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September 12th, 2023

TO: Terna

FROM: Long Duration Energy Storage Council

RE: Study on Reference Technologies for Electricity Storage*, Public Consultation, April 2023*

The Long Duration Energy Storage Council (LDES Council) appreciates the opportunity to provide feedback and participate in the public consultation on the Study on Reference Technologies for Electricity Storage published by Terna. Further, the LDES Council supports the Italian government's work to decarbonize the national energy grid and design an auction mechanism to help facilitate these goals.[1]

The LDES Council is a global non-profit with over 70 members across 20 countries. The LDES Council works to accelerate the decarbonization of our world through the application of long duration energy storage (LDES). The LDES Council provides member-driven, fact-based guidance and research to governments, grid operators and major electricity users on the deployment of long duration energy storage for society's benefit by decreasing emissions, lowering costs and adding flexibility to energy systems allowing for more resiliency.

## Background

The LDES Council conducted research showing least cost solutions to decarbonize energy grids require long duration energy storage.[2] Further, this research indicates global spending on long duration storage of up to $4 trillion USD and installed capacity up to 8 TW to decarbonize to net-zero levels.[3] Long duration energy storage resources are critical and when developed early, could save global systems up to $540 billion USD.[4]

[1] Request for consultation: https://www.terna.it/it/sistema-elettrico/pubblicazioni/news-operatori/dettaglio/studio-tecnologie-riferimento-stoccaggio-energia-elettrica.
[2] https://www.ldescouncil.com/insights/
[3] https://www.ldescouncil.com/news/long-duration-energy-storage-council-report-spotlights-opportunity-for-thermal-energy-storage-to-advance-the-clean-energy-transition/
[4] https://www.ldescouncil.com/assets/pdf/221108_NZH_LDES%20brochure.pdf

There are many benefits and needs for grid connected long duration energy storage including congestion management, load following, inertia, blackstart capabilities and more.[5] Long duration energy storage also may decrease necessary build out of renewable resources or necessary new transmission and distribution infrastructure.

All storage allows for the opportunity to charge when solar and wind generation exceed demand and deliver energy back to the grid when output from renewables is less than total demand within a single operating day. Long duration energy storage connected to the grid amplifies this ability and allows for large quantities of energy to be stored during prolonged periods where generation exceeds demand. These resources also provide added system resilience, as storage resources with long durations by nature can provide energy for longer periods of time and thus reduce the likelihood of unserved load. This is briefly illustrated in Figure 1.

**Figure 1: Technology Applications**

**Summary of existing and emerging flexibility solutions for different flexibility duration needs**

✓ Solution (✓) Partial solution

| Flexibility duration | Power system challenge | Dispatchable generation | Grid reinforcement | Curtailment or feed-in management | Li-ion batteries | LDES | Demand-side response |
|---|---|---|---|---|---|---|---|
| Intraday | Intermittent daily generation | ✓ | | ✓ | ✓ | ✓ | ✓ |
| | Reduced grid stability | ✓ | | | ✓ | ✓ | (✓) |
| Multiday, multiweek | Multi-day imbalances | ✓ | (✓) | (✓) | (✓) | ✓ | |
| | Grid congestion | (✓) | ✓ | ✓ | (✓) | ✓ | |
| Seasonal duration | Seasonal unbalances | ✓ | ✓ | | | ✓ | |
| | Extreme weather events | ✓ | | | | ✓ | |

[5] Long duration storage can also provide significant benefits for applications to decarbonize operations for applications not connected to the grid.

With additional investment and development, long duration energy storage technologies will experience declines in price accelerating the use and deployment of these technologies. ***It is crucial that governments around the world support the right balance of policy measures and financial support to create a marketplace for LDES which can enable its success and scalability.***

## Key Enablers for Long Duration Energy Storage Participation

The LDES Council identified the most common barriers hindering development of long duration energy storage, and these include:

- Short-term (such as day-ahead, intraday markets) power markets
  - Do not provide long-term agreements that could de-risk capital investment
- Weak multi-day and multi-week market signals
  - Results in sub-optimal cycling
- Lack of sufficient carbon-reduction compensation schemes

Solutions to combat these barriers and foster growth of long duration energy storage include:

- Markets capable of planning for longer durations, that capture use cases for long duration storage
- Specific storage capacity procurement targets
- Incorporation of energy storage in grid planning
- Carbon pricing and removal of fossil fuel subsidies
- Value flexibility in capacity payments
- Introduce congestion management trading platforms
- Appropriately valuing the ability of storage resources to provide peaking power
- Developing markets for products that support the grid, such as ancillary services
- Accurate counting and attribution for stand alone long duration storage resources and resources paired with renewables

## LDES Council Feedback

Below, the LDES Council submits feedback directly on the questions outlined by Terna's the Department in the Study on Reference Technologies for Electricity Storage.

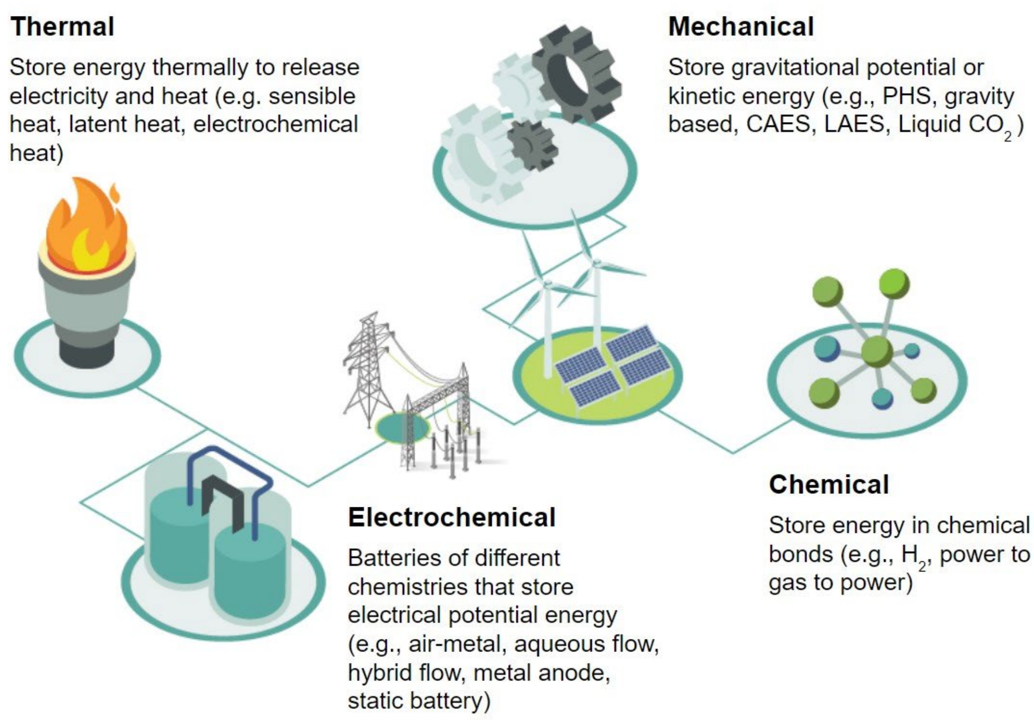
# Section 2

1. *Is it believed that the list of seven technological macro-categories includes all the electrical storage technologies currently available?*

The LDES Council understand that the reference study categorizes all storage into seven different types including: 1) lithium-ion electrochemical storage, 2) hydroelectric storage, 3) compressed air energy storage, 4) non-lithium-ion electrochemical storage, 5) power-to-gas-to-power chemical storage, 6) electrostatic storage, and 7) flywheel electrochemical storage.

The LDES council categorizes long duration energy storage into four different approaches including: mechanical, thermal, electrochemical, or chemical storage. Figure 2 provides a very high-level outline for these four approaches.[6] Within each technology family lies multiple specific technologies for storing energy and, typically, for each technology there are multiple companies developing storage solutions using that technology.

**Figure 2: The Four Families of Long Duration Energy Storage**



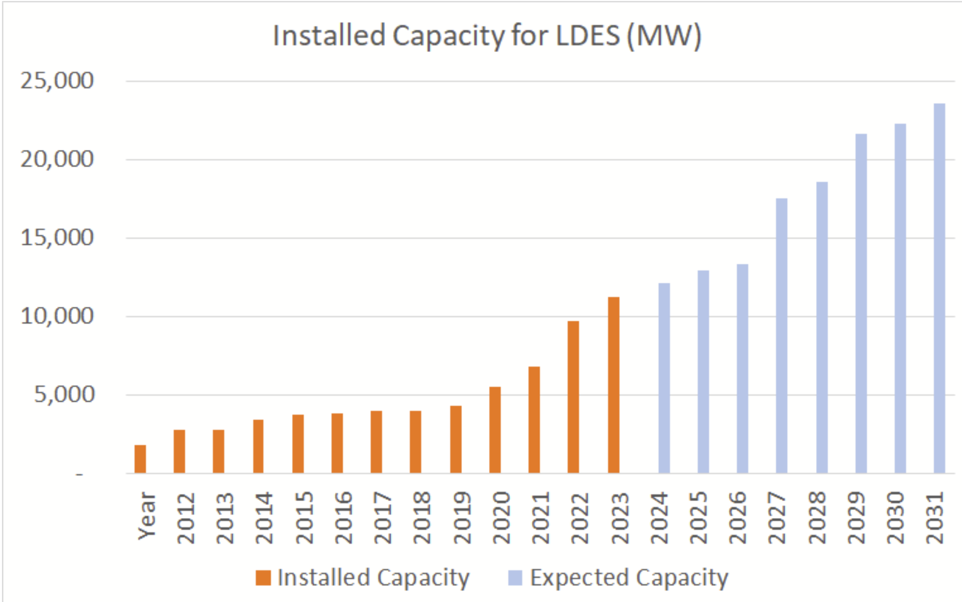

[6] LDES Technologies, LDES Council: https://ldescouncil.com/ldes-technologies/.

The reference study suggests that: "often innovative technologies, especially those with a low level of technological maturity and with limited experience in the continuous operation of the plants, need many years of development to reach the minimum level of reliability necessary to be able to be admitted participating in an auction such as the one in question." The reference study also suggests that "the only technologies with high technological and commercial maturity are lithium-ion batteries and hydroelectric pumping." The LDES Council respectfully presents the following data and facts suggesting that long-duration energy storage is a key for decarbonization, and many technologies – outside of lithium-ion and pumped hydroelectric storage - are indeed already in use as grid scale projects and are rapidly being adopted and deployed in projects around the world.

The LDES Council collects data from members and other long-duration energy storage manufacturers around the world and suggests that today there are more than 10 GW of long duration storage energy capacity installed on grids and approximately 15 GW of additional projects that have already secured funding and are anticipated to be actively on grids by 2031.[7] This information is shown in Figure 3. This data indicates many technologies are ready for grid operations, are recognized as viable energy market participants by financers, utilities, and grid operators, and are either already performing or are anticipated to be performing critical gird functions in the next few years.

[7] LDES Council notes that a significant amount of 'legacy' pumped hydro storage is not included in Figure 3, and that only about 2.5 GW of pumped hydro capacity, including capacity already on-line and capacity that is planned for future development.

**Figure 3: Installed Capacity of Long Duration Energy Storage**




Development of these technologies is not limited to a handful of markets dabbling in new technology. Countries around the world have noted the importance of long duration energy storage and are making significant investments in and efforts to fully utilize all aspects of these technologies in efforts to decarbonize.

Since 2019, global investment in long duration energy storage exceeds $58 billion[8], and is quickly growing. Today, more governments are leading the way with public/private partnerships to support the large-scale delivery of long duration energy storage needed to ensure energy can be delivered without greenhouse gas emissions. Several countries have already made large investments and/or commitments to policies fostering development of long duration energy storage including Chile, Spain, Australia, Greece, the United States, India, and the United Kingdom.

Chile is leading the way on LDES in South America by seeking to invest USD$2 billion for energy storage projects beginning in 2026. The Chilean government changed laws to ensure storage could participate in the marketplace as well as created a marketplace for all types of storage.[9]

Similarly, Spain incorporated long duration energy storage into future planning and is launching €280 million for energy storage, including standalone, thermal, and pumped hydro

[8] https://www.woodmac.com/press-releases/long-duration-energy-storage-projects-attract-more-than-us-$58-billion-investment-over-last-three-years/

[9] https://www.energy-storage.news/chile-government-seeks-multi-gigawatts-of-large-scale-storage-for-2026-2028/

technologies[10]. This, in addition to €160 million in grants for energy storage projects, aims to fund 600 MW of projects to go online in 2026.

Australia and the United Kingdom are also two hotbeds of innovation, driving development of grid-scale long duration energy storage technology. The United Kingdom ran several grants to stimulate the market, with almost £70 million awarded as part of the £1 billion net zero innovation portfolio program from their department for energy security and net zero.

In Australia, regional governments have a major role to play in ramping up ambition and delivery, with Victoria setting an interim target of 2.6 GW of storage by 2030.[11] The target includes eight hour or more of long duration storage - as well as targets for shorter duration - and was announced alongside an AU$157 million support package for renewables and storage projects in the state.

The United Kingdom also pioneered the deployment of long duration storage as part of its focus on decarbonization, announcing five innovative long-duration energy storage projects that will receive a share of almost £33 million of funding,[12] including awards for pumped hydro and thermal storage solutions. These projects will help to meet the need for more than 50 GW of energy storage.

India also signed up for Mission Innovation and became the first member country to establish a clean international incubation center (CEIIC) for supporting and promoting clean energy-based start-ups including storage and long duration energy storage.

India has some of the most ambitious targets globally for scaling renewable energy. India set goals to achieve 500 GW by 2030[13], and will need to install four times the amount of renewable power than was delivered between 2010 and 2020.

Greece has an overall energy storage deployment goal of 3GW by 2030 to facilitate a 70% renewable energy target, and launched an auction for grants towards 400MW of energy storage.[14]

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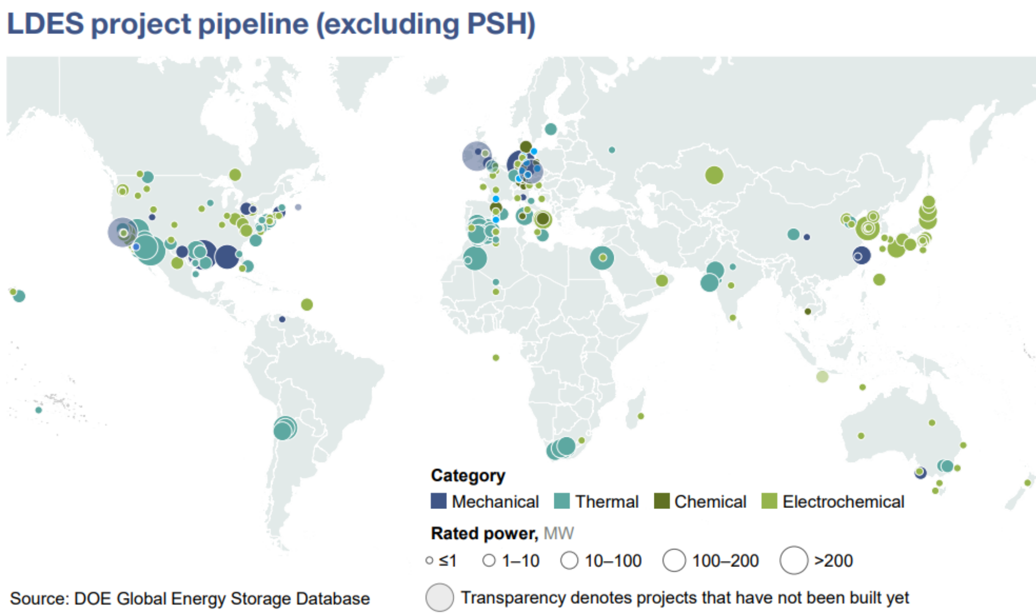
10 https://renewablesnow.com/news/spain-to-award-eur-280m-in-state-aid-for-energy-storage-projects-829095/
11 https://www.pv-magazine-australia.com/2022/09/27/victoria-targets-6-3-gw-of-renewable-storage-by-2035/
12 https://www.gov.uk/government/news/energy-storage-backed-with-over-32-million-government-funding
13 https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/india-aims-to-add-500-gw-of-renewables-by-2030-70713616
14 https://www.energy-storage.news/greece-launches-first-400mw-tranche-of-energy-storage-grant-auctions/

Significant amounts of storage are being developed in countries around the world. Figure 4 shows where development of long duration energy storage projects are already located and are anticipated within the next few years. Figure 4 shows quantities of storage developed in the last 10 years and the anticipated quantities in future years. The Australian government can build on these successes and challenges faced by other countries.

**Figure 4: Long Duration Storage Project Pipeline**

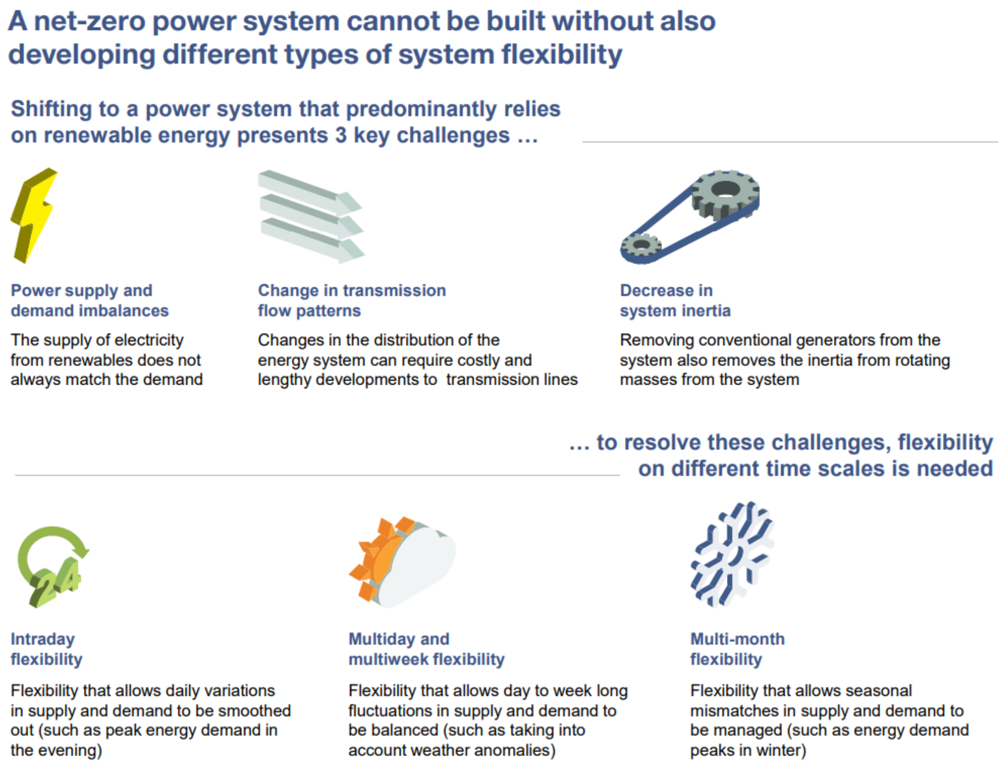



# Section 3

1. *Do you think this section accurately describes the performance characteristics of the reference technologies?*

The LDES Council would like to work with Terna to ensure the diverse benefits and performance characteristics of long duration energy storage technologies are incorporated within modeling and are considered when procuring and developing resources to reduce greenhouse gas emissions. As noted above, there are many different types of long duration energy storage solutions, which can serve a variety of system needs. If Terna does not allow for additional flexibility from reference technologies, then many critical system attributes will be missed.

**Figure 5: Net-Zero Needs**[15]




2. *Is it agreed that full-converter pumped-storage hydroelectric plants can be designed to provide active power regulation during absorption?*

Yes, pumped storage hydroelectric facilities can be designed to provide active power during normal operation.

# Section 4

1. *The CAPEX and OPEX ranges indicated for are considered consistent with current market value the two reference technologies?*

Projected capital expenditures for long duration energy storage systems are consistent with similar breakthrough energy technologies such as wind, photovoltaic solar, and electrolyzers. Energy and power capital expenditures could decline by 60 percent in the next 15 years, while round trip efficiency could grow by 10-15 percent as the commercialization of systems accelerates. In 2040, power capital expenditures costs will likely be between $380 and $960 USD/kW and an energy capital expense between $4 and $17 USD/kWh. This compares to $60 to $110/kW and $70 to $80/kWh for lithium-ion batteries, and $800 to $900/kW for single cycle

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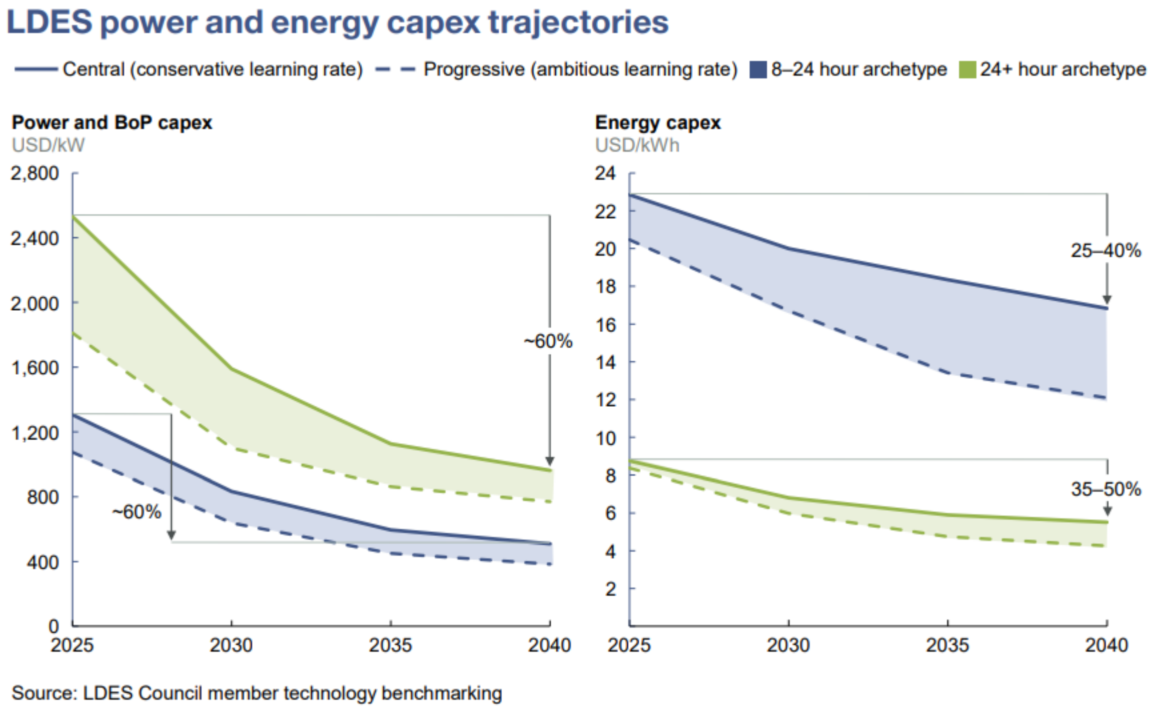
gas turbines in 2040. The capital expenditure for power for long duration energy storage, which includes charging and discharging equipment, is expected to show a comparable overall decline of around 60 percent across both archetypes, experiencing the steepest drop within the next ten years.[16]

**Figure 6: Long Duration Energy Storage Cost Projections**




# Additional Feedback

Full decarbonization of a grid is challenging and requires a combination of renewable technologies and storage resources of varying duration. The LDES Council makes two suggestions, that: 1) tender targets explicitly require certain capacity thresholds of nominal duration for storage capacity procurement, and 2) Terna begins requiring longer nominal duration of storage capacity sooner.

Tender targets should specify specific nominal duration for storage resource market participation. To decarbonize economically and maintain grid reliability longer duration resources are necessary. Procuring these resources may not be possible with simple capacity market mechanisms and may require explicit thresholds. Taking a holistic view of necessary procurement through a target year for full decarbonization and using estimates of those

[16] https://www.ldescouncil.com/assets/pdf/LDES-brochure-F3-HighRes.pdf

weather and load forecast to generate future target procurements for storage with a specific log duration storage - such as 10+, 24+, 100+, 150+ hour duration resources - will result in better success during capacity investment and reaching decarbonization goals.

This reference study notes that some long duration storage technologies take longer to implement and develop. Beginning to specify these targets early will help to ensure these resources are available and integrated onto the system in a timely manner to meet decarbonization targets.

## Conclusion

As noted, clean renewable generation and storage - especially long duration energy storage - fills reliability gaps, provides flexibility, security, energy shifting, increased dispatchability, and reduces the risk of price shocks. To avoid curtailment of future and current solar generation, and to meet the public policy goals in Italy, long duration energy storage is critical.

It is important to ensure the value of long duration energy storage is incorporated today into all phases of the capacity investment process. Enabling mechanisms for adaptability and flexibility over time will help to maximize the diverse attributes and benefits of long duration energy storage projects and deliver maximum benefits to all stakeholders.

Thank you for your time and consideration. LDES Council members are looking forward to submitting bids into this auction process and helping to decarbonize the Italian grid. We are happy to discuss LDES Council research with you and provide additional insights and look forward to working with the Italian government and Terna to accelerate markets for long duration energy storage and continue to support Italy as a renewable energy leader.

Sincerely,

Gabe Murtaugh

Gabe Murtaugh
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Long Duration Energy Storage Council