

## Webinar Q&A for “The Road Forward for Medium- and Long-Duration Energy Storage”

This document contains answers to questions asked during the 9/9/2026 webinar “The Road Forward for Medium-and-Long Duration Energy Storage.” Slides and a recording of this webinar are available here: [www.cesa.org/event/the-road-forward-for-mdes-ldes](http://www.cesa.org/event/the-road-forward-for-mdes-ldes)

Answers written here are provided by Will McNamara, Technical Systems Analyst at Sandia National Laboratories. With follow up questions, please contact Will at [jwmcnam@sandia.gov](mailto:jwmcnam@sandia.gov).

**1. How are durations of LDES installations calculated to account for variability in grid demand? What averaging and weighting of grid demand is used?**

**Answer:** LDES durations are determined largely using 8760 models that analyze short-falls in variable power generation assets. LDES is typically sized to achieve a target capacity factor or firming percentage. This practice varies from utility to utility.

**2. You say that 15GWh was built in 2025 alone, but total installed capacity is only 15-17GWh? How could that be the case? Unless nearly 100% of all installed capacity was deployed in 2025.**

**Answer:** The reference to 15 GWh is a global statistic. In other words, the reference should have stated that “Global LDES installations exceeded 15 GWh in 2025, a 49% year-on-year increase.” This is based on Wood Mackenzie data that was published in March 2026<sup>1</sup> (see citation below).

In the U.S. specifically, the total installed capacity of LDES—for this purpose defined as systems capable of continuous discharge for 8 to 10 hours or more—in the U.S. is approximately 22 to 23 GW which is almost entirely comprised of pumped storage hydropower). This is according to data from the Energy Information Administration (EIA). While overall U.S. energy storage additions reached record highs in the last year—surpassing 57–58 GWh total in 2025 (largely driven by short-to-medium duration

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<sup>1</sup> “Long-duration energy storage installations surge 49% in 2025 but sector faces critical financing crunch.” Wood Mackenzie. March 9, 2026. <https://www.woodmac.com/press-releases/ldes-2025-outlook/>

lithium-ion battery systems)—dedicated LDES technologies like compressed air, thermal storage, and flow batteries still make up a small fraction of domestic capacity.<sup>2</sup>

**3. What are the safest and most affordable metal ions to be used for LDES and MDES development?**

**Answer:** The safest and most affordable metal ions for these technologies include Iron, Zinc and Sodium.<sup>3</sup>

**4. Where is the Rye Goldendale project?**

**Answer:** The Goldendale Energy Storage Project is a planned 1,200-MW pumped-storage hydroelectric facility near Goldendale, Washington.

**5. What is the RTE for the molten salt projects?**

**Answer:** The RTE for energy storage systems using molten salt typically ranges from 49.4% to 72.2%, depending on the specific system configuration, load range, and integration strategy.<sup>4</sup>

**6. Can you provide the round-trip efficiency (RTE) of these technologies?**

**Answer:** The RTEs for the LDES technologies referenced in the presentation are as follows<sup>5</sup>:

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<sup>2</sup> “U.S. Adds 58 GWh of New Energy Storage Capacity in 2025, Largest Single Year of New Battery Capacity on Record.” Solar Energy Industries Association. February 23, 2026. <https://seia.org/news/united-states-installs-58-gwh-of-new-energy-storage-in-2025/>

<sup>3</sup> “Advanced cathode designs for multivalent metal-ion batteries: Insights from transition metal oxides, chalcogenides, and Prussian blue analogues.” Journal of Energy Storage. April 2026. <https://www.sciencedirect.com/science/article/pii/S2352152X26006808>

<sup>4</sup> “The flexibility of a molten salt thermal energy storage (TES)-integrated coal-fired power plant.” Applied Energy. December 2025. <https://www.sciencedirect.com/science/article/pii/S030626192501606X>

<sup>5</sup> Data compiled in the LDES Technology Evaluation Matrix developed by the LDES National Consortium. <https://ldesconsortium.sandia.gov/ldes-competitive-factor-matrix/>

| Technology Type | Detailed Technology                              | RTE (Low) | RTE (High) |
|-----------------|--------------------------------------------------|-----------|------------|
| Electrochemical | Lithium-ion                                      | 85        | 92         |
| Electrochemical | Sodium-ion                                       | 80        | 92         |
| Electrochemical | Lead-acid                                        | 79        | 85         |
| Electrochemical | Zinc-Anode                                       | 69        | 73         |
| Electrochemical | Iron-Flow                                        | 71        | 72         |
| Electrochemical | Vanadium-Flow                                    | 60        | 75         |
| Electrochemical | Organic-Solid Flow                               | 70        | 80         |
| Thermal         | Molten Salt TES                                  | 45        | 60         |
| Thermal         | Solid Media TES - Pumped TES                     | 51        | 65         |
| Thermal         | Solid Media TES - TPV                            | 25        | 40         |
| Thermal         | Thermochemical                                   | 50        | 55         |
| Mechanical      | Pumped Storage Hydropower (PSH)                  | 79        | 80         |
| Mechanical      | Advanced Compressed Air Energy Storage (Caverns) | 60        | 70         |
| Mechanical      | Compressed Gas Energy Storage                    | 74        | 75         |
| Mechanical      | Liquid Air                                       | 45        | 70         |
| Mechanical      | Gravitational Storage (Blocks)                   | 82        | 83         |
| Mechanical      | Gravitational Storage (Railcars)                 | 89        | 90         |
| Chemical        | Hydrogen                                         | 30        | 31         |

Note: While the RTE for hydrogen may appear low, the range was determined based on considerations of the larger hydrogen infrastructure, piping, and supply chain into their assessment.

7. **Since any storage can be slowly discharged, can you clarify how LDES is defined? Is it simply that the maximum rate of discharge is limited relative to the MWh stored? LiON is perfectly capable of LDES, but has greater value based on more rapid and frequent discharge.**

**Answer:** LDES is defined by its ability to deliver rated power continuously for 10 or more hours (sometimes cited as 8 to 12 hours depending on the regulatory framework setting the definition). While almost any battery or system can theoretically be throttled to trickle out power slowly over days, LDES is categorized by its nameplate discharge capacity—meaning it can sustain a high, steady output at its full rated capacity for that extended window, rather than just surviving off a severely derated or restricted flow. While it may be true that lithium-ion is capable of LDES, this would likely require the stacking of multiple individual lithium-ion batteries, which on their own have duration limits that would fall under the definition of LDES. Stacking multiple lithium-ion increases costs and safety hazards. By comparison, other systems like compressed air, thermal storage, and flow batteries can separate power capacity from energy capacity, making them cheaper for multi-day storage. We are seeing lithium-ion BESS making claims of 8-hour LDES energy shifting. A prominent example is the Tumbleweed project located near Rosamond in Kern County, California. Key details: 69 MW capacity, 552 MWh (discharging continuously for 8 hours) Developer: REV (a subsidiary of LS Power).

**8. Are all of these storage projects coupled with renewable generation?**

**Answer:** The presentation included references to ten (10) LDES projects to illustrate current key projects and trends. In all of the 10 projects, energy storage is coupled with renewable energy in some way, as described below:

- **The Rye Development ‘Goldendale’ project:** Yes, the Goldendale Energy Storage Project by Rye Development is explicitly designed to integrate and support intermittent renewable energy sources like wind and solar.
- **The Hydrostor Willow Rock Energy Storage Center:** Yes, the Hydrostor Willow Rock Energy Storage Center is designed to charge using surplus renewable energy from the grid.
- **Qnetic project at Metro Air Park in Sacramento, CA:** Yes, Qnetic’s project at Metro Air Park is fundamentally tied to renewable energy.
- **Crescent Dunes Energy Project:** Yes, the Crescent Dunes Energy Project is inherently a renewable energy project, as it is a utility-scale concentrated solar power (CSP) plant.
- **Google & Xcel Energy Iron-Air Battery (Pine Island, MN):** Yes, the project pairs the storage system with 1,400 MW of new wind energy and 200 MW of new solar energy.
- **Alliant / Energy Dome Columbia Energy Center (Pacific, WI):** Yes, the Columbia Energy Storage Project is designed to store excess electricity from the

grid—including intermittent renewable generation—to help support the broader clean energy transition.

- **Southern Company Inlyte Energy Utility Demonstration (Alabama):** Yes, the Southern Company Inlyte Energy demonstration project is designed to support and integrate renewable energy by providing long-duration energy storage.
- **SRP / ESS Tech Project New Horizon Iron-Flow Battery (Florence, AZ):** Yes, the Project New Horizon iron-flow battery project in Florence, Arizona, is designed to support renewable energy integration.
- **Zinc8 Energy Solutions Community Project:** Yes, the system is combined with an existing on-site photovoltaic (solar) solar array and a combined heat and power (CHP) plant.
- **REV Tumbleweed lithium-ion project in Kern County, CA:** Yes, while the project is not co-located directly on the same plot as a dedicated solar or wind farm, it acts as a bulk-shifting resource. It absorbs excess, low-cost solar energy generated during the daytime hours across the regional grid and discharges that clean electricity overnight during peak demand.

**9. For TRL, I'm assuming higher numbers are better, correct?**

**Answer:** Yes. A key metric used to determine the viability of specific technology types is the designation of “technology readiness level,” a 9-point scale used to measure how mature a technology is, ranging from basic research (TRL 1) to a fully working system used in the real world (TRL 9). Thus, a 9 TRL is better than a 1 TRL.

**10. Are there any really viable cases for hydrogen, especially green hydrogen?**

**Answer:** Yes, there are viable use cases for green hydrogen, particularly in chemical feedstocks & ammonia; heavy industry & steelmaking; and transport and shipping. For more information, please review: “Hydrogen as an alternative fuel: A comprehensive review of challenges and opportunities in production, storage, and transportation” in the February 2025 edition of the International Journal of Hydrogen Energy.<sup>6</sup>

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<sup>6</sup> Hydrogen as an alternative fuel: A comprehensive review of challenges and opportunities in production, storage, and transportation.” International Journal of Hydrogen Energy. February 2025.  
<https://www.sciencedirect.com/science/article/pii/S0360319925000382>

**11. Why do LDES technologies need to increase efficiency to compete with hydrogen, when hydrogen was reported at 30% efficiency?**

**Answer:** Hydrogen suffers from severe energy losses because electricity must first turn into gas via electrolysis, get compressed or stored, and then turn back into electricity via a fuel cell or turbine.<sup>7</sup> Hydrogen power pathways typically have a very low round-trip efficiency (often around 30% to 40%), meaning over half of the original energy is lost. Mechanical, thermal, or flow-battery LDES technologies try to achieve higher round-trip efficiencies than hydrogen to ensure they waste less clean power and keep delivered electricity affordable.<sup>8</sup>

**12. Where do you envisage funding coming from for future progress along the TRL scale?**

**Answer:** Future funding to advance LDES technologies toward higher TRL is transitioning away from early-stage venture capital and shifting toward a blend of government-backed commercialization programs, corporate off-take agreements, and innovative regulatory revenue mechanisms.<sup>9</sup> Because traditional venture capital for LDES fell significantly (by over 72% in recent years), the industry is relying on different funding structures to bridge the "valley of death" and scale up non-lithium technologies.<sup>10</sup>

**13. What are the barriers to deploying railcar LDES? The round trip efficiency numbers look great.**

**Answer:** Railcar LDES refers to the use of railway infrastructure and train cars to store large amounts of electricity and discharge it back to the grid over extended periods (typically 10 hours +). The two technology forms typically associated with railcar LDES are mechanical/gravity based energy storage and mobile battery based energy storage. There are a number of barriers to deploying railcar LDES that have slowed its

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<sup>7</sup> "Long-Duration Energy Storage vs Hydrogen Storage: Cost Efficiency Comparison." May 18, 2026. <https://eureka.patsnap.com/report-long-duration-energy-storage-vs-hydrogen-storage-cost-efficiency-comparison>

<sup>8</sup> "Long-Duration Energy Storage: When Does It Actually Win?" Net Zero Insights. June 2, 2026.

<https://netzeroinights.com/resources/long-duration-energy-storage-when-does-it-actually-win/>

<sup>9</sup> "LDES installations surge 49% in 2025 but sector faces critical financing crunch." Energy Institute. March 18, 2026. <https://knowledge.energyinst.org/new-energy-world/article?id=140178>

<sup>10</sup> Wood Mackenzie. March 9, 2026. <https://www.woodmac.com/press-releases/l-des-2025-outlook/>

commercial deployment, namely: topography requirements, land footprint, high upfront capital costs, and revenue risk.

**14. What's the lowest ambient temperature that LDES and MDES can function?**

**Answer:** As discussed in the Webinar, LDES and MDES can refer to literally hundreds of different technologies so there is no a single answer to this question. There is no single absolute lowest ambient temperature limit for LDES and MDES, because these categories cover many different technologies (such as pumped hydro, compressed air, thermal sand/rock systems, and various batteries) that each operate under unique physical limits.

**15. Do you see anything that tends to distinguish the technologies that are moving ahead vs. the ones that are slow or stalled out? Is it the chem/physics, wieldiness, organizational weaknesses, marketing, fundraising, what are the big issues?**

**Answer:** There are a number of factors that come into play, enabling some LDES technologies to advance while others fail. Factors that immediately come to mind include the following:

- *Access to abundant and inexpensive materials.* Successful LDES solutions tend to rely on cheap, non-toxic, and globally available materials such as iron, water, air, sodium, or crushed rock/sand
- *Ability to scale up energy capacity without significantly increasing costs.* For example, with flow batteries or CAES adding more duration simply requires buying larger, low-cost storage tanks or caverns while keeping the expensive power-generating machinery the same size. By comparison, for lithium-ion scaling requires a linear increase in expensive raw materials, which can quickly become economically unviable at 10 hours +.
- *Pursuing revenue streams beyond what can be achieved through merchant grid markets.* The LDES technologies that do not rely purely on unpredictable merchant grid markets and instead focus on securing bilateral offtake agreements with heavy industrial heat users or data centers where reliable, multi-day uptime is an absolute, non-negotiable priority appear to have a strategic advantage. Deployment in states that have favorable regulatory policies. The successful LDES technologies generally develop where there are strong signals coming from state regulators (e.g., through procurement mandates) that indicate favorable market conditions for deployment. There are

certainly exceptions (e.g., Texas) but generally speaking enabling policy frameworks have driven strong LDES markets.

**16. As we electrify, the energy peak will flip from Summer to Winter. Do we have technology that stores energy for several months as opposed to 4 hours? Is it still economical?**

**Answer:** The LDES technologies that appear to be well positioned to meet seasonal duration needs associated with winter peaking are those that feature low self-discharge rates and decoupled power and energy scaling so that storing energy for months remains cost-effective. These capabilities will likely lead to stronger economic profiles.

**Leading Seasonal LDES Technologies**

| <b><u>Technology Category</u></b> | <b><u>Key Examples</u></b>                         | <b><u>Primary Use Case &amp; Duration</u></b>     | <b><u>Why It Fits Winter Peak Needs</u></b>                                                                                                                                                              |
|-----------------------------------|----------------------------------------------------|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b><u>Chemical Storage</u></b>    | <b><u>Green Hydrogen &amp; Ammonia</u></b>         | <b><u>Multi-week to Seasonal (100+ hours)</u></b> | <b><u>Zero self-discharge over months. Excess summer renewables are converted via electrolysis, stored underground, and dispatched via turbines or fuel cells during deep winter freezes.</u></b>        |
| <b><u>Mechanical Storage</u></b>  | <b><u>Compressed Air Energy Storage (CAES)</u></b> | <b><u>Multi-day to Multi-week</u></b>             | <b><u>High power capacity and geological longevity. Large CAES systems utilize underground salt caverns to store air under pressure, providing bulk capacity to weather multi-day winter storms.</u></b> |
| <b><u>Metal-Air Batteries</u></b> | <b><u>Iron-Air Batteries</u></b>                   | <b><u>Multi-day (Up to 100 hours)</u></b>         | <b><u>Extremely low material cost. Using the reversible oxidation of iron (rusting), these systems</u></b>                                                                                               |

|                               |                                                     |                              |                                                                                                                                                                                                                                      |
|-------------------------------|-----------------------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                               |                                                     |                              | <u>can discharge at low cost over several consecutive days of heavy winter grid strain.</u>                                                                                                                                          |
| <u>Thermal Energy Storage</u> | <u>Pumped Thermal &amp; Seasonal Thermal (STES)</u> | <u>Multi-day to Seasonal</u> | <u>Direct heat and electricity integration. Captures waste or excess renewable heat during warmer months in underground mediums (rocks, molten salt, water) to supply district heating networks and centralized power in winter.</u> |

**17. For the \$232 to \$292 per kWh pricing on Long Duration ES, do you mean Mhr? Or Kwhr?**

**Answer:** Kilowatt-hours. The specific reference made was that the least expensive LDES technologies—such as thermal energy storage and CAES—have achieved capital expenditures (capex) of about \$232/kWh and \$293/kWh respectively. For comparison, lithium-ion 4-hour systems averaged \$304 in 2023, making these LDES alternatives highly competitive for multi-hour storage. This data came from Bloomberg NEF<sup>11</sup> and the citation is provided below.

**18. Isn't LFP cheaper than Li-ion? And safer as well? Why does Li-ion dominate?**

**Answer:** First, we should note that Lithium iron phosphate is actually a specific type of lithium-ion battery, but comparisons usually contrast LFP with higher-density nickel- or cobalt-based lithium-ion cells.<sup>12</sup> But in answer to the question, yes, LFP (lithium iron phosphate) batteries are generally cheaper to produce and buy than traditional nickel-based lithium-ion because LFP can utilize less expensive resources like iron and

<sup>11</sup> “Lithium-Ion’s Grip on Storage Faces Wave of Novel Technologies.” Bloomberg NEF. June 4, 2024. <https://about.bnef.com/insights/clean-energy/lithium-ions-grip-on-storage-faces-wave-of-novel-technologies/>

<sup>12</sup> “Understanding LFP Batteries.” XBattery. <https://xbattery.energy/learn/understanding-lfp-batteries>

phosphate (as opposed to cobalt and nickel) like cobalt and nickel). Average LFP battery pack prices sit roughly 30% to 40% lower than traditional nickel manganese cobalt (NMC) alternatives.<sup>13</sup> The reason why lithium-ion has continued to dominate stems from its higher energy density (i.e., traditional lithium-ion batteries store more power in a smaller, lighter space). LFP batteries are cheaper to produce, but their lower energy density means you need a larger, heavier pack to match the same power capacity, which can reduce their cost advantage.<sup>14</sup>

**19. \$60/kW-yr comes to about \$166/MW-day, well below the clearing price in PJM's latest capacity auction. Why isn't LDES competitive in PJM?**

**Answer:** There are a number of factors that are relevant to this question. In general, LDES struggles to compete in the PJM market due to a combination of the following factors (and there may be others as well).

- Unlike CAISO and ERCOT, where sharp price swings due to massive influxes of renewables have enabled energy storage to profit from arbitrage transactions (i.e., “charging low and selling high”), PJM has not experienced that same level of steep daily price volatility. Thus, the value of arbitrage, which is a primary revenue source for LDES, has not been as lucrative in PJM as it has been in other markets. Arbitrage values in PJM diminish significantly for every hour of discharge capacity added past the four-hour duration mark.
- For the above reason, lithium-ion remains dominant in the PJM market. Paying the premium capital costs required to build an LDES system (10+ hour system) rarely pencils out on energy arbitrage alone, thus leaving short-duration lithium-ion batteries to maintain market dominance in PJM.
- Lithium-ion remains dominant for other reasons as well: mature manufacturing scale, predictable cost curves, shorter development timelines, and established market opportunities. PJM's historical market design has focused primarily on meeting peak hours, shorter-duration (4-hour) systems have captured the market opportunities in PJM for the most part.
- Although this is not unique to PJM, wholesale markets continue to lack mechanisms that accurately compensate LDES technologies for the resilience

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<sup>13</sup> “A new generation of cheaper batteries is sweeping the EV industry.” Canary Media. November 12, 2024. <https://www.canarymedia.com/articles/electric-vehicles/a-new-generation-of-cheaper-batteries-is-sweeping-the-ev-industry>

<sup>14</sup> “Understanding LFP Batteries.” XBattery. <https://xbattery.energy/learn/understanding-lfp-batteries>

benefits that they can provide. Although PJM historically maintained a stringent 10-hour continuous output rule for full capacity credit, the market has been evolving toward performance-based and "slice-of-day" risk frameworks. However, these evolving structures still fail to appropriately compensate LDES for its true value proposition.

- Lengthy interconnection queue delays have also been a barrier for LDES technologies within the PJM market.

**20. Is it correct that we will need a portfolio that includes both short- and long-duration energy storage solutions to meet load growth affordably, reliably, and with few GHGs? If we need both short- and long-duration BESS, how do we structure policy incentives that appropriately value their unique operating characteristics?**

**Answer:** There are a number of approaches that can be characterized as “policy incentives” that could be developed to recognize the unique operating characteristics of both LDES and short-duration BESS (i.e., a “two-prong” policy approach). Some examples include, but are not limited to, the following:

- Pay-for-Performance ancillary services, specifically fast frequency response and enhanced frequency regulation, that would pay a premium for response accuracy. This would be an approach that would recognize the : Short-duration BESS excels at rapid response. Fast Frequency Response (FFR) and enhanced frequency regulation markets should pay a premium based on mileage and response accuracy, favoring the high ramp rates of lithium-ion systems (i.e., the ability to shift power output or input changes very quickly over a short period of time).
- Capacity Market Reforms: Traditional capacity markets use Effective Load Carrying Capability (ELCC) metrics that penalize storage as penetration increases. A transition to degradation-adjusted or multi-hour capability frameworks that ensure LDES assets maintain high capacity values during extended grid stress would recognize the unique value of LDES technologies.
- Arbitrage Incentives: Wholesale market policies that reward LDES technologies capable of shifting massive blocks of energy across days or weeks would help to make these technologies more economically viable.
- Developing new financial incentives that recognize the different TRL levels of technologies. These financial incentives could take the form of investment tax credits, production tax credits, and clean peak standards.

- LDES-specific carve-outs within broader energy storage procurement policies.
- Allowing utilities to earn a rate of return on BESS deployed as a Non-Wires Alternative (NWA).

**21. Do you ever envision a day where LDES might be an economically viable alternative for residential seasonal storage? The case is one where the demand is in the summer and winter, but most production happens in the spring and fall.**

**Answer:** It is unlikely any time in the near future (i.e., the next decade). At this time and for the foreseeable future, LDES is not currently practical, affordable, or sized for individual residential seasonal storage. LDES is engineered for utility grids and large communities to balance multi-day or seasonal energy shifts, rather than single-family homes.

**22. One slide (#29?) refers to kilowatt-years. What is that unit and how is it interpreted?**

**Answer:** The statement made on this slide was that “LDES needs roughly \$50 to \$75 per kilowatt-year in capacity market revenue, according to industry analyses, to support a bankable project finance case.” Those figures originated in the DOE’s Pathways to Commercial Liftoff report, securing \$50 to \$75 per kilowatt-year in predictable revenue—such as through resource adequacy mechanisms, capacity payments, or regulatory valuations—is critical for LDES technologies to achieve commercialization. A kilowatt-year (kW-year) is calculated by dividing total annual energy consumption in kilowatt-hours (kWh) by the total number of hours in a year (8,760 hours).

**23. Am a little surprised that off-grid data center energy campus developments using LDES plus a generator (solar / wind / natgas/ etc) hasn't been discussed as a major LDES deployment accelerant. Can you address this?**

**Answer:** Yes, it is true that “bring your own generation” projects planned at U.S. data centers will help to lower costs for drive opportunities for LDES technologies, but all of the issues covered in the Webinar regarding the lack of reward mechanisms curbing growth of LDES technologies still applies. A good report that delves deeper into this

specific topic was published by Reuters<sup>15</sup> earlier in 2026 and can be found here:  
<https://www.reuters.com/business/energy/soaring-ai-demand-spurs-roll-out-long-duration-energy-storage--reeii-2026-03-24/>

**24. High heat rate means more BTUs to get a kW means LESS efficient, right?**

**Answer:** Yes, heat rate measures how many British thermal units (BTUs) of fuel energy are needed to produce one kilowatt-hour (kWh) of electricity. Efficiency is the opposite of the heat rate. A higher heat rate means lower efficiency. For example, if a power plant uses 10,500 BTUs to make 1 kWh, its efficiency is only about 33% ( $3,412 \div 10,500$ ). It wastes a lot of fuel as heat.<sup>16</sup>

**25. In current economic models for LDES, how explicitly are transmission service values being monetized and revenue-stacked? Is this a possibility both from a technological and policy perspective?**

**Answer:** In current economic models for Long-Duration Energy Storage (LDES), transmission service values are rarely monetized explicitly and remain largely excluded from standard commercial revenue stacks. In competitive wholesale markets (e.g., ERCOT, CAISO, PJM), standard commercial revenue stacks are strictly limited to Wholesale Arbitrage, Ancillary Services, and Resource Adequacy/Capacity markets.

**26. RE: definition of a kW-y — isn't it more nameplate power capacity over an annual cycle rather than actual continuous output? Since a battery must cycle between charging and discharging, at most it can only discharge for 50% of the hours per year.**

**Answer:** No, a kilowatt-year is a unit of energy, not capacity. It represents the total amount of electricity delivered by a continuous one-kilowatt power output sustained over an entire year. Kilowatt-year strictly measures actual or theoretical cumulative energy production rather than just the potential capability of a system.

Key Differences:

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<sup>15</sup> “Soaring AI demand spurs roll-out of long duration energy storage.” Reuters. March 26, 2026.  
<https://www.reuters.com/business/energy/soaring-ai-demand-spurs-roll-out-long-duration-energy-storage--reeii-2026-03-24/>

<sup>16</sup> “What is the efficiency of different types of power plants?” Energy Information Administration.  
<https://www.eia.gov/tools/faqs/faq.php?id=107&t=7>

- **Nameplate Capacity:** This is the maximum theoretical output of a generator (measured in kilowatts (kW) or megawatts). A 1 kW solar panel has a nameplate capacity of 1 kW, but it only hits this output under ideal sunlight.
- **Kilowatt-Year (kW-y):** This is the actual energy produced (or consumed) if 1 kW of power flows uninterrupted for 8,760 hours (one year). It is equivalent to exactly 8,760 kilowatt-hours (kWh).

**27. What is the interplay between energy storage efficiency and falling solar energy costs? Could the situation arise where energy becomes cheap enough that utilities would be willing to eat the costs of lost energy?**

**Answer:** As I understand the question, the interplay between energy storage efficiency and falling solar energy costs is that as the global costs for solar photovoltaic (PV) systems and BESS have fallen dramatically—by roughly 87% to 93% between 2010 and 2024—this makes the combined solar-plus-storage projects cheaper than many fossil-fuel alternatives. With regard to efficiency, falling solar costs make energy storage more efficient by lowering overall system expenses and allowing larger solar arrays to fully charge batteries faster and more often.

**28. Can second life battery energy storage have a chance for becoming LDES?**

**Answer:** Yes, there is the potential for second-life battery energy storage becomes LDES by, for example, repurposing retired electric vehicle (EV) batteries—which still retain 70% to 80% of their original capacity—into large-scale stationary grid systems. Whether this is economically feasible would be a separate question.

**29. Have any of our presenters encountered the MIT adjunct The Clean Air Task Force's assertion that for California to address 100% of Net Zero by 2045 energy storage is 36 M MWh and 80% is 9.6 M MWh? Estimates around 2020.**

**Answer:** The Clean Air Task Force's (CATF) modeling<sup>17</sup> reached the following conclusions:

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<sup>17</sup> “California could cut 2045 electricity costs by up to \$44 billion a year by investing in next-generation geothermal, finds new CATF report.” Clean Air Task Force. May 21, 2026.  
<https://www.catf.us/2026/05/california-could-cut-2045-electricity-costs-44-billion-year-nvesting-next-generation-geothermal/>

- To power California with 80% advanced renewables (mostly wind and solar), the grid would require 9.6 million MWh of energy storage.
- To reach a 100% net-zero emissions target using primarily weather-dependent resources, that storage requirement jumps exponentially to 36.3 million MWh.

The CATF appears to be making the case for "clean firm power." The CATF research seems to advocate that if California complements wind and solar with weather-independent carbon-free sources—such as superhot rock geothermal, advanced nuclear, or natural gas with carbon capture—the state can bypass the multi-trillion dollar need for millions of megawatt-hours of battery backup, ultimately lowering total system costs and reducing grid reliability risks.

**30. Given that Sodium-ion batteries seemingly have a similar RTE to Lithium-ion batteries and presumably are made of less rare materials, what is stopping sodium ion batteries from replacing lithium ion batteries in whatever niches they currently perform well?**

**Answer:** It is certainly true that sodium-ion batteries are presently competitive with lithium-ion on factors such as material abundance, cost-effectiveness, cold-weather performance, and safety. Sodium-ion batteries use abundant sodium instead of scarce lithium, offering lower costs and better cold-weather performance, while lithium-ion batteries provide higher energy density for longer ranges and smaller sizes. Also, in terms of duration capability sodium-ion competes directly with lithium-ion with greater potential to exceed the 4-8 hour duration range. However, sodium ion batteries still lag in overall energy density when compared to lithium-ion batteries.<sup>18</sup> Other hurdles that sodium-ion batteries face in comparison to lithium-ion batteries are that they are heavier and bulkier, and face manufacturing and supply chain maturity hurdles.

**31. How have LDES plans changed in light of EN-ROADS analysis that AI growth will increase global warming, in any scenario?**

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<sup>18</sup> "Sodium ion batteries: A sustainable alternative to lithium-ion batteries with an overview of market trends, recycling, and battery chemistry." Next Energy. January 2026.  
<https://www.sciencedirect.com/science/article/pii/S2949821X25002418>

**Answer:** My understanding is that the En-ROADS Simulator shows that AI growth increases global warming mostly through broader economic expansion rather than just the power use of data centers. Specifically, the En-ROADS report stated that direct power use from data centers add about 0.1°C of warming by the year 2100, which is deemed small compared to other global sources. The larger threat, according to En-ROADS comes from economic growth, as AI boosts overall economic productivity. This extra activity increases energy demand across every sector of the economy. My takeaway from these conclusions is that they support the need for LDES (systems providing 10 to 100+ hours of discharge) to firm up the wind and solar arrays that would be dedicated to the loads required by AI. I have not seen any reports that specifically tie LDES plans to this EN-ROADS analysis, however.