand when solar generation has ramped down and battery storage begins discharging

Sources: Aurora Energy Research, CAISO

Storage deployment in ERCOT is driven by rapid load growth, renewables penetration, and market design that rewards flexibility

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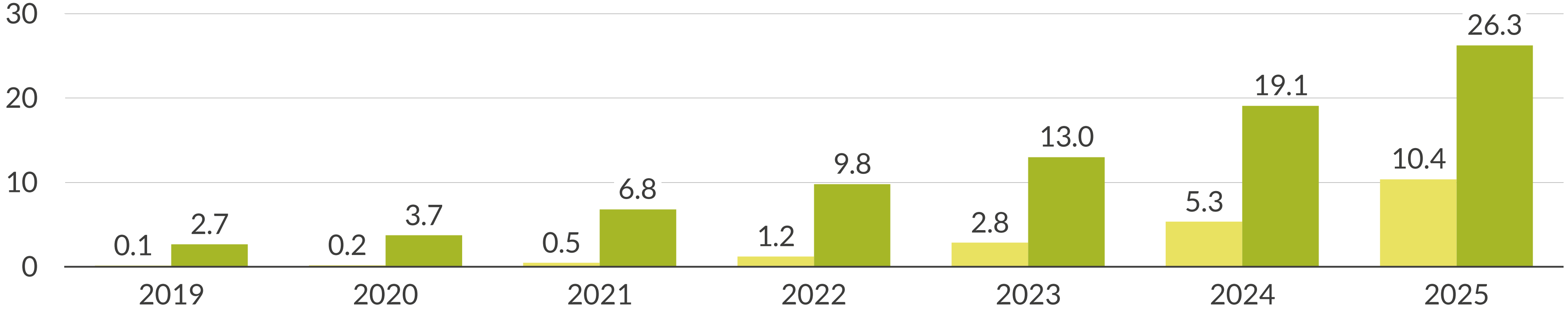
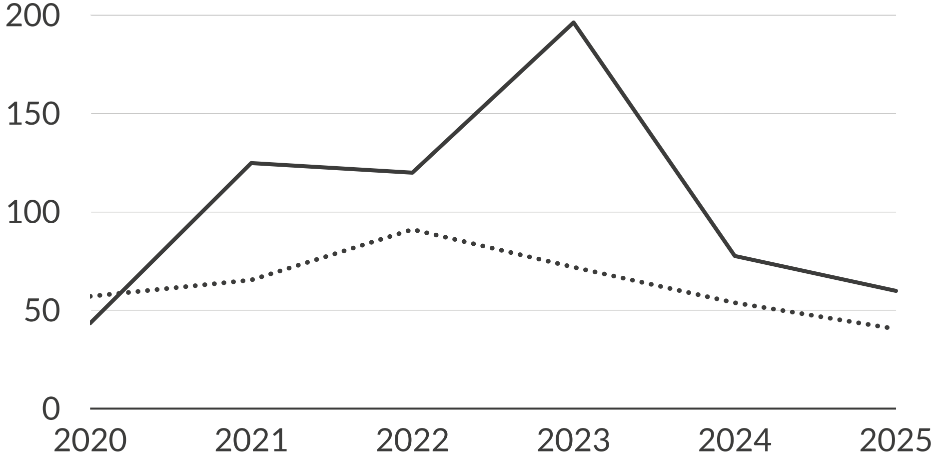
Commercially operational battery capacity in ERCOT as of April 2026[1]

GW



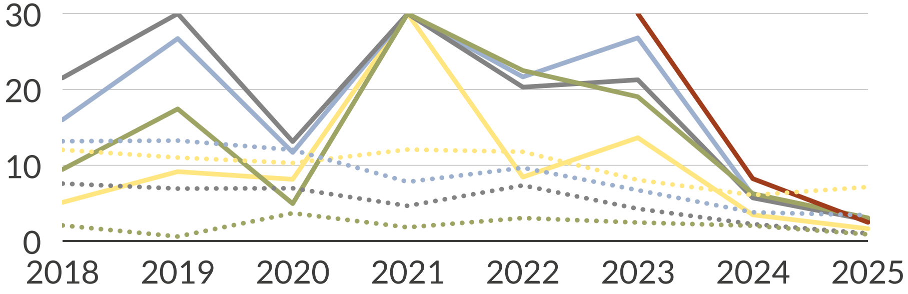
Historical 2h spreads

$/MWh



Historical ancillary services prices

$/MW/h



- ECRS[3] was established in ERCOT in 2023 to incentivize flexible capacity to enter the system to maintain grid stability during daily ramp down in solar production and intermittent drops in wind production

Battery storage | Solar | ERCOT | CAISO | Reg Down | Reg Up | RRS | Non-Spin | ECRS[3]

Drivers of storage deployment in ERCOT

Demand growth

- Over 2020-2024, ERCOT saw a 15% growth in peak load

Renewables buildout

- Renewables penetration in ERCOT outpaces all other competitive markets, with 26GW of capacity additions between 2020 and 2024.
- ERCOT's median interconnection time of 21 months is significantly faster than other RTOs which ranges from 38 months to 64 months[2]

Market design

- ERCOT's energy-only design (with high prices caps and reserve scarcity pricing curves) concentrates reliability value into real-time and ancillary markets, creating profitable opportunities for storage

1) Counted using storage projects with In-service dates as reported by the ERCOT March-published May MORA report. 2) Lawrence Berkely National Lab 3) Emergency Contingency Reserve Service. ECRS does not have a comparable service in CAISO. Was established in ERCOT in 2023 with purpose of maintaining grid stability.

Sources: Aurora Energy Research, ERCOT

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Policies in NYISO, MISO, and SPP are emerging to encourage storage deployment, which could also be effective in the PNW

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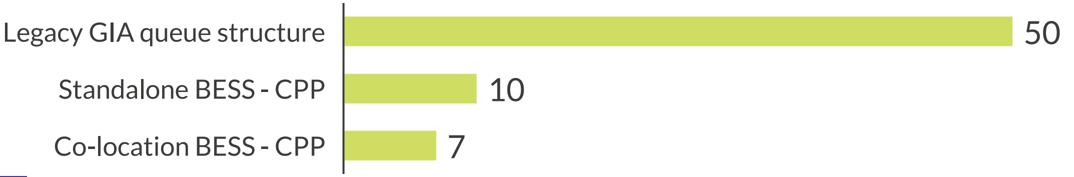
SPP: Consolidated Planning Process (CPP)

- SPP's Consolidated Planning Process (CPP) integrates transmission planning and generator interconnection into a single, coordinated framework to proactively identify and build needed grid infrastructure.
- In this new process, SPP plans transmission based on expected load and generation growth, rather than reacting to individual interconnection requests
- CPP unlocks storage by enabling projects that relieve congestion; **a similar process could help speed up interconnection process in the PNW**

Average Interconnection Time (Months)



Brazil: BESS procurement in hydro-dominant system

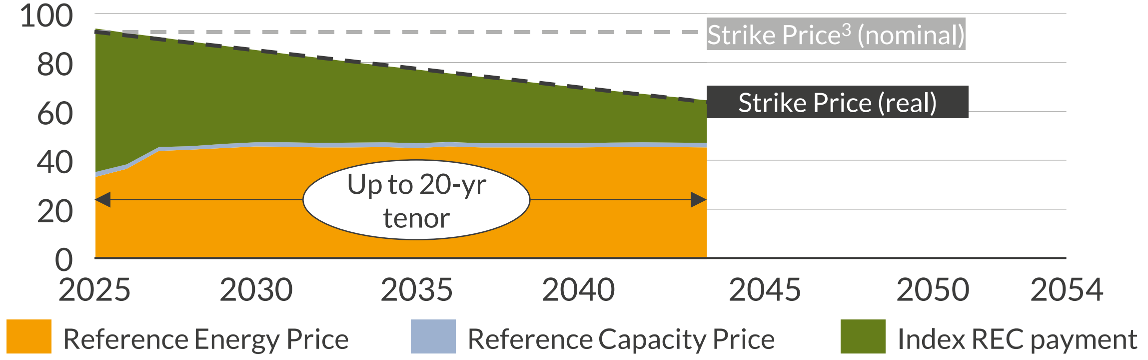
- Hydro accounts for 60% of Brazil's generation, yet the rapid expansion of wind and solar has driven growing curtailment and flexibility shortfall that hydro alone can no longer resolve
- In response, Brazil scheduled its first storage auction for December 2026 under the Long-Term Reserve Capacity Auction Program contracting storage on a power availability basis
- Auction target a combined ~2GW in storage procurement by 2028
- If awarded, contracts run 15 years with delivery starting August 2028 and projects must be at least 30MW with a 4-hour daily discharge duration
- **Like the PNW, Brazil is a hydro-dominant system that does not have a robust ancillary services market. In response to rising renewables penetration that increases the need for storage, Brazil has turned to state-led procurement**

NY-ISO: Index Storage Payments

- Under the Index Storage Credit program, storage projects will offer a Strike Price in yearly bids, aiming to reflect the project's revenue needs
- The NYSERDA/DPS filing suggests that if the Strike Price surpasses the Reference Price[1] NYSERDA[2] pays the difference to selected projects. If the Reference Prices exceeds the Strike Price, the project pays NYSERDA
- The Index Storage Credit (ISC) aims to procure 3GW bulk storage (>5MW) across three annual solicitations through 2027
- **Index storage payments provide a revenue floor to reduce risks for developers while ratepayer costs are tied to market outcomes rather than fixed subsidies**

NYSERDA Index REC Contracting Structure, 2025 entry year

$/MWh (real 2023)



1) Reference prices is the sum of the Difference between the top four and bottom four priced hours of the day-ahead zonal locational based marginal price and the adjusted capacity pot auction price. 2) New York State Energy Research and Development Authority. 3) The contracted Strike Price is in nominal dollars, which means it declines over time in real terms in line with inflation, decreasing the real Index REC payment

State policies and incentives to support long duration storage technologies are rising across the U.S.

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State-specific long-duration storage[1] incentives

California

D.24-08-064
Centralized procurement framework to catalyze emerging technologies

- In August 2024, the CPUC established a centralized procurement framework to catalyze emerging technologies
- The CPUC identified a specific need for long-duration and multi-day storage
- The CPUC authorized centralized procurement of up to 1 GW of 12+-hour storage and 1 GW of multi-day storage (e.g., more than 24-hour).

Massachusetts

S.B. 2967
"An Act Promoting a Clean Energy Grid, Advancing Equity and Protecting Ratepayers"

- Part of the "Act" contains statutory procurement mandate which requires state LSEs to procure 750MW (10-24hours duration) + 750MW (>24hours duration) storage by mid-2030
- The act also requires 1,500MW mid-duration storage (4-10hours) by the end of 2025, which has already been deployed

New York State

Renewable Optimization and Energy Storage Innovation Program

- As part of New York's Climate Leadership and Community Protection Act, this program provides grant funding for development and demonstration projects for innovative long-duration storage technologies
- Completed funding rounds have seen a combined $30M+ rewarded, with the final round closed and the awarding members to be announced

Virginia

HB 895
Codified Procurement Targets

- HB 895 requires utilities to procure or build specific amounts of short-duration (<10 hours) and long-duration (10+ hours) storage
- For the long-duration storage procurement mandate portion, half of the capacity must be 24 hours+ in duration while the other half is 10-24 hours
- This bill calls for over 2GW of multi-day energy storage

While activity is growing nationally, the PNW has not yet established comparable long-duration storage incentives

1) 10-hour minimum

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ELCC measures how much additional load a resource can reliably serve while maintaining the same system reliability

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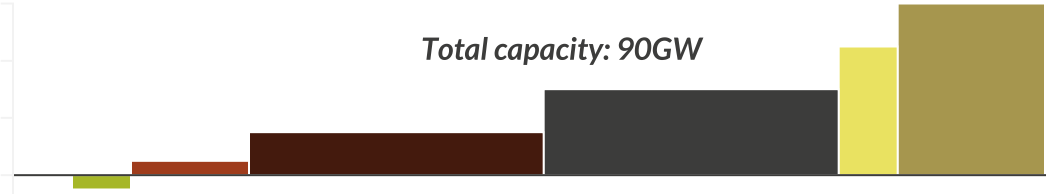
ELCC metric illustrative example

1 Prepare base case model without the new capacity from a technology class and find a peak load amount that results in a set loss of load chance.

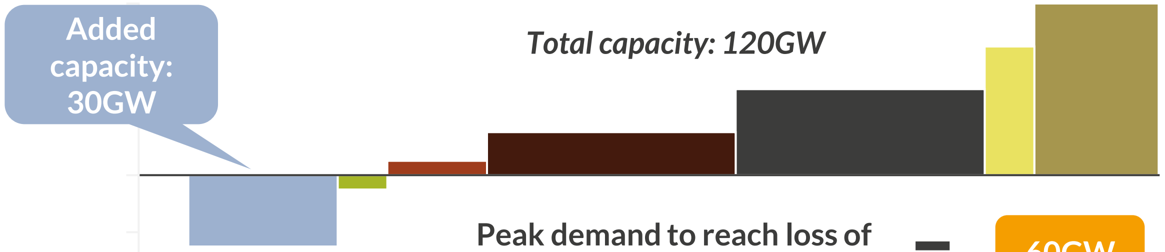
*Modelled supply stack, **base case** example for wind*



Peak demand to reach loss of load expectation (base case) = 55GW

2 Add the technology capacity back and measure the additional load needed to reach the same set loss of load chance.

*Modelled supply stack, **change case** example for wind*



Peak demand to reach loss of load expectation (change case) = 60GW

3 The difference in the base case and change case peak load is the total amount of accredited capacity for that technology

Total accredited capacity for this technology and tier: 60GW − 55GW = 5GW

4 ELCC is calculated by dividing accredited capacity by installed capacity

Total accredited capacity: 5GW Installed capacity: 30GW

Corresponding ELCC derating factor: 5GW ÷ 30GW = 16.67%

Different assumptions used in ELCC calculations can result in widely different valuations for storage

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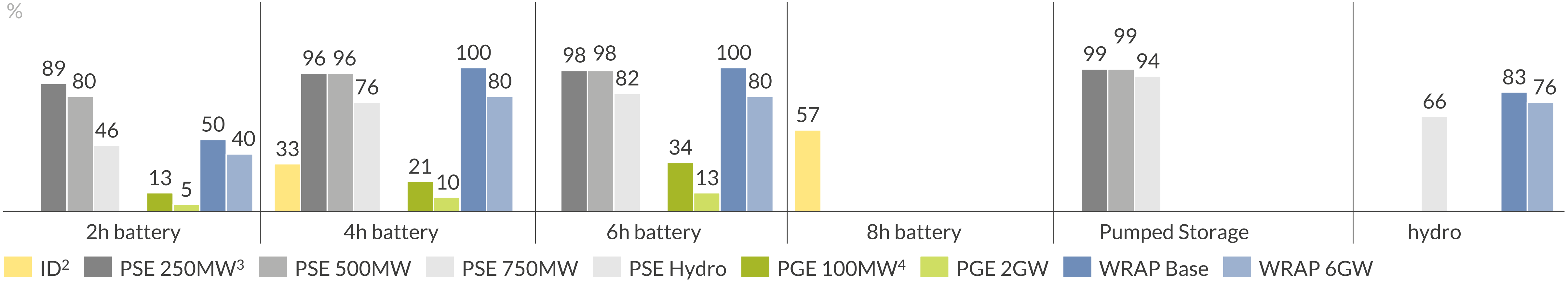
Near-tern ELCC[1] across PNW



Key methodological drivers of storage ELCC accreditation

Driver	Impact on storage ELCC
Hydro assumptions	The degree of assumed hydro flexibility shapes when load shed events occur. Low flexibility spreads stress across the day, while high flexibility concentrates it at morning and evening peaks where storage is better positioned to contribute. As a result, greater hydro flexibility assumptions can result in higher storage ELCC and vice versa
Accreditation method	Loss of Load Expectation counts the frequency of shortfall events without accounting for their depth, while Expected Unserved Energy measures the total volume of unserved energy. Because they capture different aspects of reliability risk, the two metrics produce different ELCC values for storage
Capacity mix assumptions	Higher renewable penetration changes the timing and shape of net load, creating more opportunities for storage to charge and discharge during high-risk periods. As assumptions on renewable capacity increase, storage is better able to provide capacity value, resulting in higher storage ELCC

1) All ELCC values are winter ELCCs otherwise specified 2) Idaho Power 2025 IRP Appendix D, Table 2. ELCC of future resources 3) Puget Sound Energy, 2023 Electric Progress Report Appendix L, Tables L.11, L.12 ; MW values represent ELCC sensitivities across three battery sizing tranches. 4) Portland General Electric, 2023 IRP; MW values represent two scenarios that's early stage and high-penetration storage buildout illustrating the saturation effects

Sources: Portland General Electric, Idaho Power, Puget Sound Energy, WRAP, Aurora Energy Research

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Utility planning frameworks, limited revenue streams for storage, and development bottlenecks constrain storage deployment in PNW

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Utility Planning Frameworks	Limited Revenue Streams	Development Bottlenecks
Current utility planning frameworks fail to capture storage's full value stack across capacity, energy, and ancillary services, resulting in low storage procurement	No regional ancillary service market and fragmented capacity frameworks mean storage cannot reliably monetize its revenue streams, thus producing a weak investment signal for utilities and private developers alike	Even when there is desire to build storage projects, the interconnection queue delays along with PTP transmission rights and complex siting permits result in delayed storage build-out in the region

Recommendations

Reform procurement planning frameworks	Develop ancillary services markets	Prioritize interconnection queue reform
Adopt performance-based ratemaking	Establish stronger RA frameworks	Remove PTP transmission right requirement
Revise ELCC methodology	Policies to advocate for emerging battery technologies and configurations	Streamline siting and permitting

Reforms to recognize the full value of storage in utility planning and incentives can unlock greater procurement

Recommendation	Context	Enablers and barriers	Examples in other markets
Reform procurement planning frameworks to reflect storage's full contributions to system	▪ Storage delivers value across capacity, energy shifting, and AS but current utility planning framework fails to capture all of them, leading to lower storage procurement. This shortfall is especially pronounced for LDES	▪ ✓ Regional markets will make storage's value more transparent, enabling better inputs into IRP processes ▪ ✗ Reforming IRP process is inherently difficult due to the deep integration of existing framework in utility workflows creating strong institutional inertia against change	▪ CPUC IRP: requires utilities to model storage across multiple value streams simultaneously including capacity, energy shifting and ancillary services, rather than evaluating it narrowly as peaker replacement. The CPUC has also set aside explicit storage procurement targets ▪ PJM: Requires storage to be accredited based on its ELCC[1] rather than the nameplate capacity; PJM also developed specific frameworks governing how ELCC is calculated
Adopt performance-based ratemaking (PBR)	▪ PBR ties utilities' profits to reliability outcomes and cost reduction, unlike PNW's current cost-of-service framework, which ties profits capital investment, disincentivizing procurement efficiency	▪ ✓ Growing concerns regarding energy affordability pushes PNW states for ratemaking reform ▪ ✗ PBR is technically complex with the potential of information manipulation	▪ Hawaii: PUC[2] has 14 performance incentive mechanism covering DER[3] adoption, reliability and carbon targets; capping utilities' earning/loosing up to $40M/year ▪ New York State: Full revenue decoupling and earning sharing if utilities earn excess of capped amount; performance incentives implemented covering carbon, affordability and grid efficiency
Revise ELCC methodology	▪ Storage reliability accreditation under ELCC framework is sensitive to modelling assumptions ▪ Multi-metric accreditation would be better suited to capture the range of system benefits storage provides	▪ ✓ Strong precedent exists in PJM and MISO where markets moved to energy-based or multi-metric accreditation ▪ ✗ Assumption in accreditation methodology varies and impacts ELCC; finding the right set is often difficult	▪ PJM: uses Expected Unserved Energy (EUE) as a primary metric with Marginal Reliability Improvement methods ▪ MISO: Direct Loss of Load (DLOL) method credits resources by availability during the high-risk critical hours to reflect more realistic storage modelling ▪ CAISO: uses 24-hour slice of day methodology and marginal ELCC to capture the full risk window and attempts to give the most accurate accreditation

Sources: Aurora Energy Research, CPUC, PJM, Hawaii PUC, NYPSC

Reforms to recognize the full value of storage in utility planning and incentives can unlock greater procurement

Recommendation	Context	Enablers and barriers	Examples in other markets
State-led procurement of storage	▪ Direct state-led mandates can sidestep utility processes that undervalue storage ▪ A state mandate offers certainty that private capital and developers need to underwrite projects, rather than requiring them to wait for market or planning reforms to eventually catch up	▪ ✓ There is a growing policy incentive in the western states facing growing concerns on grid's ability to meet future demand ▪ ✗ Existing framework may create conflicts with utility resource planning autonomy if states imply their own goals for procurement	▪ California SB122 and AB102 enables $380M funding in LDES projects that is longer than 8 hours in duration and non-lithium-ion ▪ The NY Public Service: 6GW storage roadmap with NYSERDA directed to develop a pricing methodology for 12+ hour resources by September 2026; NYSERDA tasked with three consecutive annual bulk storage solicitations through 2027 with each procurement aiming to secure 1GW of capacity

Sources: Aurora Energy Research, NYPSC, California State Legislature, MYSERDA

Reforms that establish revenue streams reflecting storage's full value are critical to attracting investment

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Recommendation	Context	Enablers/barriers	Examples in other markets
Develop ancillary services (AS) market	▪ Currently, there are not regional AS markets in the PNW, meaning storage is not compensated for the full value it provides to the grid	▪ ✓ Growing renewable penetration is creating uncompensated flexibility needs which is a concrete justification for AS market development ▪ ✗ Introduction of AS market is a lengthy process. Given regional day-ahead markets have just been introduced, bandwidth to construct AS market is constrained	▪ All major RTOs in the US have competitive AS markets ▪ ERCOT ECRS (2022): Added emergency-controlled reserve service to explicitly incentivize fast-ramping capacity that in turn reduced overall ancillary service cost ▪ CAISO: offers distinct ancillary service products such as Reg Up, Reg Down, Spinning, non-Spinning
Establish stronger RA frameworks	▪ To complement regional resource adequacy frameworks, states could introduce enforceable procurement requirements, clearer capacity accreditation, and robust compliance mechanisms	▪ ✓ Markets+ and EDAM both incorporate resource adequacy coordination mechanisms which could aid storage developers' access to capacity accreditation and offtake ▪ ✗ Resource frameworks are fragmented across the PNW. EDAM's capacity is voluntary, which limits its ability to force utilities to procure capacity, potentially limiting opportunities for generators to find offtake for their capacity	▪ PJM Reliability Pricing Model: the centralized capacity auction procures capacity from all resource types including storage via UCAP/ELCC accreditation with the most recent auction cleared at a record high ▪ California Resource Adequacy Program: imposes mandatory requirements for load serving entities to procure system, local and flexible capacity; storage qualifies via Net Qualifying Capacity accreditation and the "Slice of Day" framework
Enact policies to advocate for emerging battery technologies and configurations	▪ Solutions like SATA and BTM BESS can deliver significant system benefits ▪ However, the lack of standardized revenue streams limits deployment	▪ ✓ There are emerging inventive programs for BTM storage in the PNW that could serve as a reference ▪ ✗ It's difficult to quantify the system value of more novel storage configurations. This create cost-allocation and equity challenges	▪ PJM Operating Committee (2026): endorsed the first regulatory-level SATA framework proposal ▪ California Net Energy Metering 3.0: restructured export compensation for BTM batteries to incentivize paired solar + battery deployment for BTM use case

Sources: Aurora Energy Research, PJM, CAISO, CPUC, ERCOT

Addressing development bottlenecks is the final step to enabling storage buildout

AURORA

Recommendation	Context	Enablers/barriers	Examples in other markets
Prioritize interconnection queue reform to expand renewable and storage access to the grid	▪ The interconnection queue in PNW (which largely falls under BPA) is facing severe delays and cannot keep up with renewable energy and battery energy storage deployment ▪ With limited renewable energy deployment, storage systems have a hard time finding energy arbitrage opportunity, limiting its value to investors	▪ ✓ FERC Order 2023 provides a federal mandate for IXQ reform that applies to PNW ▪ ✓ BPA has outlined plans for a proactive planning approach to enable capacity to be delivered within five- to six-years	▪ SPP Consolidated Planning Process reduced interconnection study timeline by consolidating sequential studies ▪ MISO: shifted to first-ready, first-serve cluster study framework helped alleviate its congested interconnection queue ▪ CAISO: FERC 2023 compliance filing includes faster study timelines and deposit structure to deter speculative queue positions
Remove barriers requiring storage to have secure PTP[1] transmission rights to be selected as a utility network resource[2]	Requiring PTP rights for storage undermines its dispatch behavior since it charges and discharges locally and its value resides in being available on the grid near the large load centers	▪ ✓FERC Order 2222 supports non-discriminatory storage participation in energy markets ▪ ✗utilities may resist changes to transmission cost allocation	▪ PJM: allowed storage to participate in the market across multiple nodes without dedicated transmission rights ▪ ERCOT: no PTP requirement for storage with resources directly bid into the day-ahead and real-time market
Streamline siting and permitting processes	▪ Federal permitting introduces bottlenecks through complex environmental review processes ▪ Local opposition, often driven by NIMBYism[3] concerns such as aesthetics, land use, property values, and wildlife impacts, further complicates siting and permitting	▪ ✓ Washington and Oregon have passed or introduced legislation to create independent transmission authorities ▪ ✗ Local land-use opposition can stall projects	▪ ERCOT: minimal state-level siting regulation contributed the market being home to ~13.9GW operation in 2026 nearly doubled from the previous year

1) Point to point transmission rights, a reserved capacity on the grid to move power from one specific location to another 2) Sylvan3) Not in my back yard

Sources: Aurora Energy Research, Sylvan, SPP, MISO, CAISO, FERC, BPA, ERCOT, PJM