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Storing Affordability: How Battery Storage Can Reduce Data Center Cost Shifts

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Devyn W. Powell
Erik Anderson

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Project Overview

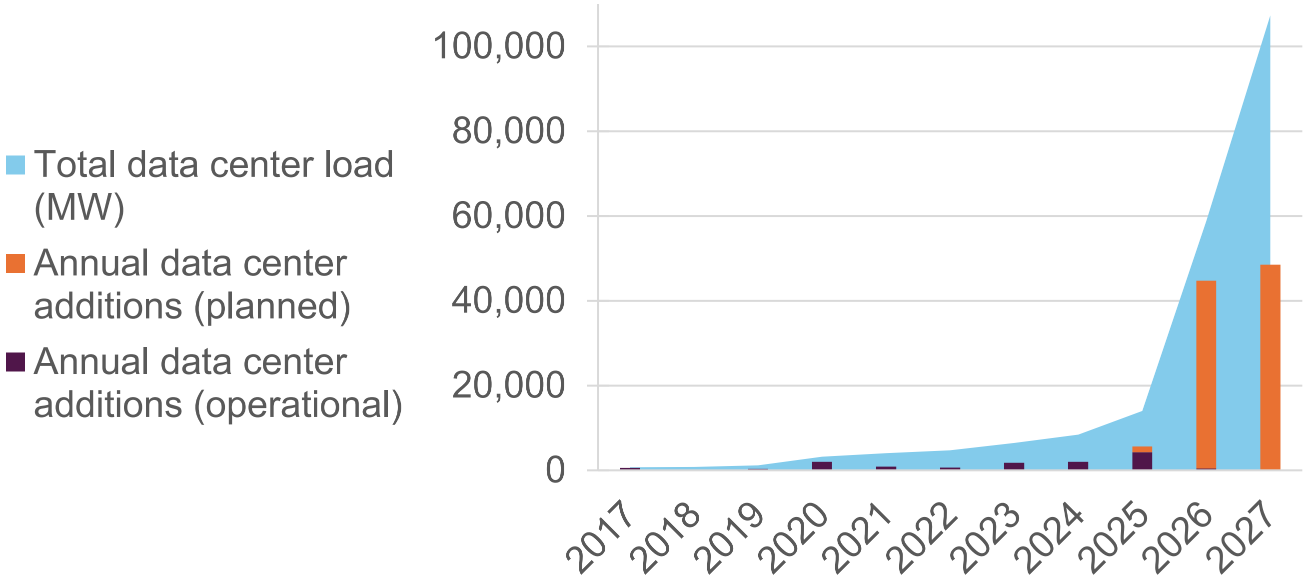
- **Goal:** Demonstrate opportunities for utilities, particularly smaller public utilities who may face more challenges meeting data center demand needs, to use energy storage to accommodate load growth and benefit ratepayers.
- **Current Practice:** Stakeholders vary in how to address competing demands related to data center load growth and the risk of cost shifts onto other ratepayers, especially as electricity prices and other costs increase. Practices include requiring data centers to curtail, requiring data centers to bring their own capacity, designing rate tariffs to allocate certain costs to data centers, and other approaches. Smaller and more rural utilities are less likely to have addressed challenges.
- **Why PNNL:** PNNL has established expertise in energy storage grid benefits, economic opportunities, and regulatory innovations. PNNL is expanding its expertise in how energy storage can mitigate various challenges related to growing data center demand. PNNL also has established relationships with rural utilities via technical assistance and other partnerships.

Project Overview

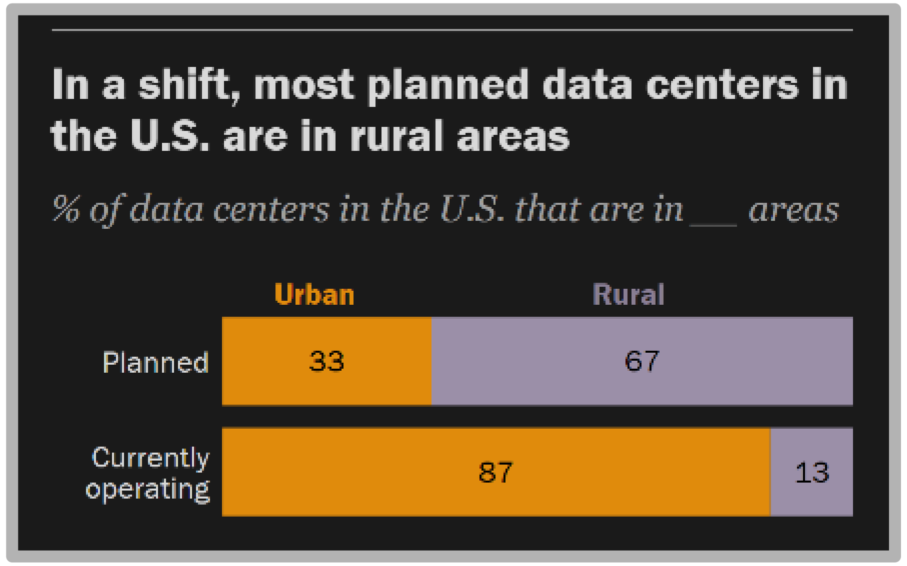
- **Innovation:** Affordability and cost-shifting risk from data center growth is a topic of high urgency. Grid utilization and load flexibility are increasingly discussed as solutions. This conceptual framework offers a resource for utilities, particularly smaller, rural utilities with limited resources, a tool to evaluate how different applications of energy storage compare to other capacity alternatives to meet resource adequacy needs while maintaining or enhancing customer affordability.
- **Duration:** FY26
- **Impact**: This framework will exist as a resource for utilities and other stakeholders who are grappling with the challenge of accommodating significant but uncertain load growth without threatening energy affordability for customers. Smaller and rural utilities can particularly benefit from frameworks to help inform decision-making. This project has been developed with consultation from a Kansas municipal energy agency, who have offered input into salient concerns of rural public utilities facing affordability and resource adequacy challenges as wholesale power prices and data center load continue to increase.
- **Vertical/Investment Area:** Analytics
- **Alignment/Supports strategic pathways:** This project will help grow grid capacity by illustrating pathways for affordable deployment of energy storage needed to accommodate new load.

Data center growth is increasing in rural areas and public power service territories

New and Cumulative U.S. Data Center Load (MW), 2017-2027



Data Source: Cleanview

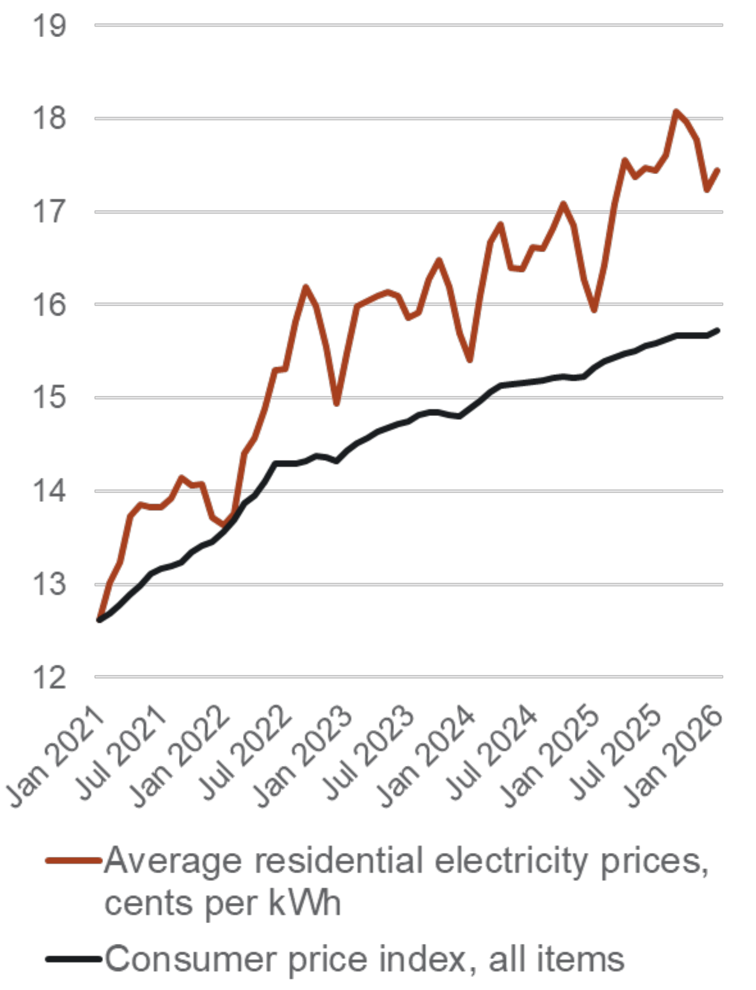


Source: Pew Research Center 2026

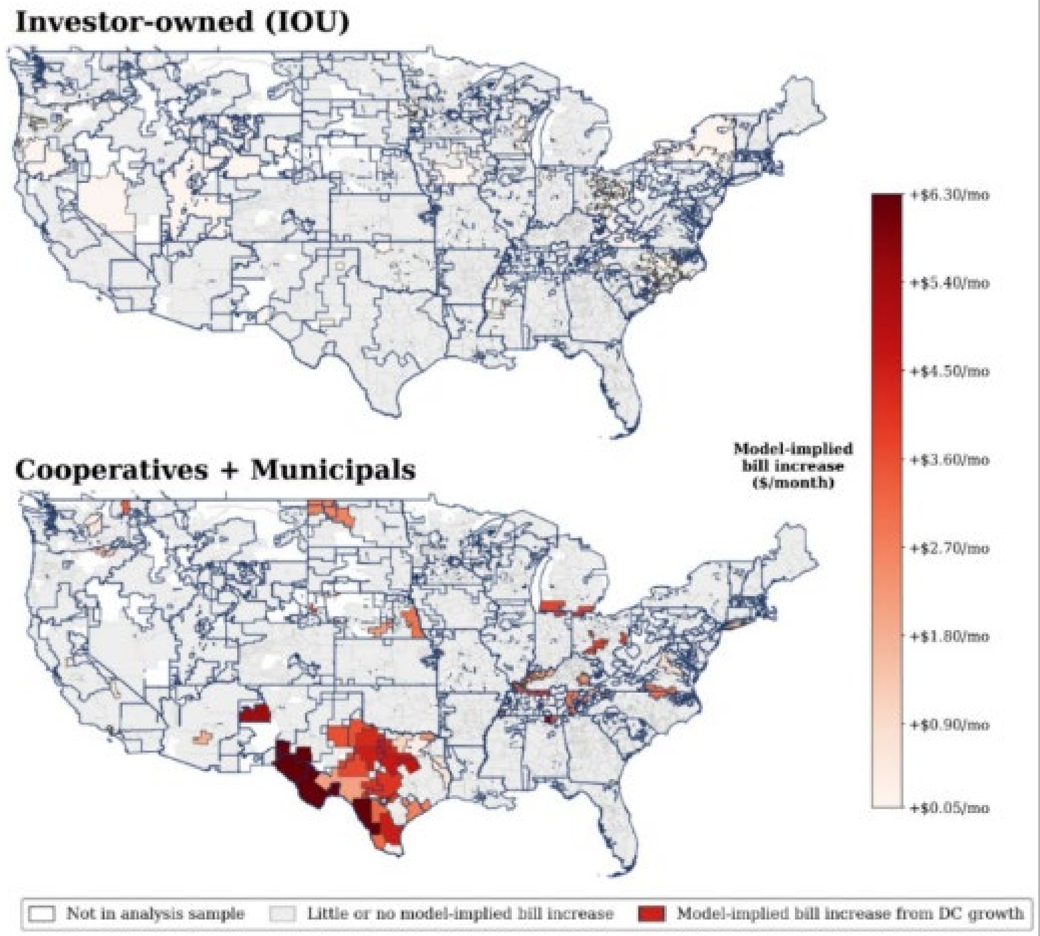
- Forecasts vary, but more than 100 GW of data center load expected to be operational nationwide by end of 2027.
- Several grid operators (e.g. MISO, PJM) predict that load growth will exceed historic system peaks within the next few years.
- Many new data centers are planned in rural areas, a shift from previous trends.
- All utility ownership types are experiencing data center growth.
- Rapid load growth combined with existing capacity constraints (driven by long interconnection delays, supply chain bottlenecks, etc.) have raised resource adequacy risks

Electricity prices are rising. Drivers vary.

Residential Electricity Prices (cents per kWh) vs. Consumer Price Index, 2021-2026



Retail residential price effect of data center growth by utility type and location



Source: Ryu and Hiatt 2026

- Over the last 5 years, national average retail electricity prices have risen approximately **38%** and have outpaced inflation.
- Research has **not** shown data center additions are a major factor in overall residential price increases to date.
- However, one University of Southern California study showed data center entry was associated with modest price increases for **municipal** (0.6%) and **cooperative** (0.4%) utilities, with variation by state and region.

Basic ratemaking principles determine affordability outcomes from load growth

Consider a **very** simplified cost allocation formula:

$$M_0 = \frac{r(B_0) + C_0}{MWh_0}$$

Where:

- B_0 is all fixed capital expenditures (transmission, distribution, generation, etc.)
- r is return on investment
- C_0 is all variable / other costs (operations and maintenance, fuel, purchased power, taxes, etc.)
- MWh_0 is total customer sales
- Costs divided by sales is M_0 , the *average* customer bill (across all customer classes).

Basic ratemaking principles determine affordability outcomes: 3 scenarios

Scenario 1: Data centers add new load (MWh_{DC}) but require no / minimal additional system costs. New average bill (M_1) becomes:

$$M_1 = \frac{r(B_0) + C_0}{MWh_0 + MWh_{DC}}$$

In this scenario, $M_1 < M_0$ and rates are lower for everyone.

When would this happen?

- Efficient grid utilization allows new load to connect using existing resources.
- All costs caused by data center entry are fully allocated to new customers.

Scenario 2: No / minimal load growth, utility costs go up (B_i is incremental cost of system upgrades, C_1 is new variable costs). New average bill (M_1) becomes:

$$M_1 = \frac{r(B_0) + r(B_i) + C_1}{MWh_0}$$

In this scenario, $M_1 > M_0$ and rates are higher for everyone.

When would this happen?

- Many data centers operate off-grid, impacting equipment, fuel, wholesale prices without contributing to utility costs.
- A given utility does not experience load growth but is impacted by broader trends.
- Load growth does not materialize, and other factors drive costs upward.

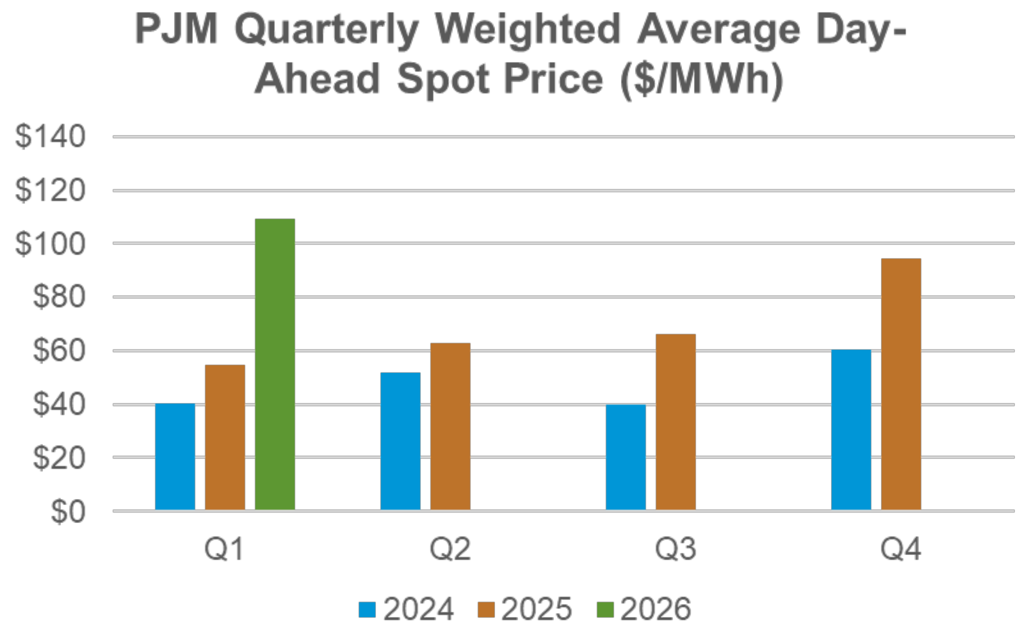
Scenario 3: Data centers interconnect and require additional utility spending (B_{DC} and C_{DC} are incremental costs from new load). New average bill (M_1) becomes:

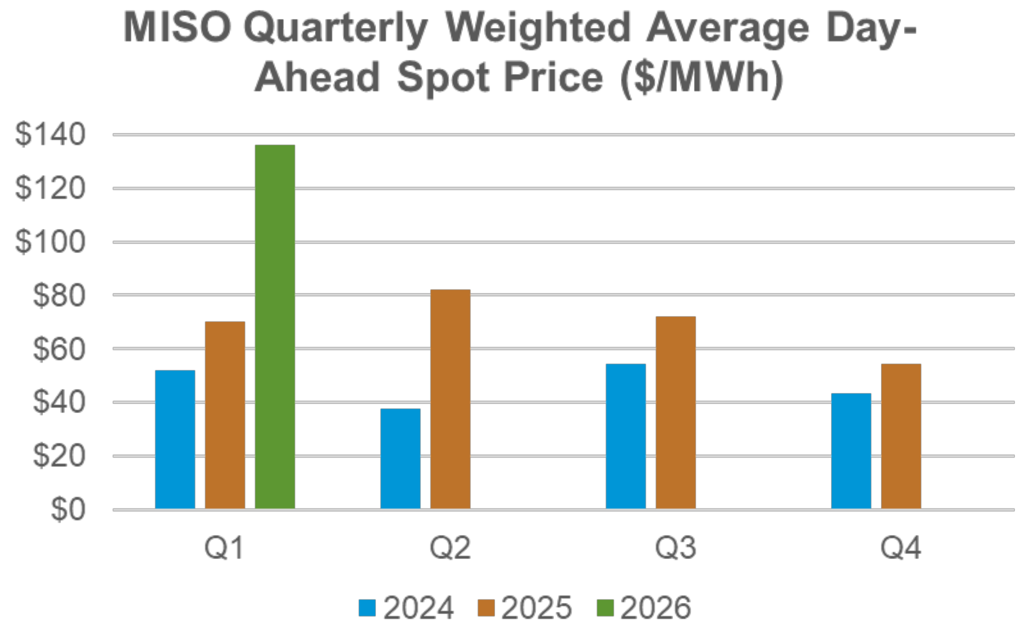
$$M_1 = \frac{r(B_0) + C_0 + r(B_{DC}) + C_{DC}}{MWh_0 + MWh_{DC}}$$

In this scenario, affordability outcomes vary.

- If new demand outpaces new incremental costs, rates will **decrease.**
- If new incremental costs exceed new demand, rates will **increase.**

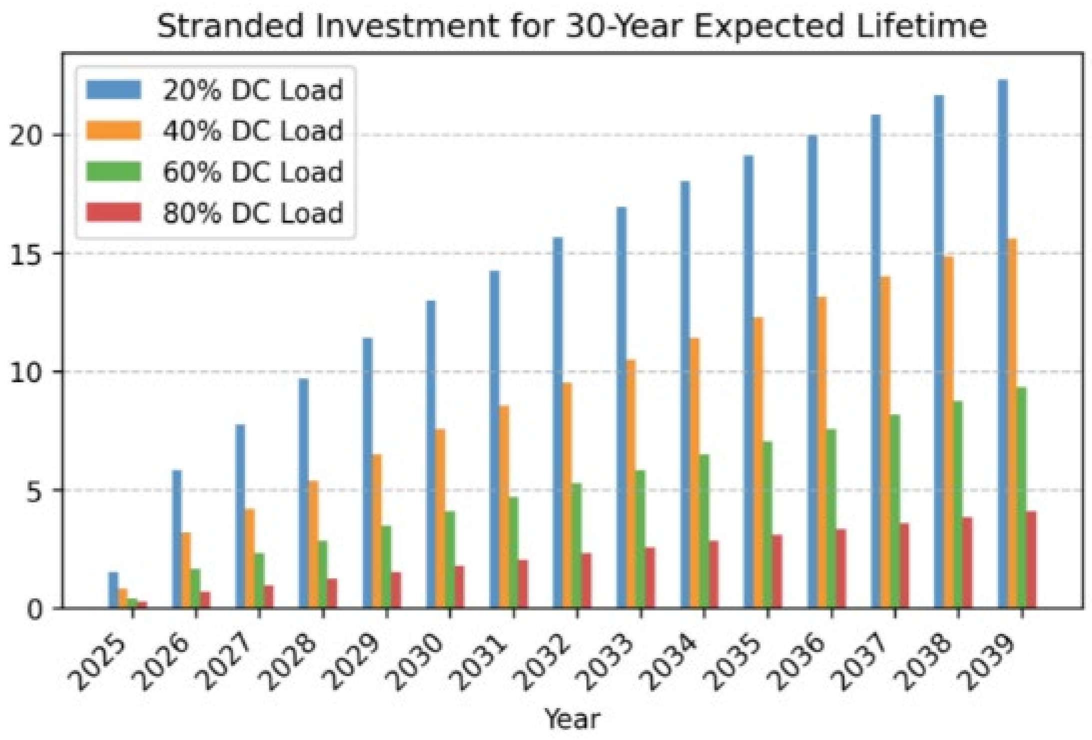
Load growth is impacting wholesale market and equipment prices





- PJM reported a 76% jump in wholesale capacity market prices in Q1 2026 compared to Q1 2025.
  - Capacity shortages driven by increase in data center load were specifically cited as a main driver.
- Data centers have also driven up gas plant capital costs and led to longer lead times as result of high demand, which also impacts market prices.
- Utilities that are more dependent on wholesale market purchases see greater ratepayer impacts from market volatility.

Key affordability factors for utilities



If system investments are made for load growth that does not materialize (even partially), there is a risk of stranded investments for existing ratepayers.

Source: Acharya et al, Measuring the Cost of Potential Stranded Assets from Speculative Large Load Interconnection Requests, PNNL 2025

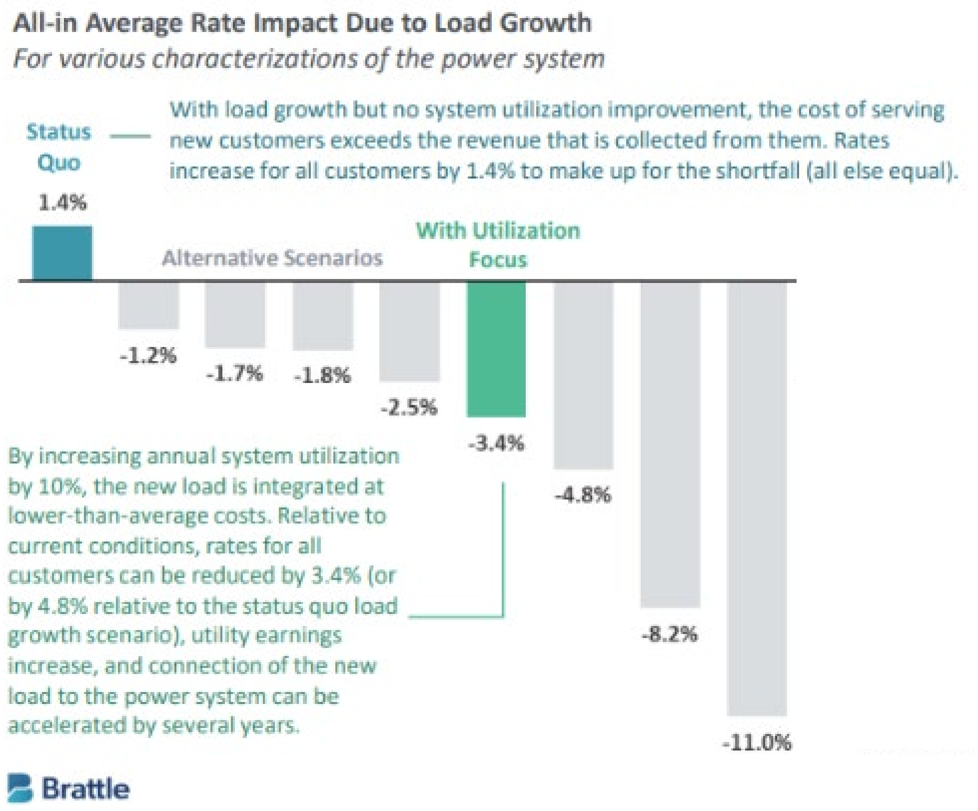
Some key factors that can increase or decrease cost shift risk:

- High-cost, long lead time system investments vs. uncertain load forecasts
- Exposure to volatile wholesale market prices
- Tariff design (new customer classes, cost allocation methods, take-or-pay contracts, etc.)

Utilities that can hedge against these risks are more likely to see ratepayer benefits from data center growth.

Energy storage has a role to play.

Grid utilization is an affordability opportunity. Batteries can help.



Source: Brattle Group 2026

- Estimates vary, but average grid utilization likely 50-65% of peak system capacity. *Higher utilization = better affordability outcomes.*
  - Norris et al (2025): 0.5% curtailment enables 96 GW new load. Brattle (2026): 10% more utilization could reduce rates >3%.
- **Energy storage can help.**
- **Cost deferral:** Utility-scale energy storage can defer utility investments in high-cost infrastructure + increase off-peak use of existing assets.
  - Can be sized to meet incremental increases in peak demand. BESS are modular and can be scaled with relative ease.
  - Additional revenue streams help offset upfront costs (ancillary services, arbitrage, etc.)
  - Reduces overbuild and stranded asset risk.
  - Aggregations of small-scale BESS can provide similar functions plus resilience benefits for customers.
- **Flexibility:** Behind-the-meter (BTM) energy storage can enable loads to curtail grid use at peak demand.

Energy storage peak shaving can hedge against market volatility

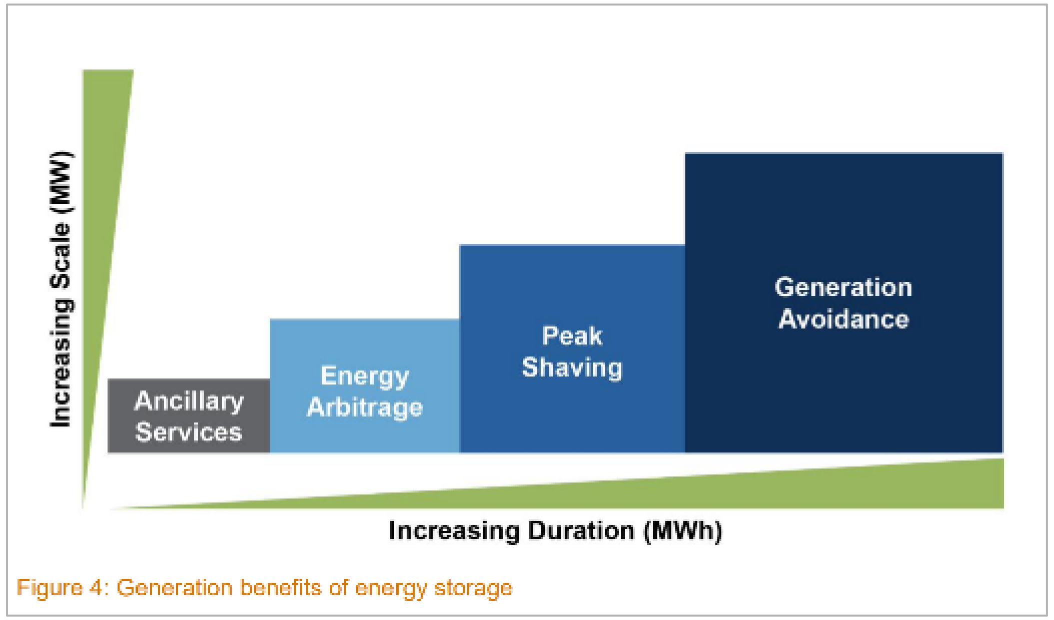
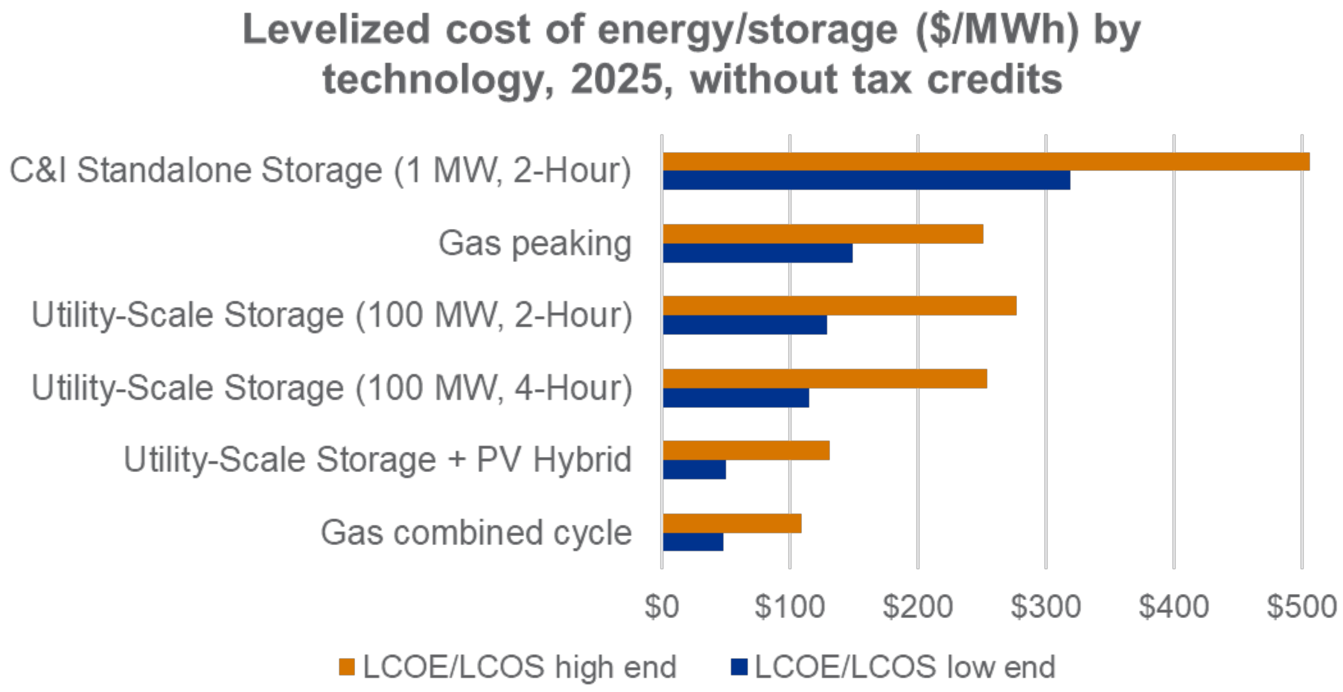


Figure 4: Generation benefits of energy storage



Sources: Twitchell et al, PNNL, 2026; Lazard 2025

- Discharging BESS (utility-scale or aggregation) can be alternative to expensive spot market purchases at peak demand
- BESS can "shave" system peaks, reducing demand charges and overall system prices
  - Curtailment of large loads with BTM BESS can also reduce system peaks
- BESS are cost-competitive with expensive peaker plants *and* reduce fuel costs
  - Example: municipal utility in Kansas uses BESS as peaker, saved $3000/month in summer diesel costs

Summary: different BESS configurations offer different benefits and tradeoffs

Front-of-the-meter (FTM) utility-scale BESS	Behind-the-meter (BTM) BESS at data center	Aggregations of small customer-sited BESS
• Large-scale batteries sited on utility side of meter; may be transmission or distribution-connected • Can be sized to meet incremental forecasted peak demand increase • Costs recovered from ratepayers • Costs can be partially offset by market revenue in some regions • Savings: Hedge against wholesale market prices, peak shaving, can defer system upgrades • Lower capital costs per kW / kWh than smaller systems • Larger projects may face interconnection, permitting delays	• Battery sited at data center on customer side of meter • Costs borne by data center, not ratepayers • Not utility asset for other grid needs, utility does not earn market revenue • Can enable data centers to curtail loads at peak demand, increasing utilization and reducing new costs • Enabling technologies and software can help battery offer real-time reliability support, including load smoothing and voltage support • Faster to deploy than FTM systems; reduced interconnection and permitting challenges	• Consumer-sited small BESS can be aggregated • Relatively low costs shared by customers, utility, aggregator; approaches vary • Aggregator and participants earn revenue; customers can receive incentives for participation • Enables direct flexibility for participating loads; can support peak shaving, defer system upgrades • Resilience benefits for participants • High operational complexity for aggregation, requires software and enabling technologies • Ability to meet grid needs depends on scale; consider utility size and DER adoption levels • Can be very quick to deploy; minimal interconnection and permitting challenges

(These options are not mutually exclusive.)

Storage vs. selected alternatives: utility assets

Approach	Ratepayer Costs	Stranded Asset Risk	Deployment Timeline	Key Benefits	Key Risks and Dependencies
Traditional Utility Investments (includes T&D, generation, peaker plants, etc.)	**High.** Capital costs recovered from ratepayers. Many component costs are rising. Capex for, e.g., gas plants is near $2000/kWh. Other system upgrade costs vary.	**High**	**Slow.** Significant interconnection, permitting, supply chain delays.	Guaranteed resource adequacy; can earn return on investment	Supply chain constraints increasing component prices; fuel price volatility; new generation assets may require transmission infrastructure, which is difficult and costly to build; long timelines; high risk of stranded assets
Wholesale Power Market Purchases	**High.** Impacted by volatility. Prices higher at peak demand.	**None**	**Fast.**	Utility does not need to procure own resources to supply needed capacity; smaller utilities can benefit from economies of scale	Rising costs and increasing market volatility raise costs for ratepayers and create uncertainty.
FTM BESS (Utility-Owned)	**Moderate.** Capital costs per kWh are relatively high but decreasing. Total cost of meeting given need can be cheaper than traditional alternatives, especially with incremental deployment.	**Low.** Can scale incrementally, deferring larger upfront investments.	**Moderate.** Larger systems risk interconnection, permitting delays.	Can defer costly investments with peak shaving; utility can earn market revenues from arbitrage, ancillary services, etc; potential for lower capital costs than traditional alternatives; grid reliability benefits; offers protections against speculation and market price volatility; can earn return on investment	If transmission-connected, utility-scale BESS subject to interconnection queue delays; revenue streams (arbitrage, ancillary services) vary, are declining in some markets.
Aggregation of Customer-Sited BESS	**Low.** Costs include program operation, customer incentives, and enabling technologies and software.	**None**	**Fast**, and can scale as participants join.	Can defer costly investments with peak shaving; can be very inexpensive; grid reliability benefits; offers protections against speculation and market price volatility; resilience benefits for participants	Operational complexity; requires enabling technologies and role of aggregator; resource adequacy benefits depend on scale, limited by customer base; depends on customer participation.

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BESS offers benefits to utilities and data centers compared to alternatives

Consideration	Traditional Solutions	BTM Gas Generation (Customer-Sited)	BTM BESS (Customer-Sited)	FTM BESS (Utility sset)	Aggregated Customer-Sited BESS
Avoids new costs for other ratepayers?	No, but tariff design determines allocation between customer classes	Yes; customer asset does not impact rates	Yes; customer asset does not impact rates	No, but lower costs mean lower risk of significant cost shifts; tariff design determines allocation between customer classes	Yes
Avoids stranded asset risk?	No	Yes; customer asset outside of rate base	Yes; customer asset outside of rate base	Likelihood of stranding reduced; modular nature of BESS reduces risk of overbuild	Yes
Offers firm grid capacity?	Yes	Maybe, depending on interconnection agreement	Maybe, depending on interconnection agreement	Yes, can be dispatched as generation	Yes, can be dispatched or generation or demand response, depending on configuration
Opportunity to earn market revenues (ancillary services, arbitrage)?	No	Potential energy/capacity revenues for customer, depending on size, interconnection, market structure	Maybe, for customer; potential energy/capacity, ancillary services, arbitrage; may require aggregator; depends on size, interconnection, market structure	Yes, energy/capacity, ancillary services, arbitrage revenues; opportunities vary by market	Yes, for customers and aggregator; aggregators can bid into markets; potential energy/capacity, ancillary services, arbitrage
Improves system utilization?	No	No	Yes; enables DC load flexibility / curtailment with minimal impact to operations	Yes; can provide peak shaving benefits	Yes; enables distributed load flexibility
Enables data center load flexibility?	No	Yes, if deployed as backup power; less responsive than BESS options	Yes, rapid load shifting possible with enabling technologies	Not directly	Not directly, unless data center-sited BESS included in aggregation
Offers smoothing for fluctuating AI loads?	No	No	Yes	Not directly	Not directly, unless data center-sited BESS included in aggregation
Offers voltage fault ride-through capabilities?	No	No	Yes, if grid-connected and fault caused by data center load	Yes	No
Offers resilience benefits during grid outages?	No	Yes, to customer	Yes, to customer	No	Yes, to participating customers

Considerations for rural utilities

- Customers can see positive rate impacts if data centers are grid-connected and investments needed to accommodate them do not rise higher than certain load growth.
  - Off-grid data centers add to planning uncertainties and eliminate possibility of rate benefits from significant load growth, especially for utilities currently facing asset condition and reliability challenges.
- Case studies of utility-scale BESS deployed as affordable non-wires alternative (NWA) to traditional utility investments exist in rural areas: wires upgrades can be more expensive if over longer distances, rugged terrain (e.g. Punkin Center, AZ)
- Aggregated BESS have potential: can be deployed quickly and offer benefits to many customers.
  - However, rural and smaller territories are less likely to have existing assets, programs, and enabling technologies needed to deploy programs at a scale large enough to meet load growth needs.

Conclusions and next steps

- **Data center rate impacts vary:** Protecting affordability means minimizing expenses relative to growth.
- **Energy storage increases grid utilization and hedges against market volatility:** Energy storage can help utilities minimize exposure to price spikes and defer investments, avoiding cost shifts and enabling ratepayer benefits from load growth.
- **Different storage models offer different benefits:** FTM systems can be operated by utility and offer grid benefits and revenue streams; aggregations can be inexpensive and offer resilience benefits if feasible at scale; BTM systems enable flexibility, reliability, and speed to power
- **Non-technical factors have key role:** Regulatory frameworks (e.g. battery ownership options), tariff design (e.g. cost allocation approaches for large loads), market conditions (wholesale power prices, revenue streams for ancillary services and arbitrage), and supply chain considerations (component delays, fuel costs) significantly impact outcomes.
- **Opportunities for future analysis:** Future efforts could build on this framework to model different scenarios for representative utility and data center(s).

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Thank you

Devyn Powell
devyn.powell@pnnl.gov
(509) 375-6543

Considerations for different capacity solutions in the context of large load growth

Approach	Summary	Ratepayer impact	Deployment timeline	Benefits	Risks and challenges	Needs or dependencies
Utility-led Planning and Procurement	Utility procures new generation via self-supply or long-term bilateral contracts, and builds new transmission / distribution infrastructure as required to increase grid capacity to meet forecasted peak	**High.** Capex for gas plants (est. $1300-$1700/kW; varies on type), plus fuel costs; system upgrades vary; new transmission lines or reconductoring can cost billions. Cost allocation approaches determine share of impacts to residential and other customers. Timeline mismatch and forecasting uncertainty raise stranded asset risk.	**Slow.** Procurement, permitting, construction, interconnection. Can be 5-10 years for utility-scale generation; up to 15+ years for major transmission siting and construction.	Guaranteed resource adequacy; utility earns rate of return on capital expenditures.	Supply chain constraints increasing component prices; fuel price volatility; new generation assets may require transmission infrastructure, which is difficult and costly to build; long timelines; high risk of stranded assets if data center load exits.	Resource needs based on load growth forecasts; impacted by forecast uncertainty.
Wholesale Power Market Purchases	Utility purchases power from wholesale market at market price to meet resource adequacy needs (assuming adequate transmission capacity). Can include long-term power purchase agreements (PPAs) and short-term market purchases.	**High and volatile.** Wholesale prices are increasing given supply constraints and rising demand. PJM, e.g., saw 76% increase in wholesale electricity prices from Q1 2025 to Q2 2026.	**Fast**. Long-term PPAs require contract between utility and power producer. Short-term market purchases are quick by definition.	Utility does not need to procure own resources to supply needed capacity; smaller utilities can benefit from economies of scale.	Rising costs and increasing market volatility raise costs for ratepayers and create uncertainty.	Prices and market structures vary by region, with some markets seeing higher price increases and greater volatility.
FTM BESS (Utility-Owned)	Utility procures grid-scale battery storage (4-hour duration typical). Can be operated as generation, transmission, and/or distribution asset, and can be alternative to costlier peaker plants.	**Moderate.** Capex for BESS (est. $1500/kW); system upgrades vary. Cost allocation approaches determine share of impacts to residential and other customers.	**Moderate.** Procurement, permitting, construction, interconnection. Timelines may be 2-4 years, potentially more if interconnection or other factors cause delays.	Can improve grid utilization; can defer costly investments with peak shaving; market revenues from arbitrage, ancillary services, etc.; potential for lower capital costs than traditional alternatives; utility earns rate of return on capital expenditures.	If transmission-connected, utility-scale BESS subject to interconnection queue delays; revenue streams vary and are decreasing in some markets.	Regulatory and market structures impact use cases, participation opportunities; scale and duration of peak load impact viability.
BTM BESS (Customer-Sited)	Data center funds, owns, and operates on-site energy storage. Acts as backup power, enables curtailment in exchange for faster interconnection, and offers reliability benefits.	**None.** Asset costs paid by developer.	**Fast.** 12–24 months; BTM projects bypass transmission interconnection bottlenecks.	Faster speed to power for customer than grid alone; provides backup power; avoids or reduces need for system upgrades; can be firm capacity; offers grid stability benefits in face of power fluctuations.	Peak shaving value requires customer participation; utility likely does not earn market revenue; utility cannot use for other needs; lost value if data center exists.	Value to grid depends on tariff design, interconnection agreements.
BTM Gas Generation (Customer-sited)	On-site turbines for primary or backup power.	**None.** Asset costs paid by developer.	**Moderate to fast.** BTM gas can be operational in 1–3 years, depending on supply chain constraints and permitting; BTM projects bypass transmission interconnection bottlenecks.	Reliable firm power source for customer; avoids or reduces need for system upgrades; faster speed to power for customer than FTM options.	Supply chain constraints and component cost volatility; risk to utility revenue and planning certainty if large load customers operate off-grid; utility cannot use for other needs; lost value if data center exits.	Considerations vary depending on whether customer is fully self-supplied or will also pursue grid interconnection.
Aggregation	Small residential/C&I batteries aggregated to provide grid-scale capacity.	**Low.** costs of program operation, customer incentives, and enabling technologies and software	**Fast if resources exist;** program can scale as participants enroll.	Aggregated DERs enable flexibility and improve grid utilization with few or no additional capital investments; fast deployment if resources and capabilities in place; local resilience benefits.	High operational complexity; may require deployment of enabling technologies; relies on voluntary customer participation; consider viability at scale for given context.	Effective deployment requires enabling technologies, aggregator; regulatory frameworks; tariff and incentive design.

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