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ACHIEVING 100% RENEWABLE ENERGY IN LOS ANGELES

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Energy Storage Update
SLTRP Advisory Group Meeting #7
December 17, 2021

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LA100 Common Investments Across All Scenarios

Electrification
Efficiency
Flexible Load

Customer
Rooftop Solar

Renewable
Energy

Solar: + >5,700 MW
Wind: + >4,300 MW

Energy Storage

+ >2,600 MW

Transmission,
Distribution

Renewably Fueled
Dispatchable
Turbines

+>2,600 MW
(in basin)

Much More

Natural gas → Biofuel/ hydrogen	
Today: Daily	**Future:** Infrequently

BESS = Battery Energy Storage System

Accelerated Energy Storage

- Utility scale energy storage at or near most in-basin Generating Stations
- Negotiate expansion of Beacon Energy Storage by 25 MW
- Expand energy storage by co-locating storage at all future utility scale solar projects
- Advertised Energy Storage Rolling Request for Proposals in 2021
- Increased usage of Castaic pumped hydro to integrate increased renewables

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Multiple Roles for Energy Storage

Low-Carbon Energy Supply	Enable greater deployment of renewables and direct low-carbon energy supply to customers
Dispatchable Resource	Provide reliability and grid stability with multiple options for output and duration
Customizable Options	Support scaled deployment in response to energy transformation

Source: EPRI

Energy Storage Cost & Duration Spectrum

Storage should have a duration that fits the need

Medium-Long Duration

Short

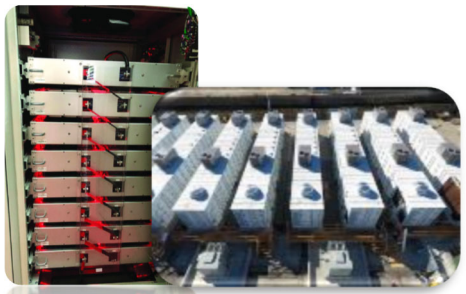
Chemical

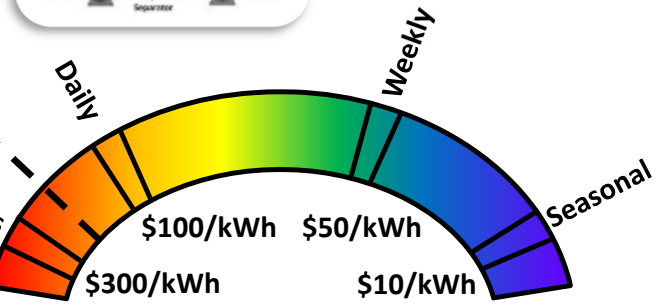
Thermochemical

Flow Batteries

Mechanical

Electro-chemical (Li-ion Batteries)





Thermal

Different technologies are best suited for each duration type

Source: EPRI

Energy Storage Today

Mechanical

Pumped Hydro

9 TWh (93%)
Size: GWhs, 8–12 hours

Electro-chemical

Lithium-Ion Batteries

0.7 TWh (7%)
Size: MWhs, 1–6 hours

Can these technologies fill all the energy storage needs?

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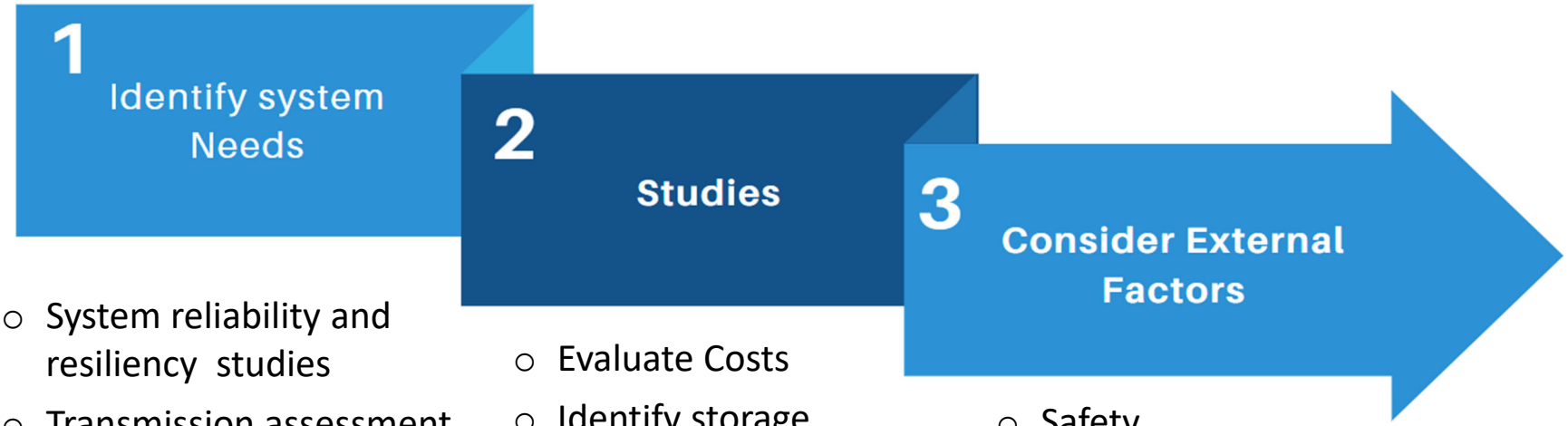
Source: EPRI

Planning Guidelines



- System reliability and resiliency studies
- Transmission assessment
- Integrating renewable energy
- Reducing peak demand
- Deferring power system upgrades

- Evaluate Costs
- Identify storage applications
- Evaluate emerging storage technologies
- Perform studies to assess use case

- Safety
- Impact to frontline communities
- Regulatory Issues
- Price projections
- End of life applications and disposal
- Environmental impact

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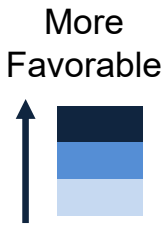
Energy Storage Technology Comparison



	Li-Ion Batteries	Pumped Hydro	Thermal	Mechanical	Chemical
Cost of Storage					
Duration					
Efficiency (AC-AC)					
Environmental					
Footprint					
Inertia					
Maturity					
O&M					
Response Time					
Safety					
Scalability					
Startup Time					

Source: EPRI

No energy storage technology is one-size-fits-all

Studies Impacting ES Deployment Strategy

- Maximum Generation Renewable Energy Penetration Study (Completed 2015)
- SB801 Compliance Study (Completed 2018)
- Transmission Hosting Capacity Study (Completed 2021)
- Distribution System Voltage Conversion Study (Completed 2021)
- LA100 Study (Completed 2021) & SLTRP (Rolling)
- System Impact and Feasibility Study (Rolling)
- 10 Year Transmission Expansion Planning (Rolling)
- Reliability & Resiliency Studies (In-progress)

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EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Leading Collaborative Energy R&D Around the World

EPRI advances energy technologies and informs decision-making through ~$420M in collaborative annual research involving nearly 400 entities in ~40 countries - spanning the generation, delivery, and use of electricity.

ENGAGING

- Utilities
- Academia
- OEMs
- Regulators

LISTENING

- Financial Community
- Policy Makers
- Consumer Advocates
- Media

Source: EPRI

Safety & Cost Studies in Collaboration with EPRI

- **P94: Energy Storage and Distributed Generation**
  - SB 801 Study (Completed) -> Eland Solar+BESS PPA Procurement (Completed 2018)
  - IPP Compressed Air Energy Storage CBA Analysis (Completed 2019)
  - Transmission Hosting Capacity Study (Completed 2021)
  - BESS End-of-Life Recycling Study (Completed 2021)
  - Fire Prevention and Mitigation Study (In-progress)
- **P174: DER Integration**
  - Inverter Based Resources Control Study (Completed 2021)
- **P197: Environmental Aspects of Fueled Distributed Generation and Energy Storage**
  - Fire Water Study (In-progress)
- **P221: Bulk Energy Storage**
  - Bulk Energy Storage Cost and Performance (In-progress)
    - Pools utilities' resources together to evaluate Long Duration Energy Storage (ES) technologies

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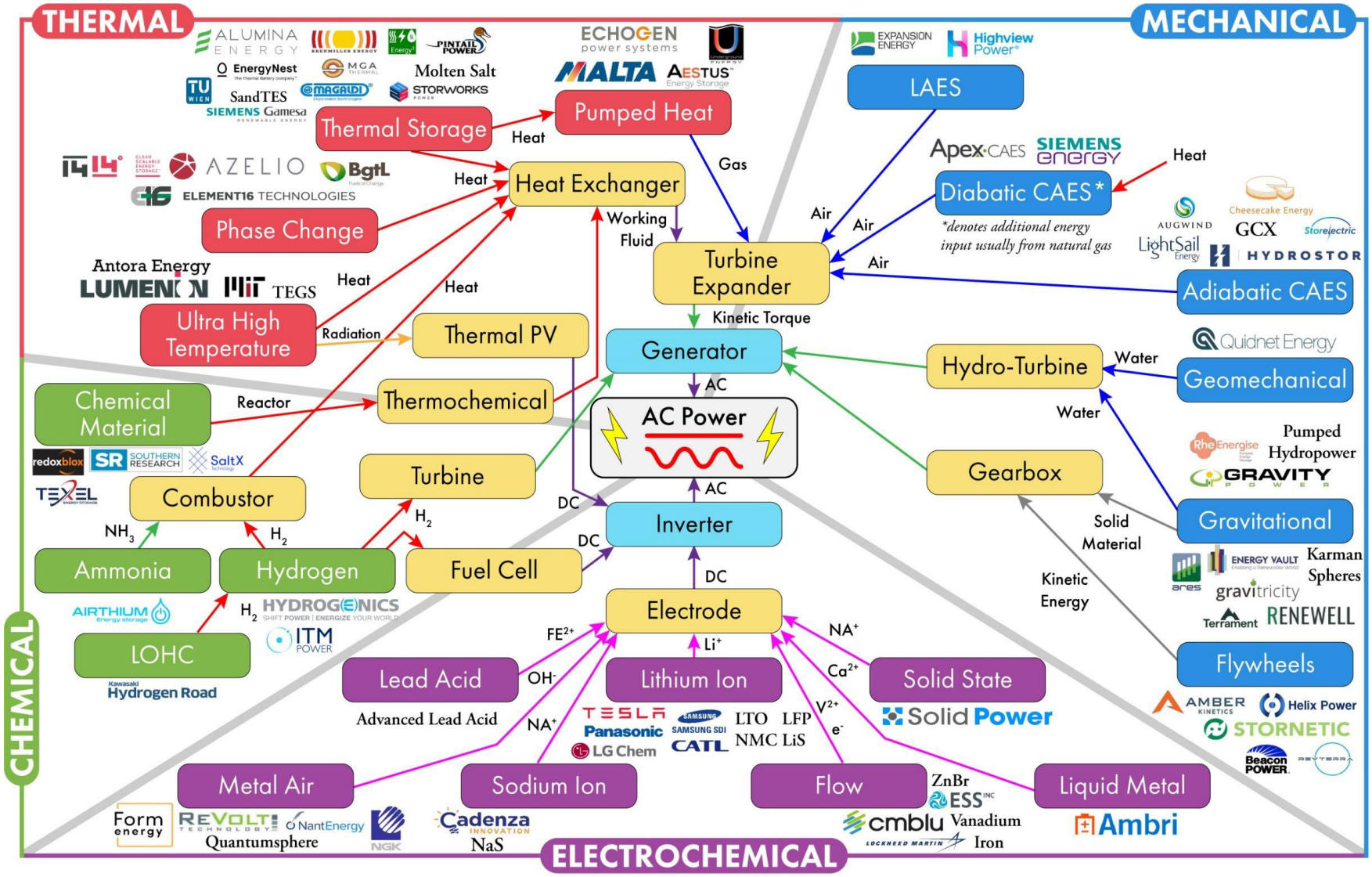
THERMAL
MECHANICAL
CHEMICAL
ELECTROCHEMICAL
Thermal Storage
Pumped Heat
Heat Exchanger
Phase Change
Ultra High Temperature
Thermal PV
Thermochemical
Chemical Material
Reactor
Combustor
Turbine
Fuel Cell
Ammonia
Hydrogen
LOHC
Heat
Gas
Working Fluid
Air
Turbine Expander
Kinetic Torque
Generator
AC
AC Power
Inverter
DC
Electrode
Li+
LAES
Diabatic CAES*
*denotes additional energy input usually from natural gas
Adiabatic CAES
Hydro-Turbine
Water
Geomechanical
Gearbox
Solid Material
Kinetic Energy
Gravitational
Pumped Hydropower
Flywheels
Lead Acid
Advanced Lead Acid
Lithium Ion
Solid State
Solid Power
Metal Air
Sodium Ion
Flow
Liquid Metal
Ambri
Quantumsphere
NaS
Vanadium
Iron
ZnBr
LTO
LFP
NMC
LiS
Tesla
Panasonic
LG Chem
CATL
Samsung SDI
Karman Spheres
RENEWELL
Helix Power
STORNETIC
Beacon POWER

Source: EPRI

Challenges With Emerging Technologies

- Unknown performance due to the lack of large scale sites in operation
- Risks with deployment emerging technology
  - Applied Engineering risk
  - Scaling up risk
  - Learning curve risk for initial years
  - Uncertainty on the cost
- Financing difficulty due to uncertain ROI (return on investment)

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Energy Storage Technology Database

Currently 52 total entries

Type	Medium	TRL	Type	Medium	TRL
Thermal	Silicon	5	Thermal	Gravel	3
Mechanical	Compressed Air	9	Chemical	Hydrogen	7
Electrochemical	Lead	8	Mechanical	Air	2
Mechanical	Gravitational	6	Mechanical	Compressed Air	4
Thermal	Ceramic	2	Electrochemical	Lithium Ion	9
Thermal	Ceramic	5	Electrochemical	Lithium Ion	9
Mechanical	Flywheel	7	Electrochemical	Lithium Ion	9
Electrochemical	Liquid Metal	4	Electrochemical	Lithium Ion	4
Thermal	Carbon	3	Thermal	Liquid Salt	4
Mechanical	Compressed Air	7	Thermal	Silicon	3
Mechanical	Flywheel	9	Thermal	Liquid Salt	9
Thermal	Aluminum Phase Change	3	Thermal	Liquid Salt	2
Thermal	Rock	5	Mechanical	Water	6
Thermal	Concrete	4	Mechanical	Steel	3
Electrochemical	Lithium Ion	6	Thermal	Sand	5
Mechanical	Compressed Air	9	Electrochemical	Sodium Ion	9
Thermal	Heat Transfer Fluid	3	Electrochemical	Sodium Sulfur	8
Thermal	Sulfur	4	Electrochemical	Lithium Ion	6
Thermal	Concrete	6	Electrochemical	Lithium Ion	8
Mechanical	Concrete	4	Chemical	Thermochemical Redox	4
Mechanical	Compressed Air	4	Mechanical	Compressed Air	8
Mechanical	Gravitational	3	Mechanical	Steel	9
Mechanical	Flywheel	4	Chemical	Metal Hydride	6
Mechanical	Liquid Air	7	Electrochemical	Flow Battery	8
Chemical	Hydrogen	7	Electrochemical	Metal Air	8
Mechanical	Compressed Air	6	Electrochemical	Flow Battery	8

Growing database of energy storage technologies of every type

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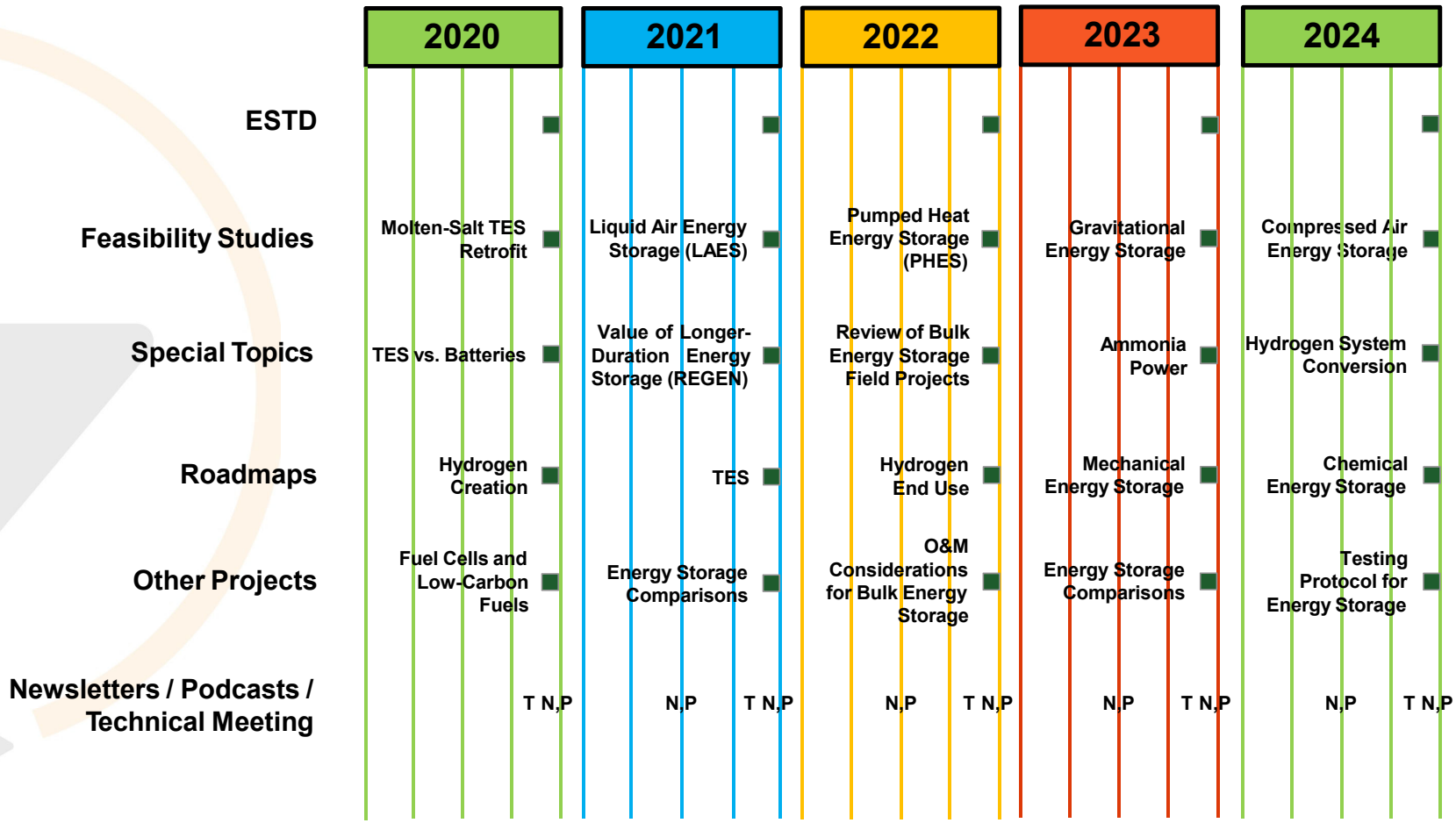
Source: EPRI

P221 5-Year Timeline*



*Subject to Member approval; Other Projects could be done if funding allows

Source: EPRI

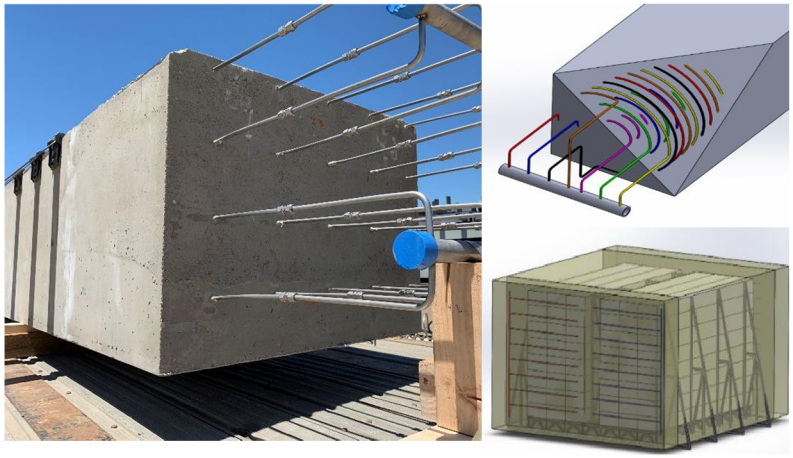
P221 Supplemental Task: Cost and Performance Assessment

Key Objectives

- Assess strategies for deploying long duration energy storage
- Compare select energy storage technologies
- Technical performance and economic benefit assessments

Value to Funders

- Actionable research to deliver reliable, dispatchable power through long duration energy storage



Simulation of long duration energy storage cost-benefit and performance

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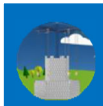
Source: EPRI

Bulk Energy Storage Cost and Performance Assessments

Research Focus Areas

Chemical
- Low-Carbon Fuels
- Synthetic Fuels
- Thermo-Chemical Systems

Advanced Cycles
- Low-Carbon Power Using Engines and Fuel Cells
- Supercritical CO_2 and Other Advanced Cycles



Mechanical
- Compressed Air
- Gravitational Systems
- Rail

Integration
- Optimal Integration with Thermal Plants
- New-Build Plants
- Retrofit of Existing Assets

Thermal
- Liquid Air Energy Storage
- Low-Cost Media (e.g., sand)
- Pumped Heat

Strategies
- Comparisons of Processes
- Seasonal Energy Storage
- Techno-Economic Analyses

Team

Dr. Andrew Maxson
Program Manager

George Booras
Technical Leader, Principal

Dr. Des Dillon
Technical Leader, Principal

Horst Hack
Technical Executive

Scott Hume
Technical Leader, Principal

Jose Marasigan
Technical Leader, Sr.

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Source: EPRI

P221 Supplemental Task Selected Technologies

- Range of energy storage systems have been selected to choose from based on established relationships/projects in place and perceived value

Organization/Technology	Type	Medium	TRL	Organization/Technology	Type	Medium	TRL
Storworks	Thermal	Concrete	5	Highview Power	Mechanical	Liquid Air	7
Echogen Power Systems	Thermal	Heat Transfer Fluid	3	Hydrostor	Mechanical	Compressed Air	6
Energy Vault	Mechanical	Concrete	4	Malta Pumped Heat	Thermal	Liquid Salt	4
Advisian	Thermal	Liquid Salt	9				





Goal is to have project diversity to provide a spectrum of results

Source: EPRI

Project Stakeholders and Participants

Project Management

EPRI

Engineering

Advisian
Worley Group

Site Hosts

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DTE

DUKE ENERGY

Southern Company

SRP

TEP

TRI-STATE

Technology Developers

MALTA

ENERGY VAULT
Enabling a Renewable World

HYDROSTOR

ECHOGEN
power systems

Highview Power

STORWORKS
POWER

Advisian*
Worley Group

Participants

Dominion Energy

Luminant

Nebraska Public Power District
Always there when you need us

Xcel Energy

LIPA
Long Island Power Authority

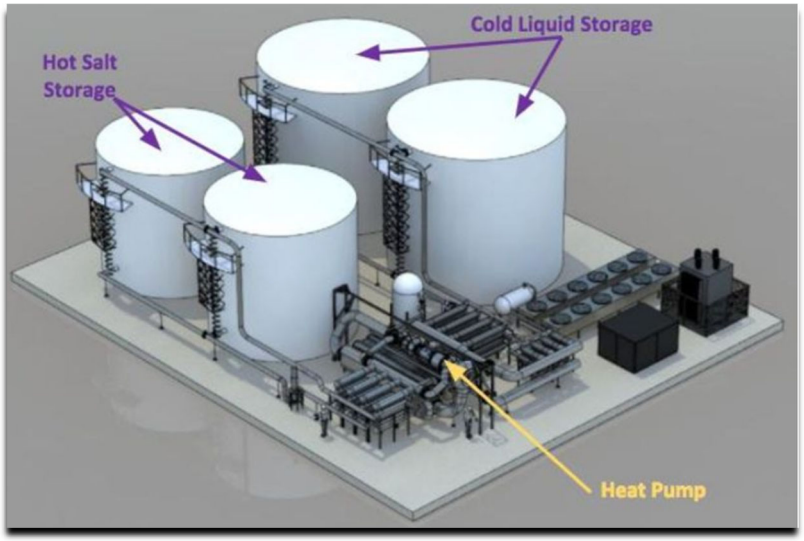
J-POWER

IBERDROLA

* Molten salt system integrator

LA DWP Source: EPRI

Thermal Energy Storage



Source: Malta

MALTA

ECHOGEN power systems

Advisian
Worley Group

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MALTA Pumped Heat ES

TRL = 4

Thermal

- Heat pump cycle for charging; closed Brayton cycle (air) with recuperation for generation
- Hot storage is “solar salt,” up to 565°C
- Cold storage is proprietary coolant down to -60°C
- Two tanks for each cycle between charged and discharged
- Plate-fin, small-channel heat exchanger, large enough to accommodate low ΔT at high efficiency
- Round-trip efficiency is ~60%
- Commercial system: 100 MW with 10 hrs duration; 2030 costs are stated to be <$100/kWh

Source: Malta

Beacon Site – EPRI Supplemental Bulk Energy Storage Cost and Performance Study

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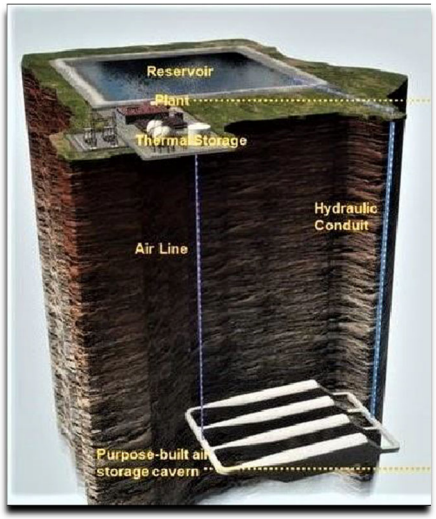
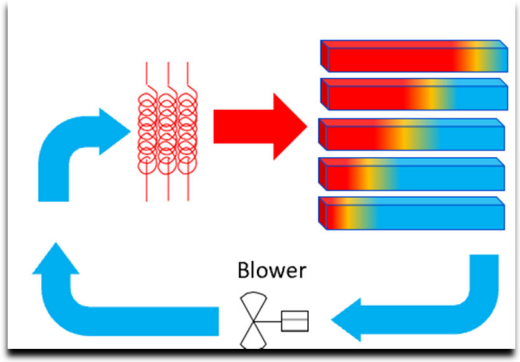
Source: EPRI

Mechanical Energy Storage

HYDROSTOR



STORWORKS POWER



Highview Power®

ENERGY VAULT
Enabling a Renewable World

Source: EPRI

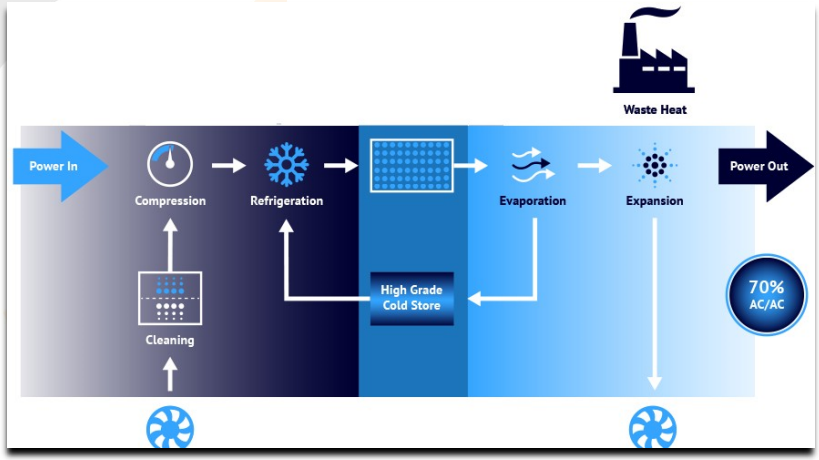
Highview Power® Liquid Air Energy Storage

TRL = 7

Mechanical

- Liquefy air to store energy
- Pressurize and heat for expansion to generate power
- 60% AC / AC conversion possible
- Can use external 'cold' from LNG vaporizers
- Can use 'waste heat' in regeneration

350 kWe / 2.5 MWh Pilot Plant, Slough UK



2 MWe Demonstration Project in UK

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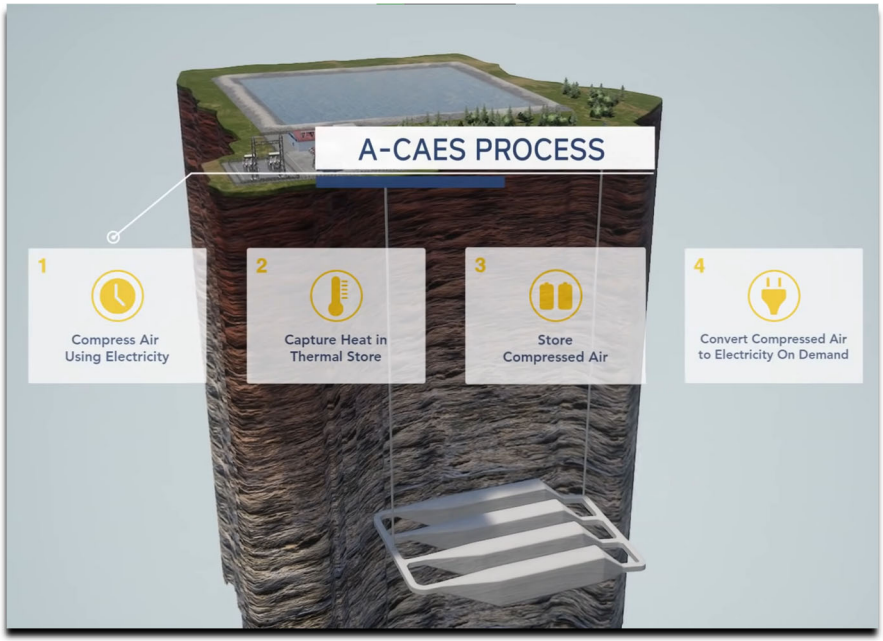
Source: EPRI

HYDROSTOR Adiabatic Compressed Air Energy Storage

TRL = 6

Mechanical

- **How it works:** Compresses air and stores underground; stores heat of compression separately. Uses a mined cavern that holds air under constant pressure by a water reservoir and column; siting not dependent on salt domes. Discharges by expanding air and using stored heat.
- **Typical AC Efficiency**: 60%
- **Cycle Life:** >30 years
- **Maturity:** Demonstration project in Ontario (1.75 MWe / 7 MWh)
- **Benefits**:
  - Capable of large sizes and longer durations
  - Low fire risk, no toxic materials
- **Challenges**:
  - Constrained to favorable geological locations
- **Applications:**
- Standalone energy storage



Source: Hydrostor

Source: EPRI

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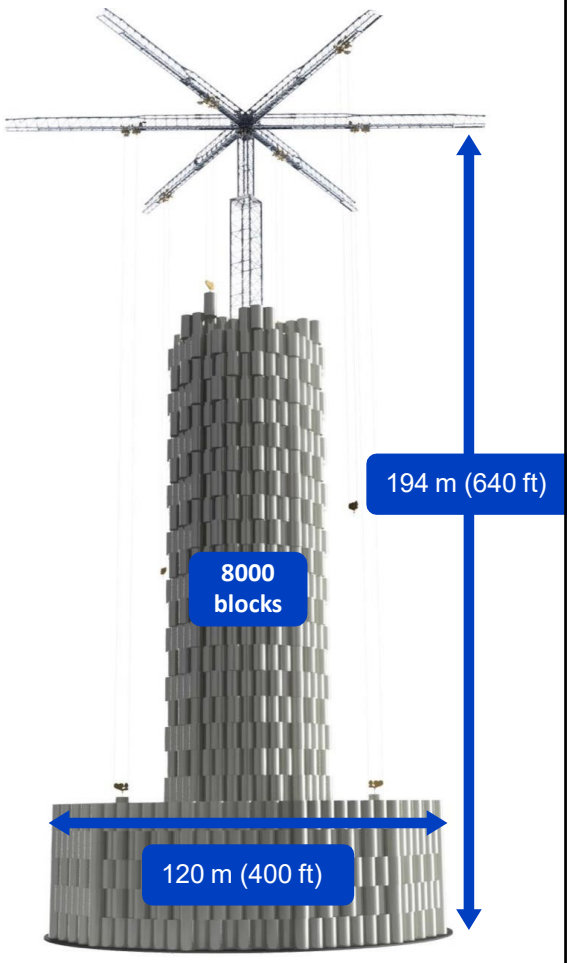
Gravity Energy Storage

TRL = 4

Mechanical

- Novel “stacked block” gravity storage
- Vision-based precision stacking system without interlocking
- 0 to 100% speed in 2.9 sec; 82% round-trip efficiency (RTE) AC-AC
- Initial market entry product is “Evie35” (35 MWh)
- Key advancement is overcoming “pendulum effect” of lifting with a counterweight, allowing for continuous movement
- One-arm pilot in Switzerland (July 2018)
- Recently funded $110M by SoftBank Vision Fund

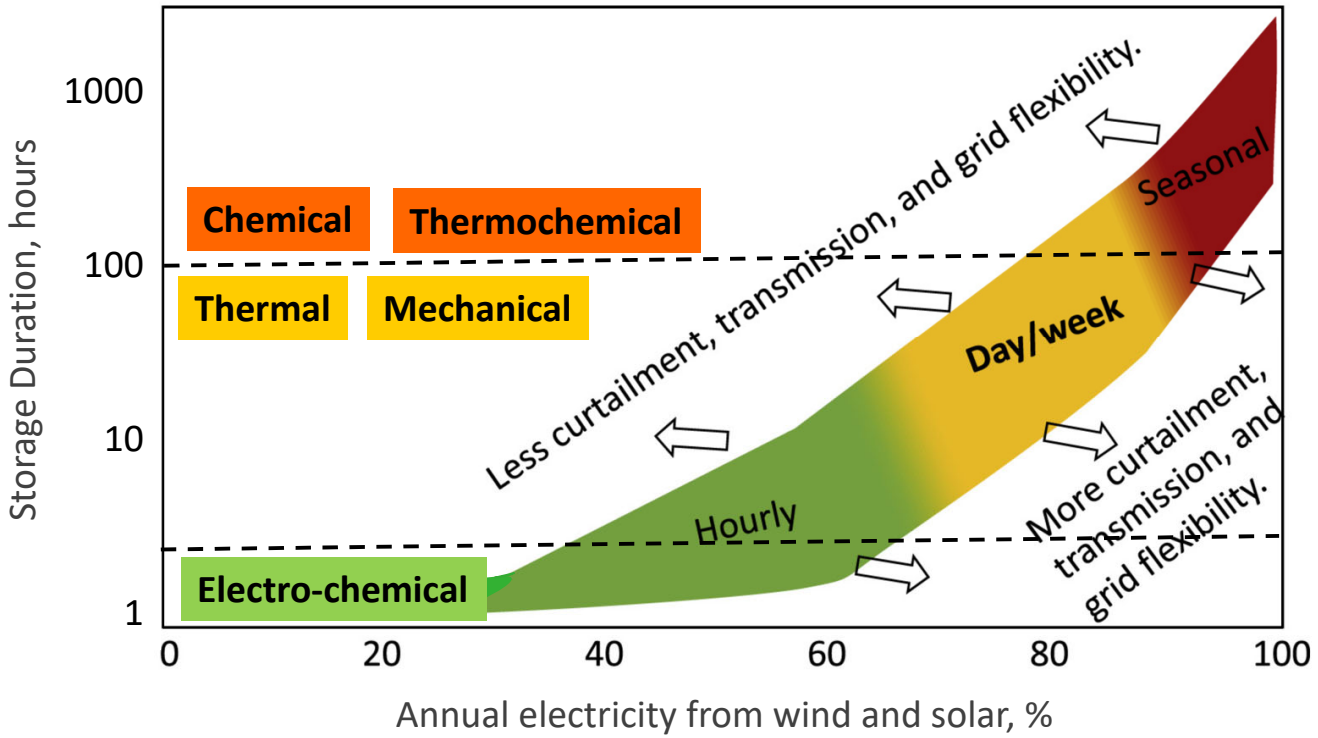


Source: Energy Vault

Source: EPRI

Ultra-Long Duration Storage

1. As Variable Renewable Energy (VRE) content on the grid increases, the duration of storage needed to provide reliability also increases.
2. As duration increases, battery costs become prohibitive, leading to a need for other, lower-cost technologies.



Source: "Long-Duration Electricity Storage Applications, Economics and Technologies," Joule, vol. 4, 2020.

Long duration storage needed at high VRE penetration

Source: EPRI

LA100 Common Investments Across All Scenarios

Electrification
Efficiency
Flexible Load

Customer
Rooftop Solar

Renewable
Energy

Solar: + >5,700 MW
Wind: + >4,300 MW

Energy Storage

+ >2,600 MW

Transmission,
Distribution

Renewably Fueled
Dispatchable
Turbines

+>2,600 MW
(in basin)

Much More

Natural gas → Biofuel/ hydrogen	
Today: Daily	**Future:** Infrequently

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Conclusions

All Durations

- Consider all durations and types of storage available and emerging in the resource planning process

Portfolio

- A portfolio of energy storage technologies is better than deploying only one

Spectrum

- Ultimately, a spectrum of energy storage will be needed: short-, mid-, and long-duration

Source: EPRI

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