Powering Reliability Through Market Design in PJM: Enabling Long Duration Energy Storage (LDES) in PJM

LDES Council White Paper in Response to PJM's *Powering Reliability through Market Design*

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Introduction and Summary

The LDES Council appreciates PJM's efforts to examine the design of its capacity market. The LDES Council is a global organization focused on accelerating the deployment of long duration energy storage (LDES) technologies, defined as a class of technologies that store energy and dispatch it as power, heat, or cooling for 8 hours or longer. We submit this white paper in response to PJM's *Powering Reliability Through Market Design* paper to provide the perspective of rapidly advancing technologies that are ready to be deployed to ensure long-term resource adequacy and affordability for the region. Because of supply shortfalls and risks to reliability from weather, PJM requires resources like LDES that can provide firm, dispatchable capacity, strengthen grid resilience, reduce the need for costly generation and transmission infrastructure, and lower long-term system costs. The workshops and paper on Powering Reliability Through Market Design are an opportunity for PJM's market design to ensure long-term and cost-efficient resource adequacy by scaling LDES in PJM as *critical infrastructure*.

However, PJM's current market design creates barriers to LDES deployment through revenue uncertainty in its merchant market, interconnection delays, and capacity accreditation methodologies that do not fully recognize the reliability value of long-duration resources. PJM's reforms must enable long-term contracts and revenue certainty, as well as proactive and forward-thinking centralized planning to enable LDES participation. In response to the proposed

pathways in PJM's *Powering Reliability through Market Design,* the LDES Council supports PJM's near-term Path A to expand long-term contracting while incorporating targeted elements of Path B to enable flexible large loads, but emphasizes that both pathways must be paired with interconnection and ELCC reforms to ensure LDES is accurately valued and bankable. On Path C, PJM should ensure that greater reliance on merchant Energy & Ancillary Services revenues does not undermine the long-term revenue certainty needed to finance capital-intensive LDES resources.

What LDES is and Why PJM Needs LDES Participation

What is LDES?

Long duration energy storage (LDES) refers to storage technologies capable of discharging electricity for 8 hours or longer, including both intraday and multi-day. These technologies are diverse, ranging from electrochemical, thermal, mechanical, to chemical systems. While short-duration energy storage (SDES, also known as BESS) and LDES are both valuable grid resources, they serve different functions within a modern electricity system. Short duration storage is effective for daily energy shifting, ancillary services, and managing short periods of peak demand. However, LDES addresses a different set of challenges, including prolonged peak demand periods, extended renewable energy shortfalls, extreme weather events, and emerging reliability needs associated with electrification and load growth.

How PJM Compares to Other Entities on LDES Deployment

LDES technologies are already deployed across the U.S. and a growing number of states are adopting policies to support their procurement and integration, including PJM states. Most operational projects are concentrated in states such as California and New York, with developers facing significant market and regulatory barriers within PJM. In NYISO, the state-backed Index Storage Credit (ISC) implements a revenue framework to achieve 6 GW of energy storage in the market by 2030. Virginia recently passed a landmark storage bill requiring 4.5 GW of LDES technologies by 2045 to be procured by Dominion Energy and Appalachian Power within the PJM territory. Pennsylvania has legislation pending in the House chamber that targets both intraday and multiday LDES with a Senate version planned in late 2026, early 2027. States are realizing the need for LDES resources in their portfolio as they hope to achieve resource adequacy among rising electricity demand – we now need grid operators to realize the importance of properly accounting for their costs, reliability value through capacity accreditation, and interconnecting them quickly. PJM must use this moment of reform as an opportunity to understand how their rules can help bring on new resources instead of hindering them.

Why PJM Needs LDES

As PJM confronts rapid load growth, generator retirements, and increasingly frequent extreme weather events, LDES has become an essential resource for the following three reasons, which we will discuss individually: 1) maintaining resource adequacy, 2) reducing the need for

costly infrastructure and lowering system costs, and 3) strengthening grid resilience to extreme weather.

First, long duration storage resources are essential infrastructure assets that provide reliability and capacity value to the grid. Specifically, LDES addresses resource adequacy in PJM by:

1. **Providing firm, dispatchable capacity during extended reliability events.** LDES can discharge for multiple hours or days, supplying energy through prolonged periods of high demand, renewable shortfalls, or generator outages when shorter-duration resources are depleted.
2. **Reducing the risk of energy supply shortfalls.** Because PJM measures resource adequacy using probabilistic reliability metrics such as Loss of Load Expectation (LOLE) and Expected Unserved Energy (EUE), LDES improves reliability by reducing the likelihood and magnitude of unserved energy during system stress events.
3. **Maintaining reliability as load and renewable penetration increases.** As electricity demand grows and the grid relies on more variable renewable generation, LDES provides the flexibility needed to balance supply and demand over longer time horizons.

Importantly, longer duration resources can often provide equivalent reliability outcomes with fewer installed megawatts because they can sustain output for significantly longer periods. The 2025 report, *Outlook for Energy Storage in PJM*, conducted by the Brattle Group, found that storage is one of the most cost-effective technologies to address PJM's resource adequacy. The study found that within the next 7 to 15 years, PJM will require 16 to 23 GW of storage to

address PJM's resource adequacy needs and state goals. Long-term concerns over resource adequacy spawn an imperative for PJM to address barriers in its market structure and rules for energy storage.

LDES supports a more reliable and cost-effective resource mix. By providing multi-hour and multi-day energy shifting, LDES complements other generation resources, reducing the need for excess capacity procurement. Long duration resources also reduce the amount of upgrades and investment in costly transmission and plant infrastructure, lowering overall system costs. LDES technologies reduce transmission constraints and absorb excess renewable energy, opening up additional capacity for subsequent projects to connect, and reducing the need for grid upgrades and investment. PJM should therefore view interconnecting LDES as an opportunity to cost-effectively maximize the existing grid assets and shore up its system in the long run with LDES serving as critical infrastructure.

Lowering systems costs in PJM requires accurate technology cost assumptions. As energy storage systems evolve, the way storage costs are calculated influences how technologies are evaluated in planning and modelling analyses. When long duration energy storage is assessed using assumptions developed for short-duration technologies, its cost characteristics may not be well represented for extended-duration applications. According to a 2026 study conducted by the LDES Council in partnership with Electric Power Research Institute (EPRI), *Cost Benchmarking for Long Duration Energy Storage Solutions*, technology costs are declining for all types of LDES technologies between 2025 and 2030, up to 47%. The report presents costs on a consistent basis across a wide range of LDES solutions, providing practical insights for long-term planning, modeling, and policy design. Updating cost assumptions to reflect the rapidly improving

economics of LDES will help PJM identify more affordable reliability solutions and reduce long-term costs for consumers. LDES technologies are rapidly advancing and PJM's rules should match that reality.

Finally, PJM needs LDES resources because LDES strengthens PJM's resilience to increasingly prolonged weather events by sustaining energy delivery through multi-day heat waves, winter storms, and periods of low wind or solar generation. For example, long duration resources are necessary to provide significant capacity value during summer heat waves like the Hot Weather Alert PJM issued on June 30, through July 3, which will potentially break the region's demand record set in 2006. The Brattle Group's *Outlook for Energy Storage in PJM* (2025) found that PJM could avoid up to 15 GW of load shed risk during challenging system conditions in 2032, such as extreme cold snap periods. LDES deployment would ensure that PJM addresses resource adequacy cost-effectively. As PJM evaluates pathways to achieve its resource adequacy and affordability goals, maintaining a diverse portfolio that includes both BESS and LDES will help PJM meet its reliability standard under evolving grid conditions.

Why PJM Should Pursue a Combination of Path A and B

LDES Council Supports Path A To Provide the Revenue Certainty Needed for LDES

The LDES Council supports the near-term implementation of PJM's **Path A**, which would require utilities to secure more long-term contracts. Mechanisms that provide long-term revenue visibility and stability are critical for reducing investment risk and overcoming insufficient revenues from energy and capacity markets. Instruments such as contracts for

difference (CfDs), long-term utility procurement, capacity payments, and government-backed financial guarantees improve project bankability by providing predictable revenue streams beyond those available through merchant markets alone. For example, California provides revenue certainty to LDES projects through long-term utility procurement and centralized solicitations; California's Integrated Resource Planning is a planning approach that has already successfully connected LDES to the grid, such as the Tumbleweed Energy Storage facility that provides up to 8 hours of continuous discharge, or Hydrostor's Willow Rock Energy Storage Center that provides 8 hours of continuous discharge with capacity of 500 MW / 4000 MWh. In Canada, Ontario's IESO grid operator has issued a long-lead time RFP, allowing technology types with long lead times with great MWh capacity to be procured with up to 40-year contracts. Greater use of long-term hedging and forward commitments would reduce revenue uncertainty for LDES projects, improve bankability and investment certainty, and preserve PJM's shared reliability framework. If PJM maintains a predominantly merchant market rather than transitioning toward long-term utility planning, it is essential that its capacity market accurately compensate the true reliability contributions of LDES resources through appropriate accreditation methodologies so that these resources can attract the investment needed to meet future resource adequacy needs.

Path B Can Unlock Large-Load Flexibility Through LDES

At the same time, the LDES Council recognizes the value of targeted elements of Path B, which would prioritize the rationing of scarce capacity during periods of system stress. Path B

addresses an emerging reliability need that Path A alone cannot solve: enabling rapidly growing large loads to provide flexibility to the grid. As PJM experiences unprecedented load growth from data centers and other large electricity consumers, reforms that facilitate flexible interconnection arrangements and appropriately recognize the reliability contribution of behind-the-meter (BTM) LDES would help integrate new load more quickly without compromising reliability. Large loads increasingly seek resilient, around-the-clock power, creating an opportunity for PJM to enable LDES to interconnect alongside these facilities and provide the flexibility needed to sustain critical operations through multi-day reliability events while reducing reliance on the shared grid during periods of scarcity. This model is already emerging in the market, with Google partnering with Arizona's Salt River Project (SRP) to procure LDES in support of its 24/7 carbon-free energy goals, and Meta partnering with Noon Energy to develop 1 GW of 100+ hour energy storage capacity.

Markets should also send wholesale price signals that reward large loads and flexible technologies, including power-to-heat LDES, for responding to grid dispatch instructions. Large electricity consumers capable of responding to dispatch signals can provide valuable reliability services comparable to those of traditional generation, giving grid operators additional tools to maintain reliability during extreme conditions while reducing overall electricity costs. Rather than treating large loads solely as consumers of reliability, these reforms would enable them to become providers of flexibility during prolonged system stress. Large loads that can shift demand away from peaks because of LDES lowers system costs, benefiting PJM and ratepayers. However, without the right price signals to compensate this flexibility, large load customers will have insufficient incentive to do so.

Why PJM Should not Pursue Path C, as it is Currently Proposed

Path C Must Preserve the Financeability of LDES Investment

On Path C, we are concerned that shifting more revenue recovery toward merchant Energy & Ancillary Services revenues, without a durable long-term contracting framework, could materially weaken the investment case for LDES resources. LDES projects are capital-intensive infrastructure assets with long development timelines, long operating lives, and significant upfront financing needs. While these resources can provide high-value reliability services, they cannot be financed on the basis of uncertain and episodic scarcity revenues alone. As PJM evaluates Path C, it should apply a core financeability test: whether the resulting market design can support investment-grade, long-term revenue certainty for resources that provide extended-duration reliability value.

Specific Market Design Areas that Should be Included in the Market Scope

PJM's capacity market design reforms should address barriers to participation from reliable resources and should be included within the market scope. LDES deployment in PJM remains limited by longstanding regulatory and market design barriers, including **revenue uncertainty, interconnection delays, and capacity accreditation methodologies** that do not fully recognize the reliability value of long duration resources. Considered together, these reforms can create a more durable investment framework for resources capable of providing extended-duration reliability.

Revenue Uncertainty

PJM's merchant market structure creates significant revenue uncertainty for LDES developers because investment decisions depend on annual capacity auctions and volatile wholesale market revenues rather than long-term contracted income. The LDES Council agrees with PJM that “Long-term revenue certainty is a structural requirement, not a preference” (page 31). The LDES Council’s *Report on Accelerating LDES Bankability: A Practical Framework for Overcoming Obstacles to Investment in Long Duration Energy Storage* finds that investors do not finance in isolation; they finance according to durability, regulatory certainty, and contract type, in addition to high revenue. While PJM acknowledges that today's market conditions require greater investor certainty to bring new resources online, the current framework was designed for an era of predictable load growth and shorter development timelines. Additionally, political intervention has undermined confidence in the materialization of future revenues. As a result, many LDES projects, which have long development and financing horizons, struggle to secure financing despite providing substantial reliability benefits. PJM's proposed Path A, which expands the use of long-term contracts, would help address this "missing money" challenge by providing more stable revenues while reducing price volatility for customers.

Interconnection Delays

Interconnection delays have become one of the largest barriers to storage deployment in PJM, preventing new resources from reaching the market quickly enough to meet rapidly growing demand. Lengthy queue timelines, uncertainty around network upgrade costs, and slow

study processes delayed projects for years while supply shortages worsened. PJM, FERC, and other stakeholders have recognized these delays as a major contributor to resource adequacy challenges, prompting reforms such as FERC Order 2023, PJM's temporary Expedited Interconnection Track (EIT), and broader transmission planning initiatives. The reforms are improving the process for projects ready in the queue - over 66.5GW of energy storage applied to connect to the grid through the first Cycle of PJM's reformed process, demonstrating how quickly and ready energy storage is to be deployed in PJM - however, most storage projects in the queue remain short duration storage. To ensure LDES can compete, PJM should establish procurement pathways that allows in projects not yet in the interconnection queue, reduce minimum project size requirements where appropriate, and recognize the longer development timelines associated with many LDES technologies. Accelerating interconnection for longer duration storage resources remains essential to ensure LDES can provide reliability to the PJM system. Long duration resources can reduce transmission constraints and absorb excess renewable energy, which would open up additional capacity for subsequent projects to connect, and defer or avoid the need for grid upgrades and investment. PJM should therefore view interconnecting LDES as an opportunity to maximize the existing grid assets and shore up its system in the long run with LDES serving as critical infrastructure.

Capacity Accreditation

PJM's transition to marginal Effective Load Carrying Capability (ELCC) represents an important step toward valuing resources based on their contribution to reliability across all hours

of the year rather than only peak demand. However, because ELCC methodologies continue to evolve, there is a risk that they may not yet fully capture the reliability value of long-duration storage during prolonged system stress events. While UCAP, as derived through ELCC methodologies, provides a consistent framework for accreditation, it may not fully reflect the ability of certain resources to sustain output across longer-duration system stress events. PJM's own analysis shows that ELCC values of short duration (~4hr) storage resources will likely continue to erode. If LDES is systematically undervalued through capacity accreditation, projects receive lower capacity revenues than their true contribution to resource adequacy warrants, weakening investment signals in a market that relies on merchant revenues.

As PJM reforms its capacity market, continued refinement of ELCC methodologies is essential to ensure that duration, operational flexibility, and extended energy delivery are accurately reflected in capacity accreditation and compensation. Specifically, PJM should add categories for longer duration resources, including 16 hours, 24 hours, 48 hours, 72 hours, and 96 hours.

Conclusion

Overall, PJM's reforms must enable long-term contracts and revenue certainty, as well as proactive and forward-looking centralized planning, to enable LDES participation. These approaches would improve investment certainty for LDES while enabling the technology to provide the differentiated reliability increasingly demanded by large electricity consumers. No single reform path will be sufficient unless paired with measures that address the remaining barriers to LDES deployment, particularly faster and more flexible interconnection processes and

capacity accreditation methodologies, such as marginal ELCC, that more accurately reflect the reliability contributions of long duration resources.

As PJM confronts rapid load growth, generator retirements, greater reliance on variable generation, and increasingly prolonged extreme weather events, LDES can play a critical role in maintaining resource adequacy and lowering system costs. LDES can help PJM meet its evolving reliability needs cost-effectively by providing firm, dispatchable capacity over extended periods, maximizing the use of existing grid infrastructure, and sustaining energy delivery through prolonged system stress.

By modernizing its market design to better recognize, compensate, and integrate LDES, PJM can unlock investment in a diverse portfolio by modernizing its market design to better recognize and compensate LDES, a market that encompasses long duration resources that complements shorter-duration storage and other generation resources. Integrating LDES into market design considerations will ensure PJM's electricity system is prepared to reliably and affordably meet the demands of a rapidly changing grid.