November 16, 2021

To: Jason Rondou, LADWP (jason.rondou@ladwp.com)
Stephanie Spicer, LADWP (Stephanie.Spicer@ladwp.com)
Power SLTRP Team (powersltrp@ladwp.com)

Subject: CESA's Response and Recommendations to SLTRP Draft Scenarios Poll

Re: CESA's Recommendations on LADWP 2022 Strategic Long-Term Resource Plan (SLTRP) Draft Scenarios

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Dear LADWP SLTRP Team:

The California Energy Storage Alliance (CESA) continues to appreciate the opportunity to participate in LADWP's SLTRP Advisory Group (AG) and offer our unique insights to help LADWP conduct supplementary modeling and identify the no-regrets investments and actions that can be taken to further the city's goals and requirements.

Upon reviewing the draft scenarios matrix, however, **CESA believes that LADWP should conduct an additional scenario that identifies an alternative pathway to invest in the "10% technologies needed to meet the 100% goals and ensure in-basin reliability and resiliency in the face of potential low-probability contingencies and outages**. Currently, to address these issues, LADWP expressed its plans to model a scenario that would use green hydrogen fueling for the three existing gas generation facilities. Preliminary analysis by the National Renewable Energy Laboratory (NREL), as presented at the November 10, 2021 AG meeting, found that in-basin, long-term dispatchable generation is needed to mitigate vulnerabilities to transmission outages, which is particularly concerning in portfolios that do not allow any in-basin combustion technologies and thus require significant reliance on out-of-basin renewables and energy storage. Even if transmission outages may be low-probability events, LADWP indicated that it also wanted to have resiliency to low-renewables, high-demand events. NREL's analysis also showed that the capacity factor of the in-basin combustion and green hydrogen utilization is low (*i.e.*, between 0% and 2%), thus potentially mitigating concerns about the potential local emissions impact of green hydrogen combustion.

CESA does not dispute these findings and agrees that it is appropriate to plan for reliability and resiliency. We also support green hydrogen-fueled generation as a potential viable form of long-duration and seasonal storage. However, CESA does not believe that the draft scenarios presented by LADWP presented at the November 10, 2021 AG meeting capture the range of the AG's interests and priorities for the SLTRP process. **Specifically, the draft scenarios do not present a menu of options for LADWP to consider for mitigating any contingency-related risks, where the results may be predetermined to identify green hydrogen combustion at existing gas generation sites as the only viable option to support reliability and resiliency**

needs. While supportive of an alternative scenario for "Highest DER (Max DER)" to further limit or reduce the capacity factor of green hydrogen combustion, this scenario would not identify any alternative options to provide in-basin reliability and resiliency in the event of transmission outages and/or low-renewable/high-demand days.

As evidenced at the AG meetings, stakeholders still have questions about the costs and impact of green hydrogen combustion, such that it may still be helpful to consider an additional scenario that assesses the viability of alternative technologies that could serve the same reliability and resiliency function and meet the parameters of the "10% technologies": (1) site in-basin; (2) site in specific locations; and (3) operate for extended periods. Specifically, **LADWP should either: (1) model long-duration energy storage (LDES) candidate technologies by leveraging a Request for Information (RFI) to solicit information on costs, capabilities, and other relevant specifications; or (2) model LDES as categories of generic technologies by differentiating their performance characteristics and costs per MW and per MWh**. The LA100 study did not include LDES technologies and instead modeled them by proxy using either concentrated solar power (CSP) with thermal storage, pumped hydro storage (PHS), or hydrogen-fueled generators.[1] However, such proxies are clearly limited and may not present the full range of viable options for *in-basin* reliability and resiliency since CSP is, by its nature, out-of-basin generation, and PHS represents large, site-specific infrastructure investments.

In the same vein, hydrogen-fueled generators *may* serve as a proxy for LDES capabilities, but they are clearly different to many LDES technologies in terms of emissions profile, infrastructural needs (*e.g.*, hydrogen transportation and storage availability), and cost structure. To CESA's knowledge, LADWP also has not yet elaborated on the pathway by which the green hydrogen fuel will be created, transported, and/or stored. If generated from grid-charged electricity, hydrogen-fueled combustion turbines will face the same or similar barriers as LDES in having sufficient charging energy for multi-day or seasonal storage – to which, CESA would contend a case could be made for LDES inclusion in the SLTRP supplementary modeling.[2] Alternatively, if green hydrogen is produced offsite and transported, or if green hydrogen is generated using biofuel or biomass fuel stock, there are additional end-to-end considerations to support the development of associated infrastructure, which are not an issue for grid-connected LDES projects. In other words, LDES technologies cannot be modeled by proxy with hydrogen-fueled generation given the aforementioned differences.

Instead of the current draft scenarios proposal, CESA recommends that LADWP refer to a CESA-commissioned report published in 2020,[3] referred to as the "CESA LDES Study" hereafter, which provide a modeling approach that can be incorporated into the SLTRP supplementary modeling. Using these approaches may mitigate some of the limitations of the assumptions and inputs available at this time, though we note that similar limitations are currently the case for green

[1] *See* NREL LA100 Study Chapter 6 at 3, 22, and 25. https://www.nrel.gov/docs/fy21osti/79444-6.pdf

[2] In other words, if existing transmission is used to generate the hydrogen for use as a fuel in the combustion turbines, then the same charging operations and timing of LDES technologies could provide similar low-capacity-factor, contingency-focused, long-duration storage capabilities.

[3] "Long Duration Energy Storage for California's Clean, Reliable Grid" prepared by Strategen Consulting for CESA on December 8, 2020. https://static1.squarespace.com/static/5b96538250a54f9cd7751faa/t/5fcf9815caa95a391e73d053/1607440419530/LDES_CA_12.08.2020.pdf

hydrogen technologies. Therefore, taking CESA's recommended approach, such as those from our CESA LDES Study, may be a reasonable means to reflect these uncertainties but also present a range of futures to achieve the city's 100% renewable goals. We detail the two potential approaches and justifications below.

Altogether, CESA generally supports LADWP's proposed scenarios matrix, *with the modification* that an alternative scenario be included to present a potential future that can be compared against LADWP's proposed green hydrogen future. **Specifically, CESA recommends that LADWP include an additional scenario named the "Aggressive Interim, High DER, and LDES" scenario that includes LDES Option 1 and LDES Option 2 as eligible technologies and would allow natural gas technologies to retire by 2035**. With this additional scenario, LADWP and AG members will be presented with the various outputs and outcomes of at least one option that does not use hydrogen-fueled generation and instead leverages an otherwise all-of-the-above approach using maximum DERs and LDES technologies. As a result, if LDES technologies emerge and scale further in the next few years, LADWP could potentially pursue these options further.

CESA generally supports green hydrogen storage as a viable and effective means to support in-basin reliability and resiliency goals, but it should *not* be presented as the exclusive or only option to achieve these ends. To address stakeholder concerns, LADWP stressed that it will take a close look to model and present resource and performance characteristics as well as the associated emissions impact and costs for fueling and infrastructure. To be responsive to these concerns and more comprehensively show the range of futures to address in-basin reliability and resiliency options, LDES technologies must be modeled separately. Importantly, if LADWP wishes to convince AG members of the benefits of hydrogen-fueled generation as a necessary path to reach 100% and maintain in-basin reliability and resiliency, an appropriately structured counterfactual that does not involve the hydrogen option should also be modeled, which may even serve to boost the case for LADWP's preferred option over CESA's proposed "Aggressive Interim, High DER, and LDES" scenario. However, unless modeled, we will never know, and it will leave AG members wondering if we exhausted or explored all options.

1. Model LDES candidate technologies by leveraging a RFI to solicit information on costs, capabilities, and other relevant specifications

To model specific candidate LDES technologies, LADWP should issue an RFI to solicit the costs and performance characteristics of various LDES technologies. Data should then be aggregated and anonymized before inclusion in the study, which will thus provide the inputs necessary to conduct modeling of this additional scenario. In the interest of maintaining confidentiality of market-sensitive information, LADWP could collect this information by signing non-disclosure agreements (NDAs) or having a neutral third party be contracted to collect and anonymize this information before sending to LADWP. Either way, this is a viable and proven pathway to collect the necessary information to overcome limitations in data from publicly-available sources. Such an approach was used recently for LDES technologies by community choice aggregators (CCAs) through its joint powers authority,[4] and used for green hydrogen technologies by LADWP itself. If sufficient for green hydrogen technologies, a similar effort should be extended LDES technologies, which could highlight key tradeoffs and considerations.

Concerns about technological viability and commercial readiness are becoming obsolete, as major investment dollars are being directed to LDES companies and startups and as they collectively pool their efforts to achieve *global* ambitions for decarbonization.[5] Granted, there is uncertainty about which technologies will emerge to commercial prominence, but the assumption that LADWP must choose green hydrogen or risk multi-day reliability risks are misplaced given the wide availability of diverse LDES technologies that could provide multi-day or seasonal storage capabilities. Some of these technologies are also being piloted in many different parts of the country and world, while others are actively seeking interconnection and competing in ongoing solicitations to meet mid-term reliability needs.[6] In addition, many of these LDES technologies have minimal or no emissions impact, and certain LDES technologies are modular and are not geographically constrained, offering comparative advantages that will not be understood if not modeled. Finally, in line with the presentation by Office of Public Accountability (OPA) on September 30, 2021, LADWP should "keep options open" and focus in the near term on proven technologies. In a couple of years, the LDES technology and project landscape may be completely changed, with the optionality to pursue this more modular option potentially foreclosed with the sunk-cost investments made to support green hydrogen infrastructure.

To support modeling, an RFI can facilitate the inclusion of specific or aggregated LDES information. In the appendix of these recommendations, we include a non-exhaustive sampling of LDES companies and technologies that convey the range of potential LDES technologies. Beyond those listed in the appendix, additional LDES technologies are also being provided by many other CESA members.[7]

2. Model LDES as categories of generic technologies by differentiating their performance characteristics and costs per MW and per MWh

CESA's experience with modeling LDES has showed us the difficulty of establishing cost and performance characteristics for technologies that have been seldom deployed, despite their commercial availability. In order to mitigate this complexity, CESA and Strategen opted to move away from a technology-based approach to modeling LDES since it would be unnecessarily specific and arbitrary. In contrast, we included LDES options that were intended to capture trends of the technology characteristics and can be thought of as generic, technology-neutral resource options.[8] Our LDES options therefore

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[4] *See* https://www.peninsulacleanenergy.com/previousrfo/rfi-long-duration-storage/
[5] Colthrope, Andy. "BP, Breakthrough Energy Ventures in Long Duration Energy Storage Council, launching at COP26." *Energy Storage News* on November 4, 2021. https://www.energy-storage.news/bp-breakthrough-energy-ventures-in-long-duration-energy-storage-council-launching-at-cop26/
[6] *See, e.g.*, multiple procurements ongoing to address 1,000 MW LDES requirement pursuant to CPUC D.21-06-035.
[7] https://www.storagealliance.org/our-members
[8] Strategen Consulting, *Long Duration Energy Storage for California's Clean, Reliable Grid,* 2020, at 32.

developed for use in the CESA LDES Study were not representative of any single technology, but instead were intended to represent a class of storage solutions that have similar performance capabilities, tradeoffs, and cost profiles.

A similar, albeit more thorough, approach was recently used by a team of researchers from Princeton and MIT in their paper *The Design Space for Long-Duration Energy Storage in Decarbonized Power Systems* (2021).[9] For this paper, the research team modeled a total of 1,280 discrete combinations of cost and efficiency parameters encompassing performance levels that are consistent with projections for existing LDES technologies found in academic peer-reviewed studies as well as domains that are currently infeasible but that could be the focus of technology development efforts in the future.[10] This approach could bring substantial value for this effort because it would not only ease the inclusion of additional candidate resources, but it would also allow LADWP to identify the technology characteristics that address the in-basin reliability/resiliency and decarbonization goals. Non-technology-specific methodologies can amplify the set of LDES technologies that could be included into this project's datasets and models and overcome current publicly-available data limitations.

In our study, CESA constructed two categories of generic LDS by differentiating their performance characteristics and costs per MW and per MWh, informed by leading LDES manufacturers and providers and benchmarked against some preliminary industry estimates. CESA recommends that LADWP adopt our proposed cost structure for the "general representative" LDES technology resource, as shown below.

Technology	**Cost multiplier (Annualized all-inclusive cost)**				**Round Trip Efficiency**	**Minimum duration (hours)**
	$/MW		**$/MWh**			
	2030	**2045**	**2030**	**2045**		
Lithium-ion	1	1	1	1	85%	1
Tech Neutral: LDES Option 1	6	6	0.25	0.25	72%	10
Tech Neutral: LDES Option 2	7.5	7.5	0.125	0.125	64%	100

This approach eases comprehension of the projected cost trends and has been vetted by leading LDES technology vendors and manufacturers. If LADWP wishes to either update these cost structures or validate these numbers, it could conduct an RFI to find a representative range of costs and tradeoffs across different characteristics based on submitted information.

Similar to the Princeton/MIT approach, LADWP could also conduct a sensitivity for the "target costs" and capabilities that must be reached in order to make this a viable future, which may inform if there are potential off-ramps to a future involving LDES to

[9] Sepulveda *et al*, *The Design Space for Long-Duration Energy Storage in Decarbonized Power Systems*, 2021.
[10] *Ibid.*

support in-basin reliability and resiliency needs if these technologies commercialize further, reach higher levels of deployment, and/or experience significant cost reductions with scale and technology maturity.

CESA appreciates the opportunity to provide these recommendations and hope these responses, in addition to our survey response, are helpful. Please do not hesitate to reach out if you have any follow up questions or would like to discuss further.

Sincerely,

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Policy Manager
CALIFORNIA ENERGY STORAGE ALLIANCE

Sampling of Commercially-Available Long-Duration Storage Technologies

ENERGY VAULT
Enabling a Renewable World

Gravity-Based Energy Storage Solutions

Energy Vault is the creator of **gravity and kinetic energy based**, long-duration energy storage solutions that are transforming the world's approach to delivering reliable and sustainable electricity.

our mission
to supply customers with **energy storage technology** that supports **affordable, sustainable, dispatchable power & reduced green energy procurement cost**

advantages
- no storage medium degradation >> *favorable economics*
- no end of life disposal issues >> *beneficial for the environment*
- no fire and hazardous gas risks >> *high level of safety*
- levelized cost of storage 40% lower than equivalent Li-ion solution (10 hours).

applications
- renewable shifting
- capacity support
- T&D investment deferral
- microgrid resiliency

environmental remediation
Energy Vault provides the **unique opportunity to remediate environmental liabilities at low cost** by sequestering then converting waste materials into beneficial use for brick and beam production.

Proven Technology
fundamental physics combined with proprietary automated control software

Environmental Remediation
opportunity to sequester waste material for production and construction

Best In Class Economics
40% lower LCOS; 100% automated operation with minimal OpEx

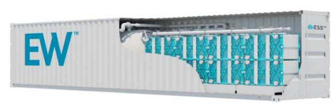
Unmatched Performance
30+ year life with zero degradation & 85% round trip efficiency

Flexible – Modular Scalable
portfolio of solutions from power applications (10-15min) to long duration storage (10+hrs)

 www.energyvault.com | info@energyvault.com Confidential

ESS INC

Iron Flow Battery

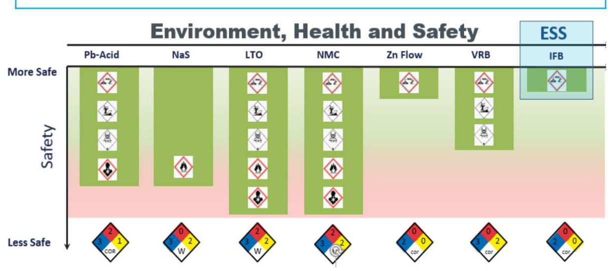


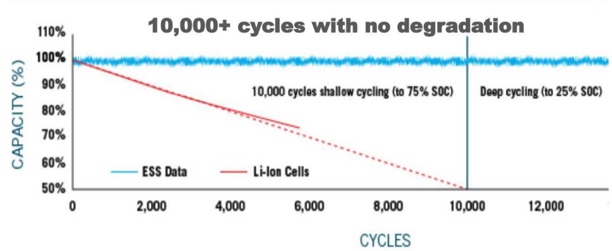
Company Overview

- Founded 2011, headquartered in Wilsonville, OR
- Key investors: Breakthrough Energy Ventures, Softbank Energy, BASF, Evergy Ventures, and PTTGC.
- Scaling to 1 GWh/year of battery production
- Investment-grade warranty backed by Munich Re
- C&I, microgrid and utility applications
- 100% Manufactured in America

6 – 12 Hours of Energy Storage

- Iron, salt and water chemistry
- Unlimited cycling capability
- Non-toxic, non-flammable, 100% recyclable
- Wide operating range: - 5^{C} to 50^{C}
- Sealed system requires no augmentation
- No toxicity, fire, chemical or explosion risk
- 25-year design life, low cost of total ownership





CESA
CALIFORNIA ENERGY STORAGE ALLIANCE

Energy Storage to Enable a 100% Renewable Energy Future

form energy

Storage Needed To Make Renewables as Reliable and Cost-Effective as Gas Power Plants Year-Round

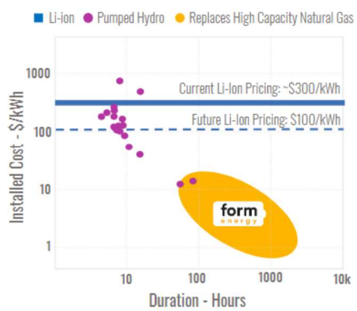
Reliable: Storage duration >24 hours is required.

Affordable: 1/10th the cost of lithium-ion storage.

Scalable: Globally abundant materials match the scale of energy infrastructure needs.

Modular: Can be sited anywhere, even behind the meter.

Safe: No mechanism for thermal runaway. No heavy metals. High recyclability.



Technology

Aqueous, air-breathing battery. Globally abundant commodity components. Modular, scalable architecture. Safe and recyclable.

Market

Firm renewables over any weather event or season, transmission capacity without new wires, reliability without thermal generation, and multi-day zero-carbon energy resiliency during grid outages.

Team

40+ employees based in Somerville, MA and San Francisco, CA. $51M in funding from current investors Eni Next, Breakthrough Energy Ventures, Prelude Ventures, MIT's The Engine, Macquarie Capital, and Capricorn Investment. Executive team of seasoned energy storage entrepreneurs:

- **CEO**: Mateo Jaramillo, Founder/VP Tesla Energy
- **Chief Science Officer:** Yet-Ming Chiang, MIT Prof., serial entrepreneur
- **COO/President**: Co-founder Aquion, Harvard Business School
- **CTO**: Billy Woodford, MIT Ph.D., 24M Director of Technology
- **SVP BD/Analytics**: Marco Ferrara, MIT Ph.D., VP Analytics IHI
- **VP Finance**: Charlotte Beard, Director Energy Finance Tesla

Going further with Pumped Hydro Storage

Large-scale renewable energy source with unique benefits to allow energy transition

Unprecedented storage scale
100x storage capacity vs. battery solutions

Sustainable
40-80 years lifetime GWh of storage

Limited environmental footprint:
closed-loop configuration, use of existing mines as reservoirs

Dispatchable renewable energy
Match consumption and demand, integrate variable Renewables

Highly flexible and reactive power solution
up to **400 MW** in less than **70 seconds**

Grid support capabilities
- Balancing
- Stability services

Huge untapped potential

600 000+ sites identified globally, equivalent to **23M GWh** of storage capacity

	Storage needs (GWh) to support 100% renewables		PHS Storage potential (GWh)
Australia	500	X 300	150 000
USA	7000	X 200	1 400 000

Source: Australian National University Study

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Liquid Air Energy Storage

Clean, cost-efficient, flexible and reliable

Highview Power's CRYOBattery™ technology makes use of a freely available resource – air – which is cooled and stored as a liquid and then converted back into a pressurized gas which drives turbines to produce electricity. Just as pumped-hydro harnesses the power of water, the CRYOBattery™ unleashes the power of air. It is the only long-duration energy storage solution available today that offers multiple gigawatt hours of storage, is scalable with no size limitations or geographic constraints, and produces zero emissions. Our cryogenic energy storage system delivers the lowest cost clean energy storage solution for large scale, long-duration applications.

- Synchronous Inertia
- Frequency Regulation and Reserves
- Synchronous Voltage Support
- Black Start
- Carbon Capture

30-40 year lifespan with mature components

Lowest cost locatable technology at utility scale

Zero emissions and benign materials

Zero water impact No external cooling

Proven technology with established supply chain

Build anywhere with no geographical constraints

~70% efficiency by utilising waste heat/cold

Giga-scale scalable to multiple GWs/GWhs


SLOUGH, UK


PILSWORTH, UK


FUTURE PLANT DEVELOPMENT CA, AZ, VT AND MANCHESTER, UK

Highview Power

www.highviewpower.com

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LOCKHEED MARTIN ENERGY

ABOUT LOCKHEED MARTIN ENERGY

Lockheed Martin is a global security and aerospace company principally engaged in the development, manufacture and integration of advanced technology systems. It is home to Lockheed Martin Energy, which delivers energy solutions to advance resilient, clean and sustainable energy around the globe for utility, commercial, industrial and military applications.

ENERGY STORAGE
GridStar® Flow – a coordination chemistry flow battery for short and long duration energy storage

FEDERAL RESILIENCY
Energy storage to ensure mission readiness while reducing base operating costs

NUCLEAR INSTRUMENTATION & CONTROLS
Instrument and controls systems to support Navy nuclear fleet and commercial facilities

GRIDSTAR FLOW

GridStar Flow is a redox flow battery based on coordination chemistry that provides energy storage capable of addressing short and long-duration (6+ hours) applications.

ADVANTAGES

- Durability
- Flexibility
- Safety
- Low Total Cost of Ownership

STATUS

GridStar Flow has been in development since 2011, with multiple test systems in operation. The first commercial GridStar Flow system is scheduled to go online in 2020.

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For more information visit lockheedmartin.com/energy

Long-Duration, Utility-Scale Energy Storage for California

Malta's **molten salt** storage solution converts electricity into **thermal energy** for storage then converts it back to electricity for dispatch to the grid. With **on-demand** capacity of **4 to 24+ hours**, it can be **safely sited** nearly anywhere and is **generation-source neutral**.

Malta's expected **30+ years** of **unlimited cycling**, **degradation free** system life will **help California** to become **100% carbon free** in a **cost effective** manner.

Multiple Use Cases, No Waste or Disposal Concerns

Malta's solution can be safely used for **renewables firing**, **grid balancing**, and **T&D deferral**. **District heating** using system heat is also available. It has **no waste** byproducts throughout its long lifespan posing **no longterm challenges** with disposal or **recycling**.

World-Class Partners and Investors

Malta's partners include world-renowned heat exchanger manufacturer **Alfa Laval**, a world-class turbomachinery manufacturer, **Breakthrough Energy Ventures** (BEV), and **Concord New Energy** (CNE).

FEATURES

LONG DURATION
4 to 24+ HOURS

UTILITY SCALE
10 to 100+ MW

FLEXIBLE SITING
No geographic restraints

PRIMARY APPLICATIONS

RENEWABLES FIRMING

GRID-BALANCING

T&D DEFERRAL

MALTA

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Eagle Crest
Energy Company

Eagle Mountain Pumped Storage Project
Making Renewable Energy Dependable

- Closed-loop hydroelectric pumped storage power project will provide safe, clean and reliable power.
- Uses former mining pits to create the upper and lower reservoirs
- Site has undergone extensive environmental review and fully permitted
- 1,300 megawatts of power – enough to supply more than 1 million homes
- Long duration storage, with the ability to discharge for up to 18 hours
- Projected useful life of more than 50 years
- Project will cost-effectively avoid solar curtailment, improve transmission efficiency and provide electrical grid stability

NEXTracker – PV + NX Flow

NEXTracker is the leading global PV tracker supplier with 27GW under fulfillment / delivered. Our controls platform, software and NX Flow battery provide intelligent, dispatchable, firm renewable power plant capabilities.

Our innovative DC-coupled design allows for the highest DC / AC ratios, increasing plant capacity factors, improving performance and reliability, and providing a "future-proofed" flexible architecture.

NX Flow Specifications

- Expandable building blocks
- 4 to 12 hour duration
- 100% Depth of Discharge*
- < 2% lifetime Degradation*
- 20-30 year component coverage*
- *98% capacity and availability service plan

NAS™ Battery Storage Systems - Proven Reliability

- Most of the world's largest battery projects use NGK's NAS storage.
- Deployed for over 18 years in over 200 projects, over 4 GWh, over 580 MW.
- 6 hours capacity. Cascadeable.
- Long life - 15 years, 4500 cycles.
- NGK is a $4 billion, publicly traded, profitable Japanese company.
- GWh-scale manufacturing capacity / year.
- NGK supplies the electric power, automotive and microelectronics industries with a wide range of ceramics-based products.

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NGK INSULATORS, LTD.

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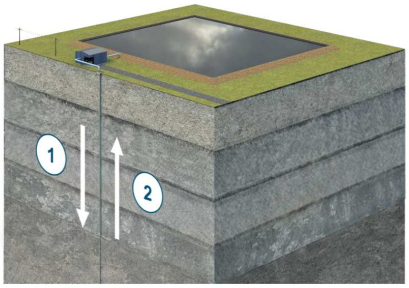
Quidnet Energy

Geomechanical Pumped Storage opportunity overview

Geomechanical Pumped Storage (GPS)

Storing energy as pressurized water in the subsurface without need for elevated terrain



1 **Charging** into high-pressure storage lens

2 **Discharge** from high-pressure storage lens

Long-duration storage resource opportunity in California

- **2 TWh** geologic storage resource in California

A step-change in technoeconomics

- 1-10 MW modules / **10+ hours storage** capacity
- 75% round-trip efficiency
- **$5 capex per incremental kWh**; 50% less capex vs pumped hydro

Mature execution platform

- Construction and O&M leverages **well-established supply chain** for drilling and industrial machinery
- Geo-assessment & construction procedures tested in North Texas
- Backed by Breakthrough Energy Ventures, US Department of Energy

Breakthrough Energy VENTURES

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Compressed Air Energy Storage (CAES)

RANGE ENERGY STORAGE SYSTEMS

- Proven technology that can come online quickly
  - Existing plants in operation 30+ years; 160 MW facility planned for LADWP
  - CAES can be developed incrementally (160 MW at a time) and relatively quickly (~3 years)
- Dispatchable/flexible load
  - Capability to absorb large quantities of midday solar overgeneration through compression and hydrogen production
- Time-shifting long duration storage to supply evening load
  - Capture renewable energy when generated and dispatch energy when load ramps up
- Seasonal energy storage
  - Store spring/winter overgeneration to supply high summer net load
- Renewable integration multiplier
  - Maximizes utilization of fixed transmission capacity
  - 1,200 MW of CAES can integrate more than 3,600 MW on limited transmission capacity without curtailment (WECC TEPPC Study)
- Next Generation fueling
  - Conventional CAES utilizes natural gas in the generation phase; Siemens is developing a CAES turbine which will be capable of 100% hydrogen fueling within the decade

Flexible Use Cases

Use Case	Characteristics
Daily Operating Cycle	• 8 hours/day in generation • 7 hours/day in compression • 7 days/week
Long Duration	• 28.2 hours in generation • 40 hours in compression
Deep Discharge	• 52.2 hours in generation • ~74 hours in compression

Ancillary Services

- Ramping
- Regulation
- Spinning and non-spinning reserves
- Load following
- Black start
- Resource adequacy capacity

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Seasonal storage will be needed as integration of higher renewable fractions in California will lead to persistent overgeneration in spring and summer months creating seasonal imbalance. Hydrogen is the first viable option for seasonal storage needs.

Hydrogen is critical for a lower carbon energy mix. It can be used broadly across several industries, including for transport, steel, ammonia, methanol, refining, in residential and commercial buildings, and in the power system

Technology

Addressing this seasonal imbalance will require large scale storage resources capable of storing power over longer durations cycles (days, months etc.).

Renewable hydrogen produced using a renewable energy source such as solar, wind etc. can be stored in geologic formations like naturally occurring porous rock formations (e.g., sandstone and fissured limestone), depleted gas or oilfields. Hydrogen can also be blended, stored and transmitted in the existing natural gas infrastructure.

Hydrogen is also capable of offering a multitude of grid support services including energy arbitrage, demand response, peaker replacements, black start, T&D deferrals, power quality and reliability.

Deployments

LADWP's Intermountain Power Project will convert existing power plant to 100% renewable hydrogen by 2045. Underground salt caverns will be utilized to store renewable hydrogen for long term or seasonal storage needs serving Los Angeles, Southern California, and the Western region.

SoCalGas' vision to be the cleanest natural gas utility in North America sees hydrogen as a strategic energy resource to help California advance its clean energy agenda