

DOCKETED

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CA Energy Storage Needs

September 2, 2020

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Quick Takeaways

- **CESA studied** SB 100 compliance using cutting edge model (Blue Marble)
 - Highlight quantity and combinations (durations) of storage needed for SB 100 compliance
 - Look for cost-savings by deploying portfolios with longer-duration storage solutions
 - Educate on many types of long-duration energy storage available now or near-term
- **Findings: *Get Moving on storage deployments!***
 - **MORE THAN 40 GW / 400 GWh needed by 2045!** Start now! Current amounts of storage are de minimus compared to need
 - Longer-duration energy storage (e.g. 6+ hour) needed *en masse* – CA would be wise to further develop this part of 'tool-kit' now with bigger buying ahead
 - Portfolio diversity with different durations of energy storage must be a priority – lots of roles for shorter and longer duration storage
- **Implications for SB 100 Report: Needs and urgency are understated, especially for long-duration energy storage**
 - Perfect foresight models likely underestimate the needs for storage in local areas and in 'many cloudy days' scenarios
 - Storage is a no-regrets and necessary addition to our grid if we are to reliably achieve significant renewable penetrations, e.g. clean-peak policy (SB 338, Skinner)

About the study

- Energy Action Fund (EAF) and the California Energy Storage Alliance (CESA) leveraged the expertise of Strategen Consulting to assess the opportunity for long duration energy storage (LDES) in California



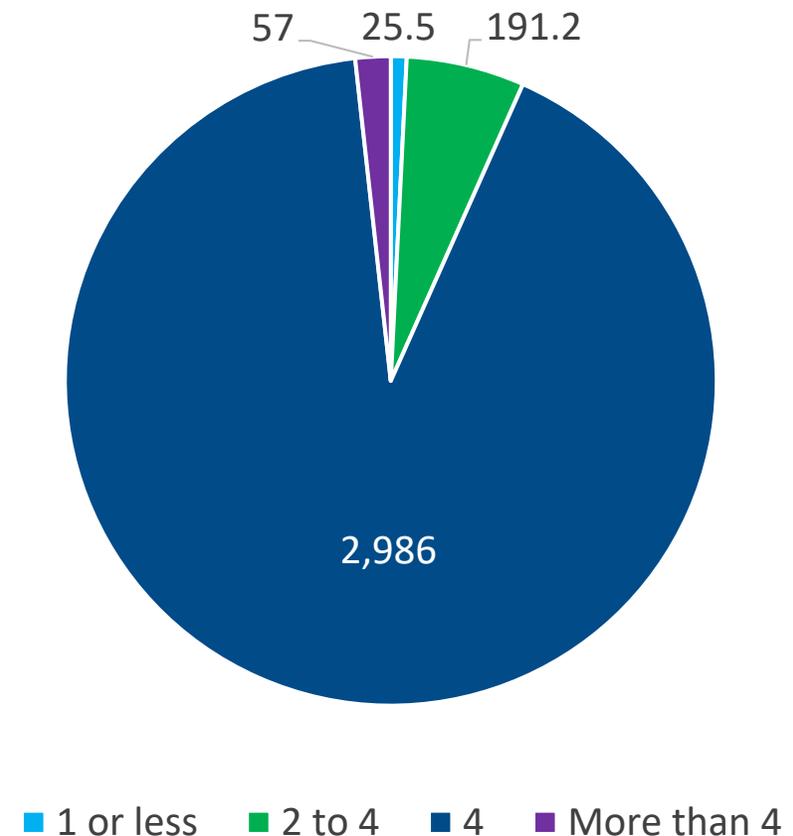
- **A modified RESOLVE Reference System Plan (RSP) analysis shows need for >40 GW / 400 GWh of energy storage by 2045, much of which is long-duration, enabling:**
 - Retirement of ~10 GW of natural gas generation
 - \$1.5 B / yr reduction in system capacity costs
 - Higher utilization of renewable energy, with ~17% lower curtailment
 - Reduced in-state emissions during non-peak months
- **California's decarbonized future is dependent on LDES; rule changes can enable its development**
 - Modify RA while retaining viability of already established storage contracts
 - Use the IRP proceeding to establish clear procurement targets for no-regrets resources
 - Promote more 'readiness' of storage tool-kit through diversity in fleet

Energy storage is essential to achieve California's decarbonization goals, but our regulatory framework limits long-duration storage deployments

Where are we now?

- Very small amounts of energy storage deployed to date, despite fanfare*
 - Mostly 4-hour storage per RA rules
- Regulators have noted the need for longer duration storage given expected peak needs
 - CAISO's Local Capacity Requirements Technical Study (LCRTS) shows need for 9-hour duration storage to decarbonize local areas
 - The CPUC's IRP RSP shows battery storage deployments of ~7 hours

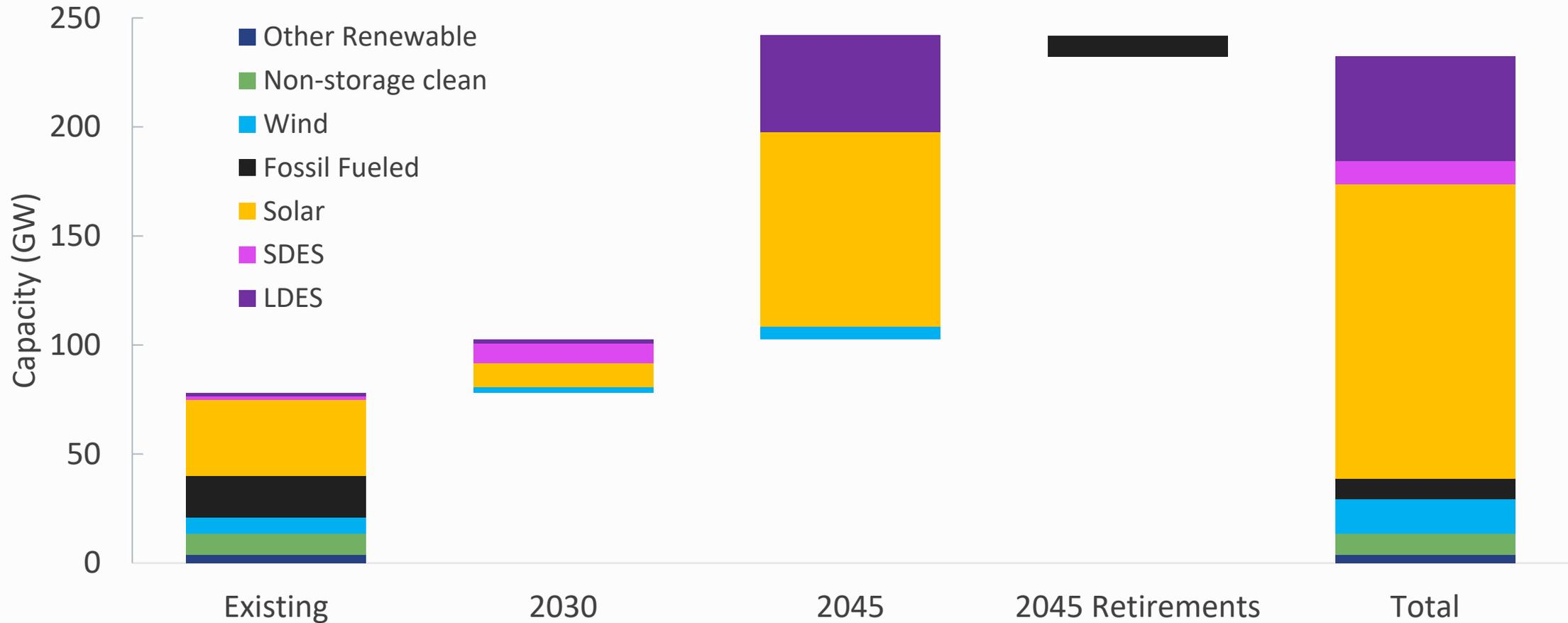
MW of energy storage procured in past decade in California by duration (*Hours*)



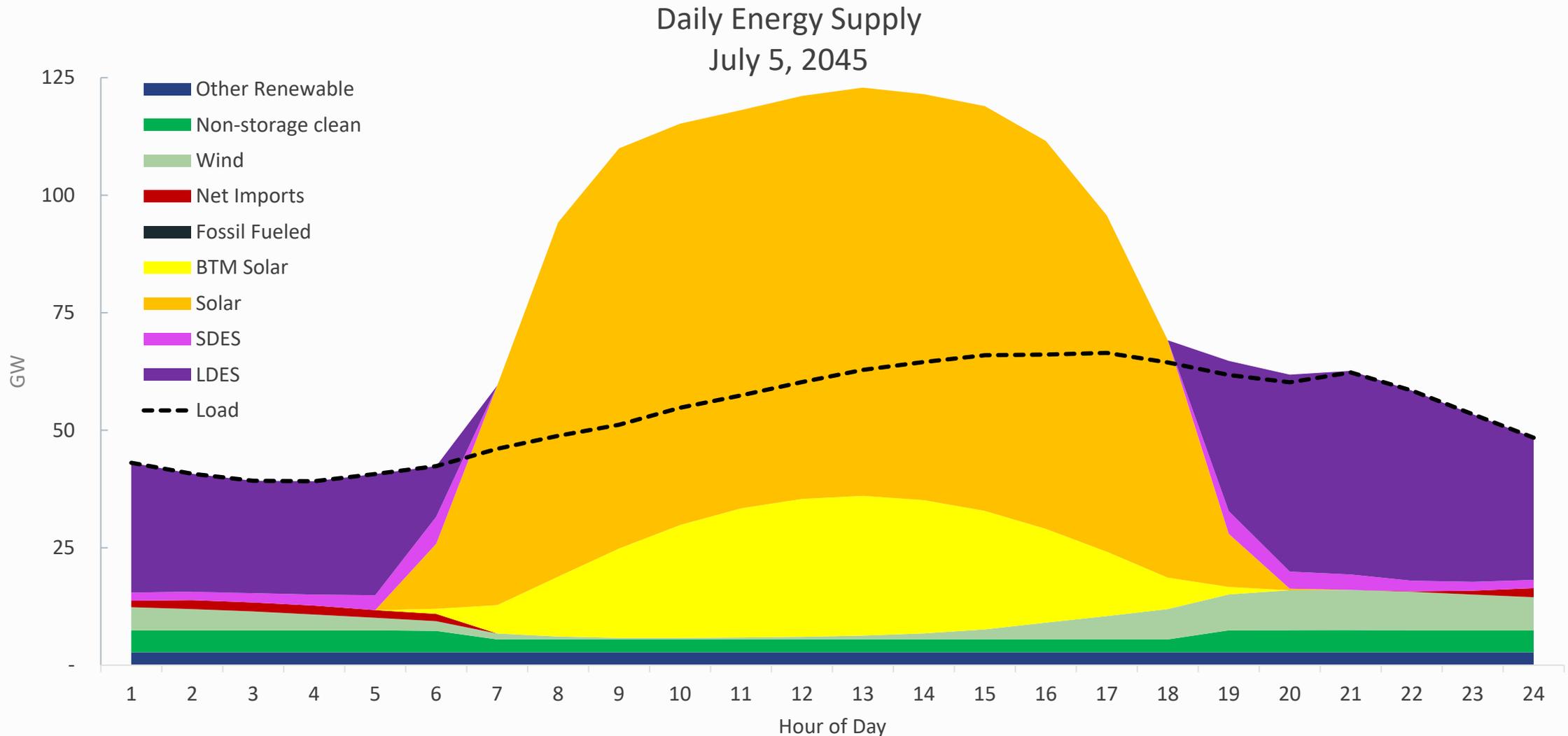
*based on procurement tracking by CESA, which includes SGIP

What will the future look like?

Installed Capacity by 2045
(GW)

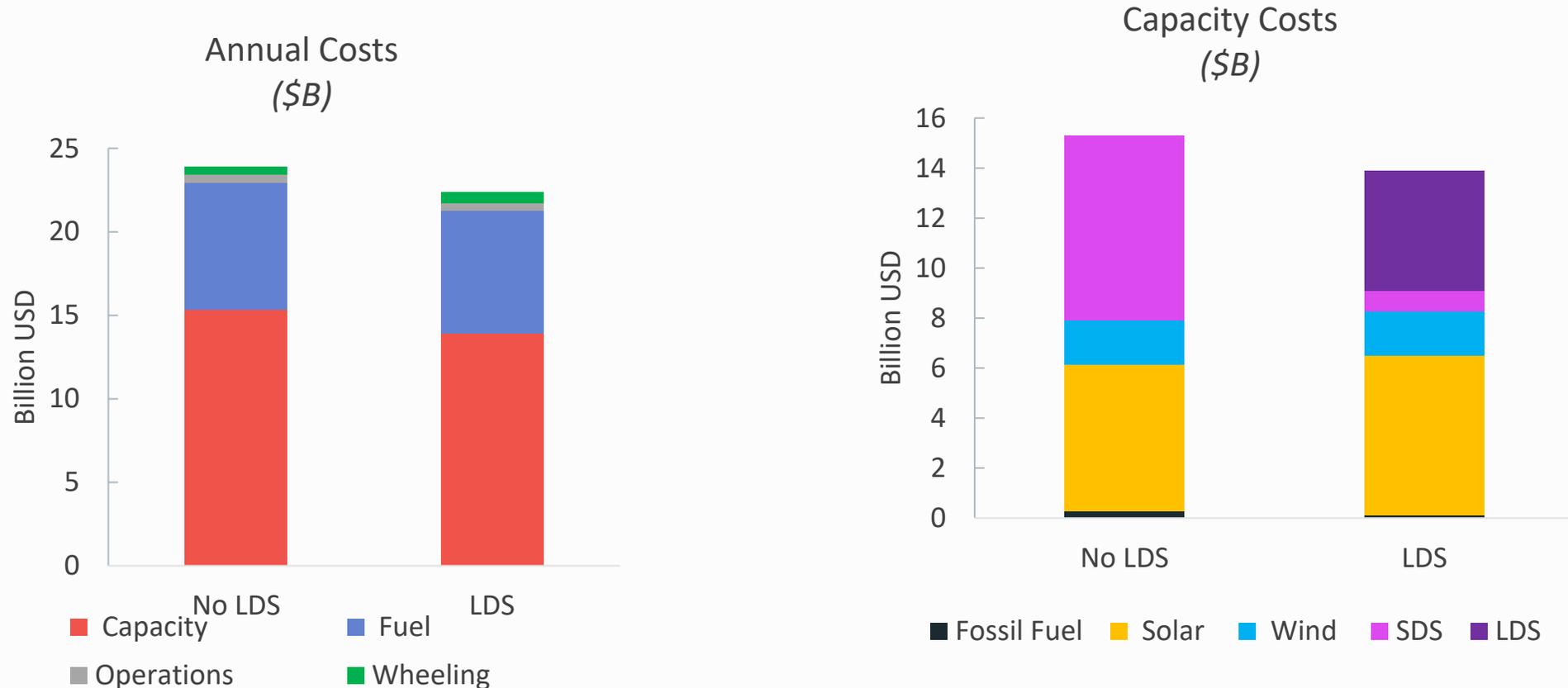


LDES meets evening energy needs under high solar



“Other Renewable” includes small hydro, geothermal, and biomass. “Non-storage clean” includes hydro, nuclear, and demand response. “Fossil Fueled” includes CCGT, Peakers and other natural gas.

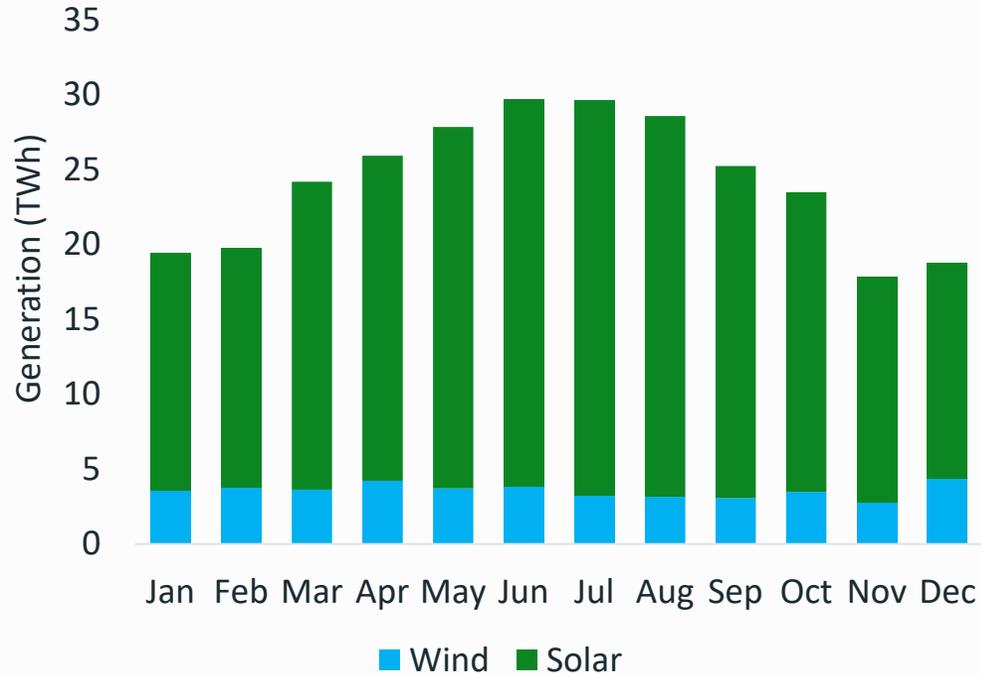
LDES saves ratepayers \$1.5 billion/year



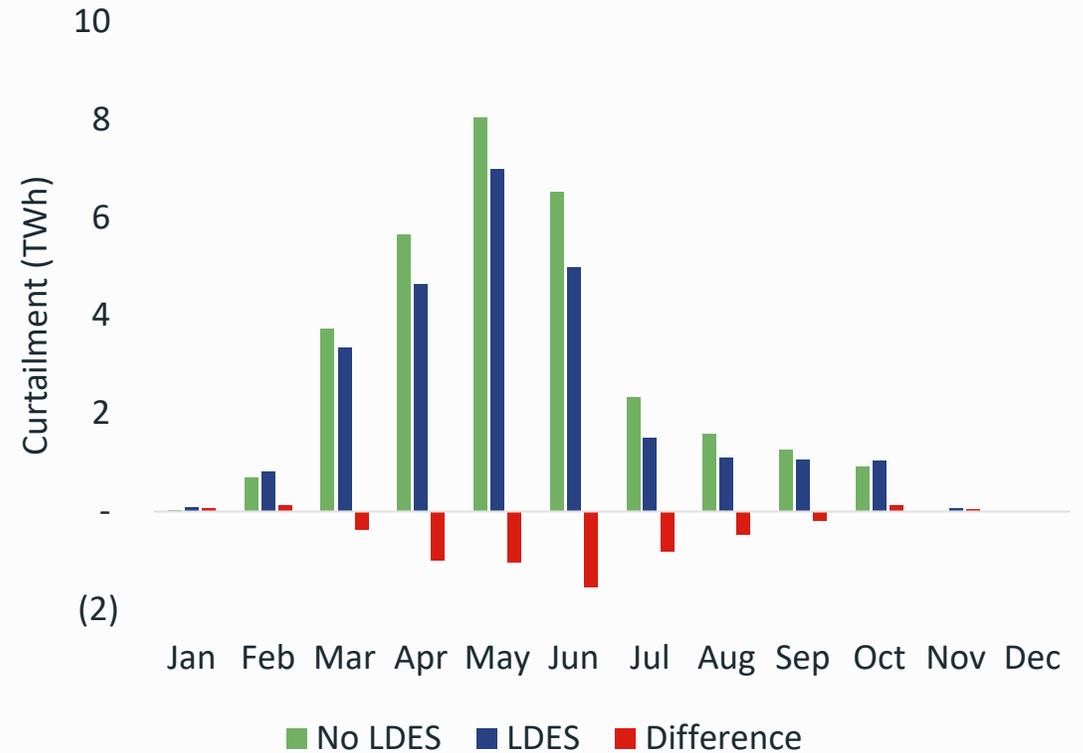
Inclusion of LDES reduces customer costs by \$1.5 B per year while eliminating the need for fossil-fueled capacity

LDES maximizes the use of renewable energy

Monthly Renewable Generation,
LDES Case
(TWh)

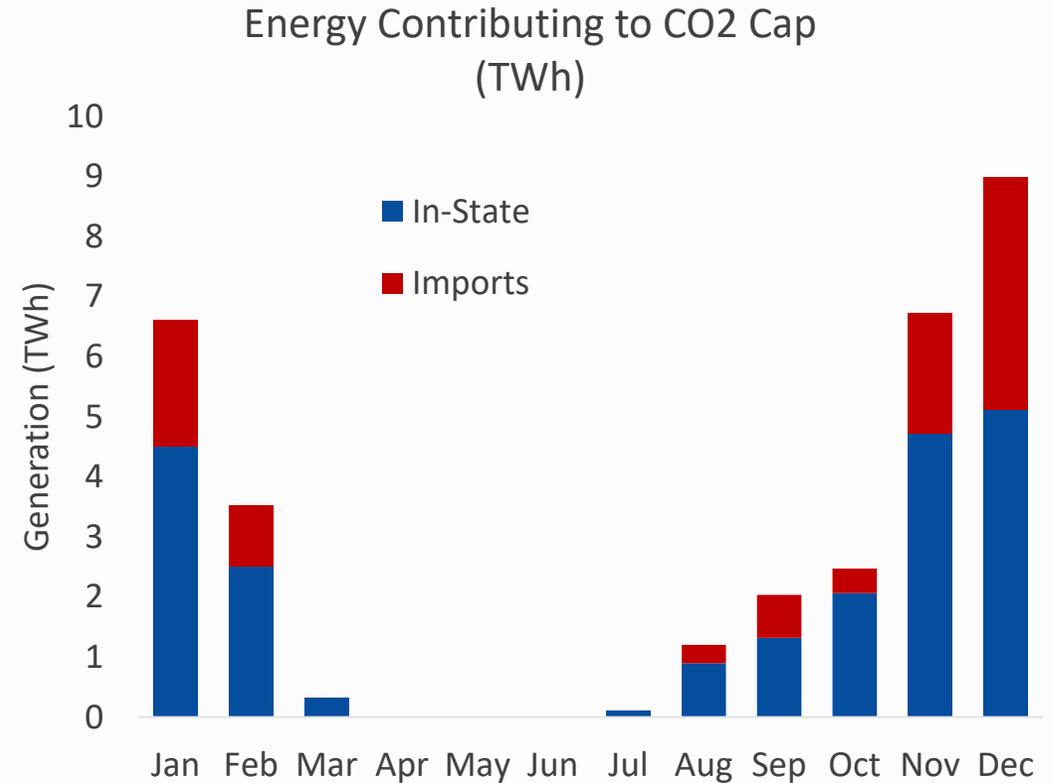
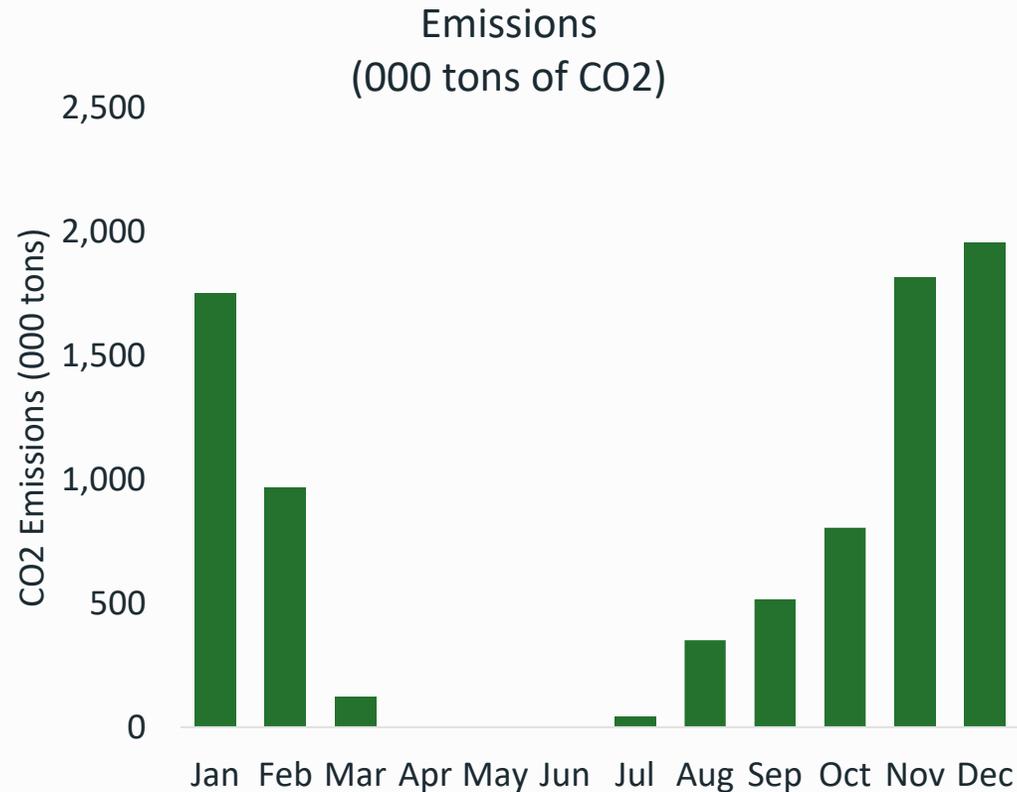


Curtailement
(TWh)



Portfolio of energy storage reduces curtailment by ~17%

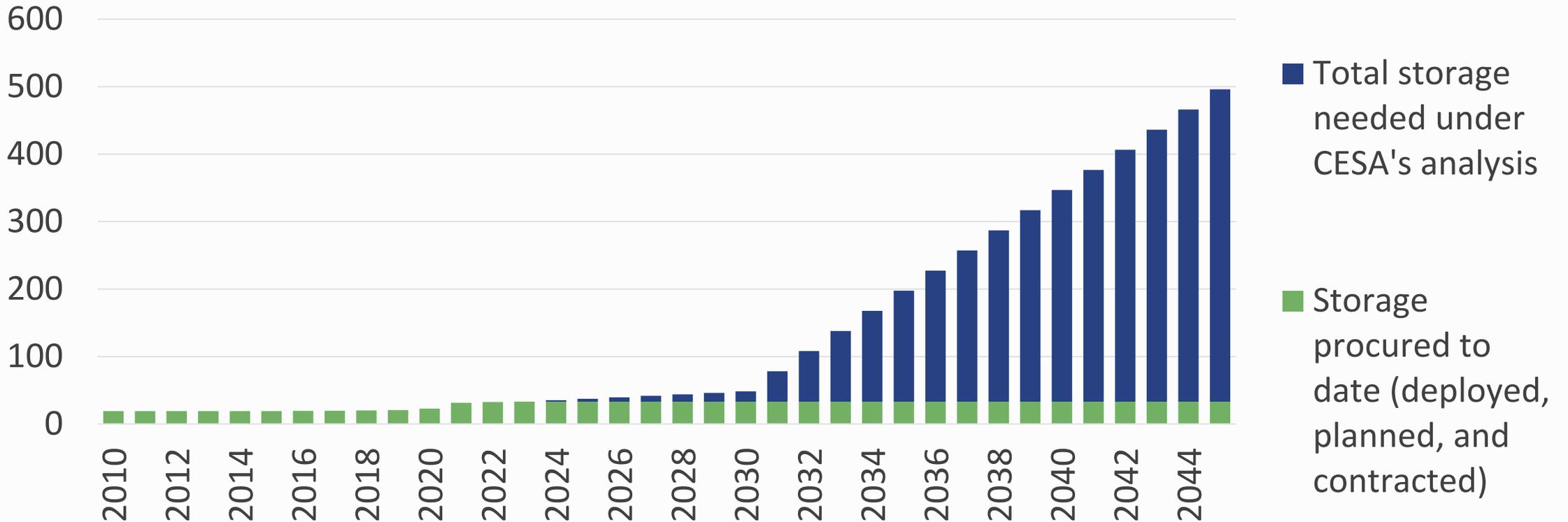
LDES limits in-state emissions



LDES limits the use of in-state fossil-fueled resources to the winter months

We must act now to ensure reliability and sustainability

Energy Storage Deployment Needs (GWh)



The pace of deployment in 2030 & beyond may necessitate early action

How can CA provide appropriate direction?

Near-term, no-regrets procurement

Leverage IRPs or IRP proceeding (procurement track) to ensure the timely deployment of LDES and other no-regrets resources

Base RA on future grid needs and resources

Modify RA program to support development of portfolios of energy storage to meet needs

Transform with certainty

Promote 'readiness' and viability of broad array of storage solutions with 'diversity procurements', better certainty of needs for short and long-duration storage, and grandfathering mechanisms/contract certainty. Allow energy markets to direct dispatch with peak/off-peak prices

Existing proceedings can create opportunity for long-duration storage

THANK YOU

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Appendix



A study aligned with California

Methodology	Inputs	Scenarios
<ul style="list-style-type: none">• Used GridPath, a RESOLVE-like model developed by former E3 consultants• Focused on full 8760-hour dispatch horizon to allow for improved resource optimization & cost-effectiveness	<ul style="list-style-type: none">• Aligned with state planning assumptions about resource availability, demand and carbon reductions• Modified storage costs to correctly represent long duration energy storage based on member feedback	<ul style="list-style-type: none">• Benchmark against CPUC Reference System Plan (RSP)• Understand incremental value-add of long-duration energy storage in California's resource portfolio by 2030 and 2045

Modeling was designed to align with California policy and planning, while providing a specific focus on the need for and value of long-duration energy storage

A study aligned with California

	Cost multiplier (Annualized all inclusive cost)		Round Trip Efficiency	Minimum Duration
	\$/MW	\$/MWh		(hrs)
Lithium Ion	1.0	1.0	85%	1
Flow Battery	8.0 – 9.6	0.62 – .7	70%	1
Pumped Storage	10.1 – 12.4	0.39 – .64	81%	12
Tech Neutral: LDES Option 1	6	0.25	72%	10
Tech Neutral: LDES Option 2	7.5	0.125	64%	100

Some storage options are based on assumptions from the CPUC's IRP

Some storage options are unique to this study, and intended to be indicative of long duration energy storage solutions

Storage solutions were designed to present plausible, but distinctly different storage options for the model to choose between

A study aligned with California

- Modeled two years
 - **2030:** used CPUC planning assumptions including CAISO 32.4 MMT carbon cap
 - CPUC RSP assumes a statewide 46 MMT carbon cap for the electric sector
 - CAISO footprint carbon cap is 37.9 MMT, but includes 5.4 MMT for REC allowances → 32.4 MMT carbon cap
 - **2045:** used CPUC planning assumptions, including CAISO 12.3 MMT carbon cap
 - Current statewide interpretation of SB 100 allows for losses ($\approx 10\%$ of total generation) to some emitting resources → 12.3 MMT carbon cap
- These results focus on 2 scenarios
 - **No LDES:** use CPUC assumptions for storage resources BUT do not allow model to select any LDS resources
 - **LDES:** use CPUC assumptions for storage resources AND generic, technology neutral long duration energy storage solutions; allow model to select any type of storage
 - CPUC Reference System Plan was also analyzed as a benchmark

Examples of Long-Duration Energy Storage CESA Member Companies

1. Energy Vault: Gravity Based Energy Storage
2. ESS: Iron Flow Battery
3. Form Energy: Aqueous Battery
4. General Electric: Pumped Hydro Storage
5. Highview Power: Liquid Air Energy Storage
6. Lockheed Martin: Redox Flow Battery
7. Malta: Molten Salt Storage
8. NextEra Energy: Eagle Mountain Pumped Hydro
9. NexTracker: Vanadium Flow Battery
10. NGK: Sodium Sulfur Battery
11. Quidnet Energy: Geomechanical Pumped Storage
12. Range Energy: Compressed Air Energy Storage
13. SoCal Gas: Renewable Hydrogen

Does not represent all CESA member companies nor all long-duration storage companies. Longer energy storage durations can also be provided by 'stacks' of batteries or through other tech combinations, e.g. solar+storage solutions.

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*
- leveled 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



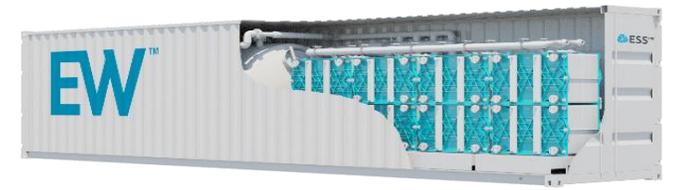
Unmatched Performance

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)



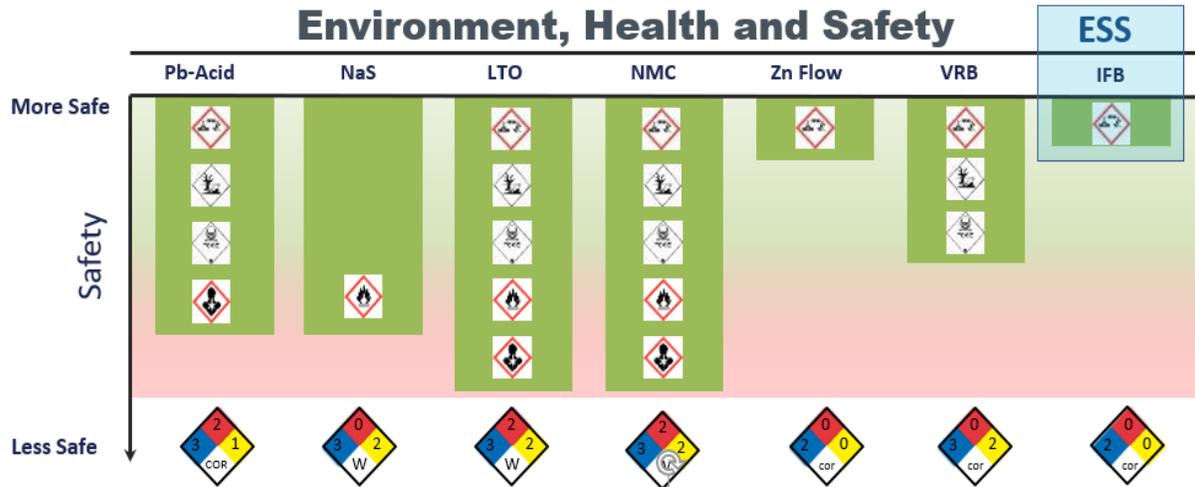
Company Overview

- Founded 2011, headquartered in Wilsonville, OR
- Key investors: Breakthrough Energy Ventures, Softbank Energy, BASF, Eversource Energy, 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

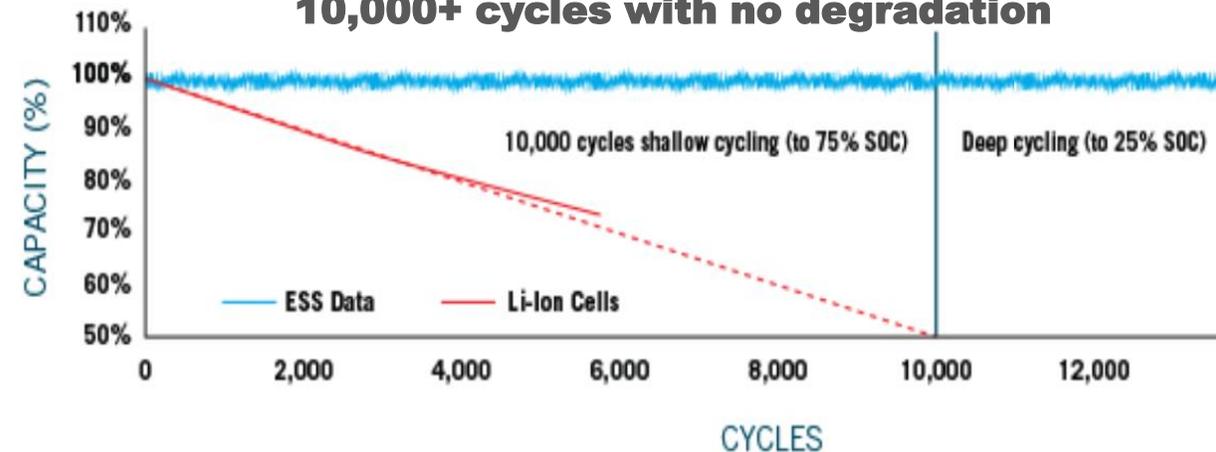
6 – 12 Hours of Energy Storage

- 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

Environment, Health and Safety



10,000+ cycles with no degradation





Energy Storage to Enable a 100% Renewable Energy Future

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

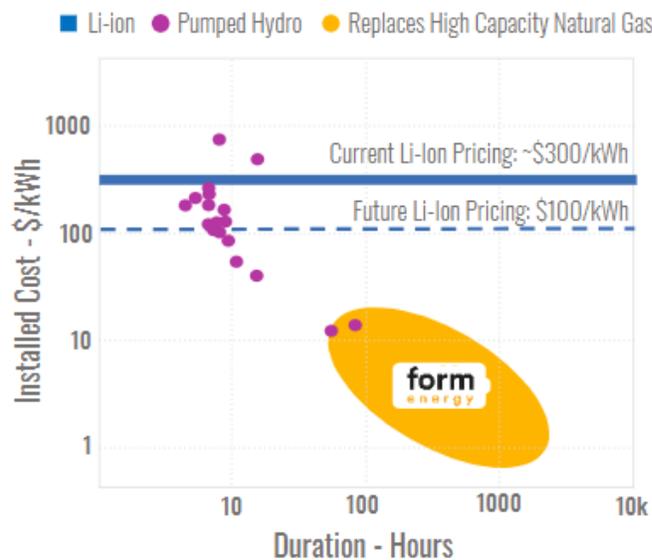
Reliable: Storage duration >24 hours is required.

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

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
- Synchronous Voltage Support
- Frequency Regulation and Reserves
- 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

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.



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 firming**, **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 FIRING



GRID-BALANCING



T&D DEFERRAL



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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

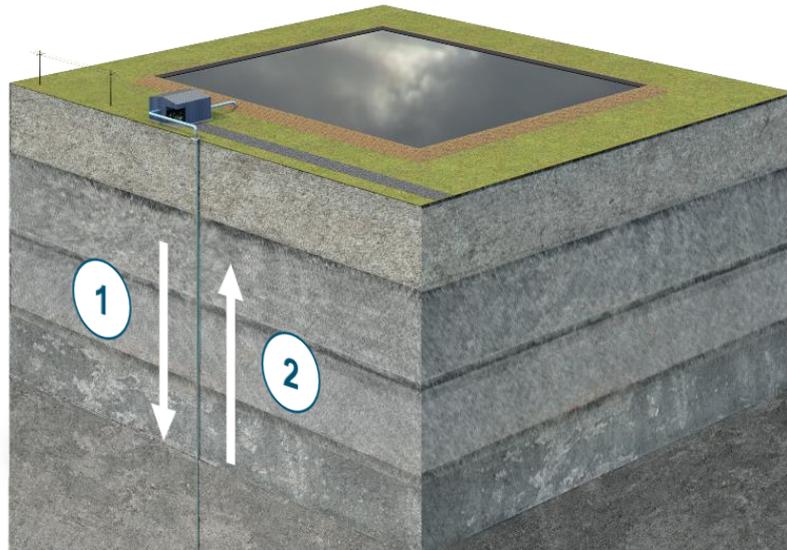
- Most of the world's largest battery projects use NGK's NAS storage.
- Deployed for over 18 years in over 200 projects, over 4 GWh, over 580 MW.
- 6 hours capacity. Cascadeable.
- Long life - 15 years, 4500 cycles.
- NGK is a \$4 billion, publicly traded, profitable Japanese company.
- GWh-scale manufacturing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



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



Compressed Air Energy Storage (CAES)

- 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	<ul style="list-style-type: none"> • 8 hours/day in generation • 7 hours/day in compression • 7 days/week
Long Duration	<ul style="list-style-type: none"> • 28.2 hours in generation • 40 hours in compression
Deep Discharge	<ul style="list-style-type: none"> • 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

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