# Long-Duration Energy Storage Field Projects

## EPRI's involvement with LDES pilots

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# ABOUT US

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

# KEY ASPECTS

## Nonprofit
Chartered to serve the public benefit, with guidance from an independent advisory council.

## Thought Leadership
Systematically and imaginatively looking ahead to identify issues, technology gaps, and broader needs that can be addressed by the electricity sector.

## Independent
Objective, scientific research leading to progress in reliability, efficiency, affordability, health, safety, and the environment.

## Scientific and Industry Expertise
Provide expertise in technical disciplines that bring answers and solutions to electricity generation, transmission, distribution, and end use.

## Collaborative Value
Bring together our members and diverse scientific and technical sectors to shape and drive research and development in the electricity sector.

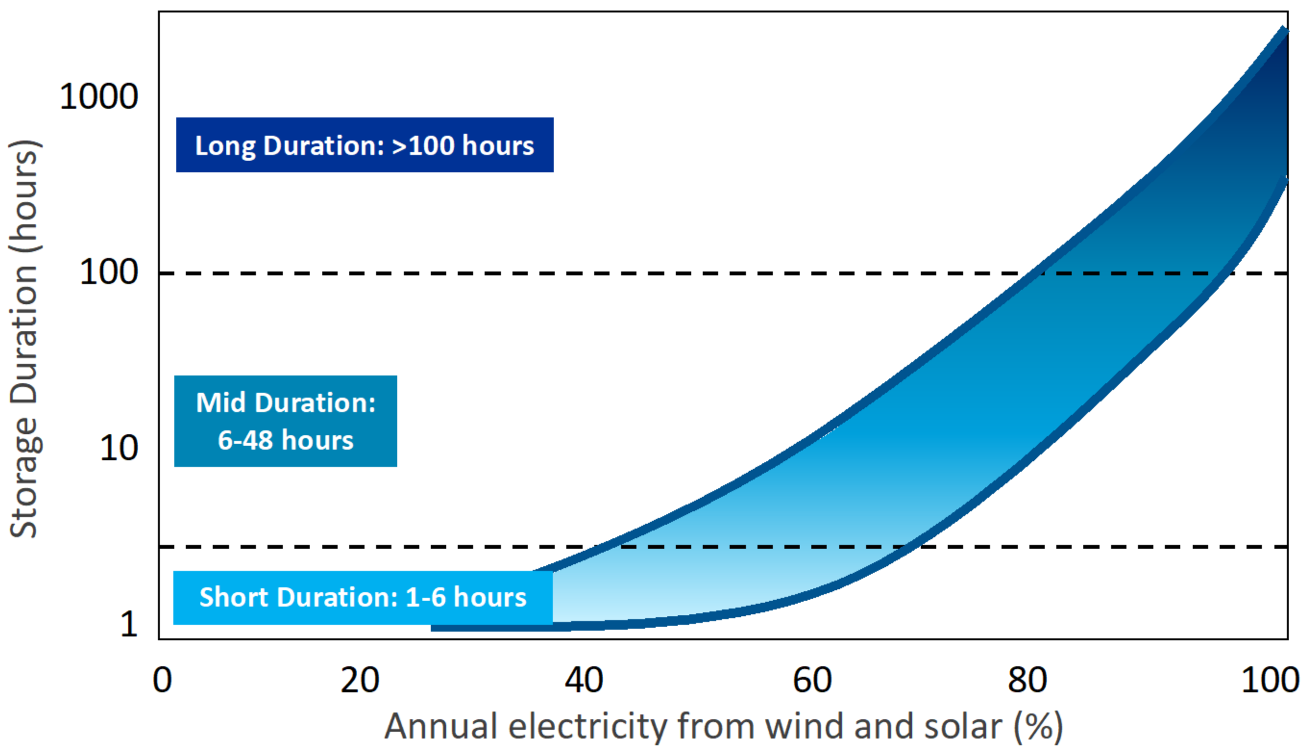
# On the LDES Memorandum of Understanding

- Objectives:
  - Support development and domestic manufacture of LDES technologies
  - Provide access to specific core competencies of each party
  - Facilitate understanding and dissemination of knowledge about benefits
  - Convene relevant stakeholders to identify deployment barriers, solutions
- EPRI's role: third party verification of standards, performance validation, model evaluation, etc.

# Energy Storage Evolution

**As intermittent renewables increase, the duration of energy storage needed also increases**

**As storage duration increases, different types of energy storage are needed**




*Adapted from "Long-Duration Electricity Storage Applications, Economics and Technologies," Joule, vol. 4, 2020.*

**Different durations of energy storage will be required**

# Energy Storage Types

| Electrochemical | Thermal | Mechanical | Chemical |
|---|---|---|---|
| Reversible chemical reaction generates an electrical potential difference | Energy storage achieved by heating bulk media | Kinetic or potential (compression or gravitational) | Reaction produces product that can generate heat or power |

**Different technologies for different purposes**



# Bulk Energy Storage (BES)

## Mission

Provide actionable research to advance larger-scale, longer-duration energy storage with focus on chemical, mechanical, and thermal types

## Why EPRI Bulk Energy Storage?

### Value of Collaboration

The BES program works closely with multiple programs in the Generation and PDU sectors, 50+ energy storage developers, and leading R&D and government teams in the energy storage space.

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### Research Focus Areas

- Assessment and comparison of energy storage technologies
- Design reviews
- Energy storage integration to thermal power plants
- Energy storage roadmaps
- O&M and testing support
- Participation in demonstrations
- Seasonal energy storage
- Techno-economic and benefit assessments

### Unique Insights

- 8 staff (3 Technical Executives) with 8 advanced degrees and 85 years experience combined at EPRI
- 500+ member meetings on energy storage in 2022
- 550+ papers, articles, and other published works

### Impactful Content

- **Web-based software:** Energy Storage Technology Database
- **Benefits assessments:** 3002019890, 3002021099, 3002024309
- **Cost and performance studies:** 3002022615, 3002022120, 3002021098, 3002024283

### Technology Application

- Concrete thermal energy storage pilot
- Seasonal energy storage
- Thermal energy storage repowering
- Bulk energy storage costs and performance

# Bulk Energy Storage Field Studies

## Objectives and Scope

- Perform multiple studies on existing or soon to be completed bulk energy storage pilot plants
- Review test plans and performance data, obtain lessons learned, identify current technology gaps, and assess the trajectory towards commercialization
- Coordinate site visits for EPRI members

## Value

- Technology developers receive exposure to motivated utilities seeking cost-effective, scalable bulk energy storage technology
- EPRI members receive real-world test data and information to inform subsequent planning and procurement efforts
- Independent assessment of test data by EPRI increases industry confidence in emerging storage technologies

## Project Profile

- Project duration: 12 months
- Project Managers:
  Justin Raade (jraade@epri.com, 408-515-2983)
  Horst Hack (hhack@epri.com, 908-447-4925)

# Malta

## How It Works:

Heat pump cycle for charging; closed air-Brayton cycle with recuperation for generation. Hot storage up to 565°C, cold at -60°C. Plate-fin, small-channel heat exchanger.

Source: Malta

## Benefits:

- Low fire risk, no toxic materials
- Uses mature components
- Small footprint
- System inertia

## Challenges:

- Capital costs are higher
- Process has yet to be demonstrated at scale
- Small systems are less efficient

## Applications:

Standalone energy storage or integration with existing power units, energy shifting, inertia provision (charging and discharging), and potential for long-duration energy storage

## Vital Statistics

| | | | |
|---|---|---|---|
| **AC RTE:** | 55–65% | **TRL:** | 5 |
| **Life:** | 30 years | **Largest Pilot:** | 10 kWe |

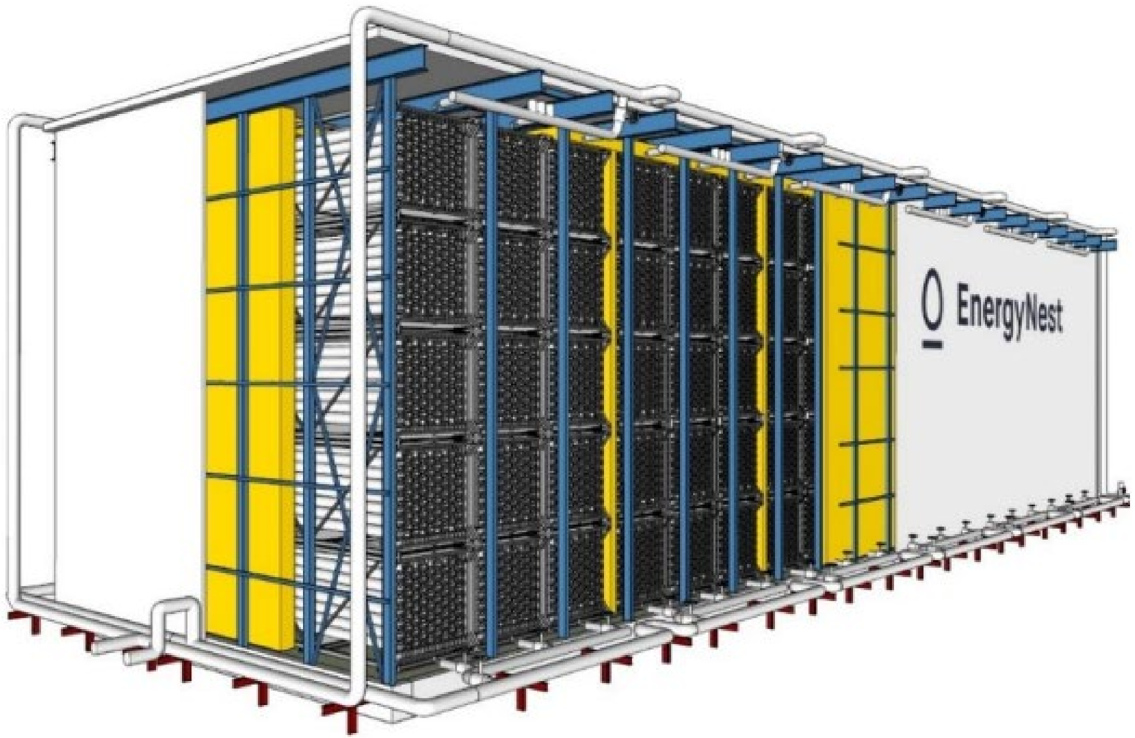


EPRI

# EnergyNest

| How It Works: | |
| --- | --- |
| Modular TES that integrates into thermal plants and industrial processes to provide heat. Consists of heat exchanger tubing encased by HEATCRETE® (concrete) in cylindrical steel casings. | |

| Benefits: | Challenges: |
| --- | --- |
| • Low-cost material with high availability<br>• Has been tested at larger scales for multiple applications | • Not currently designed to provide power, only heat<br>• Requires substantial use of steel, which could increase costs for longer durations |



Source: EnergyNest

**Applications:**

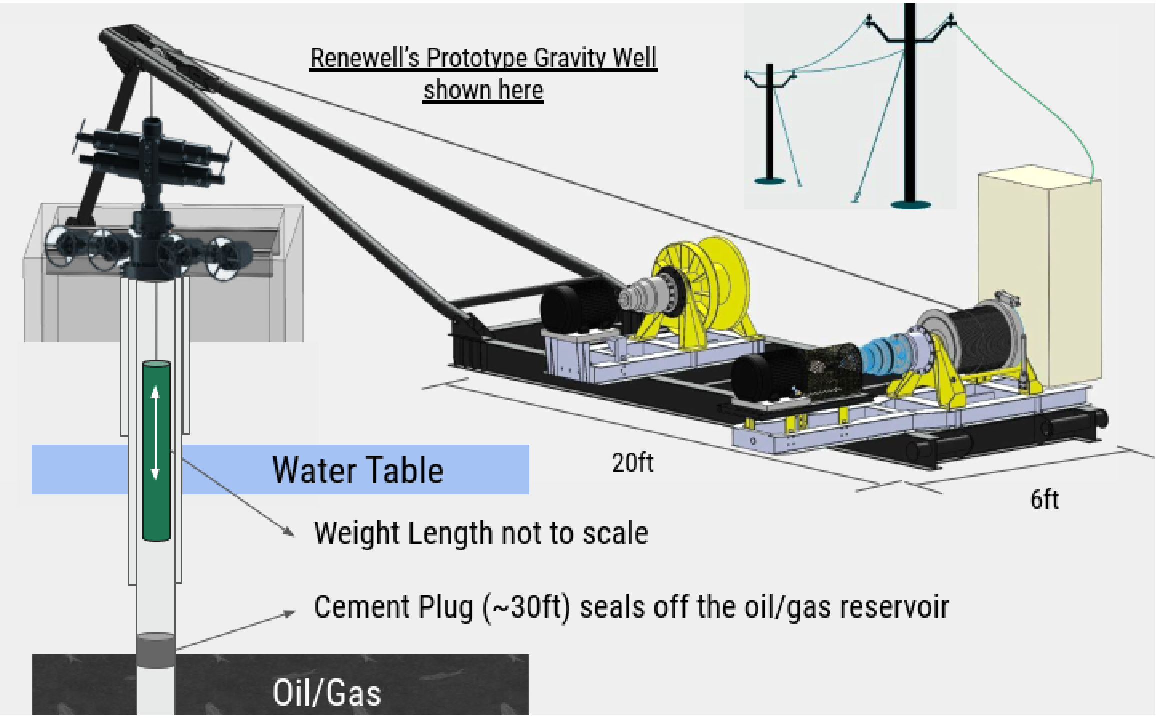
With temperature limited to 410°F (230°C), can be used for steam production for industrial use but isn't suited to utility-scale power applications. Would be useful for supplying auxiliary steam.

| Vital Statistics | | | |
| --- | --- | --- | --- |
| AC RTE: | 80–95% (heat in-to-heat out) | TRL: | 6 |
| Life: | 30 years | Largest Pilot: | 4 MWhth |

# Renewell Energy

## How It Works:

Gravity-based energy storage system that uses the steel "production" casing in the wellbore of an out-of-service oil well to guide the raising and lowering of a weighted steel tube hung by a wire-rope cable as a means of storing and releasing energy




Source: Renewell Energy

| Benefits: | Challenges: |
| --- | --- |
| • High efficiency<br>• Added benefit of avoiding well closure costs<br>• Simple, potential low cost | • Requires an array of out-of-service oil wells<br>• Wire rope bending and tensile stresses and material life have yet to be field validated |

## Applications:

Energy shifting, spinning reserve, peak shaving/demand response, and frequency regulation

## Vital Statistics

| | | | |
| --- | --- | --- | --- |
| **AC RTE:** | 80% | **TRL:** | 4 |
| **Life:** | 30 years | **Largest Pilot:** | 100 kWhe |

# Energy Dome

## How It Works:

A closed-loop variant on compressed air energy storage with $CO_2$ as the storage medium/working fluid. Heat of compression captured in thermal energy storage systems and returned to $CO_2$ upon discharge. $CO_2$ density in liquid phase allows for compact pressure vessel storage at ambient temperature. Discharged $CO_2$ stored in elastomeric bladder at near-atmospheric pressure.

Source: Energy Dome

## Benefits:

- High efficiency
- Low cost

## Challenges:

- Requires significant footprint
- Risk of $CO_2$ leaks

## Applications:

Standalone energy storage, energy shifting, and inertia provision (charging and discharging) with 10-hour durations

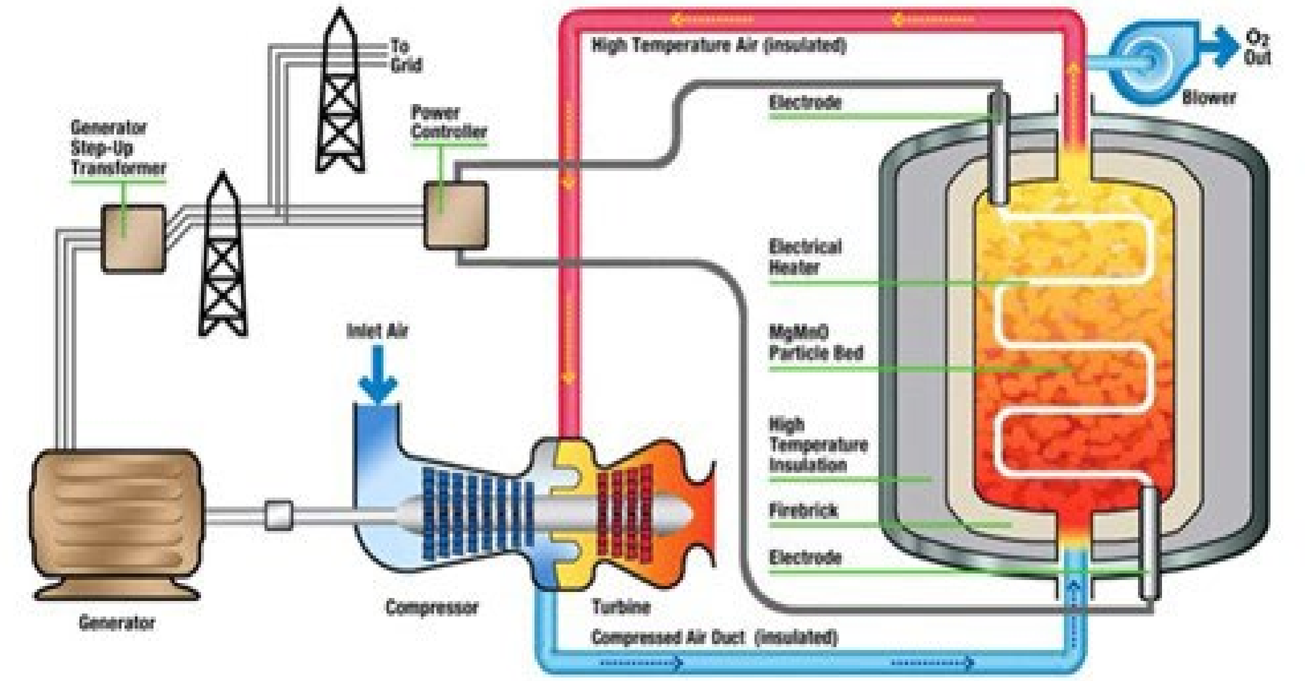
## Vital Statistics

| | | | |
|---|---|---|---|
| **AC RTE:** | 75–80% | **TRL:** | 7 |
| **Life:** | 30 years | **Largest Pilot:** | 2.5 MWe / 4 MWhe |

# RedoxBlox

## How It Works:

Reversible reaction adding/releasing oxygen from magnesium-manganese oxide. Pressurized pellet bed heated electrically to high temps. Discharges like a carbon-free gas turbine with 10-hours duration.




Source: RedoxBlox

## Benefits:

- Gas turbine operating characteristics
- High energy density (3x molten salt)
- Low cost
- No fire risk

## Challenges:

- Costs of holding all material in a pressure vessel
- Retrofit cases spatially difficult, additional pressure drop

## Applications:

Standalone energy storage or integration with existing gas turbine power units with external combustors. Inertia provision (discharging) and instant demand response (charging).

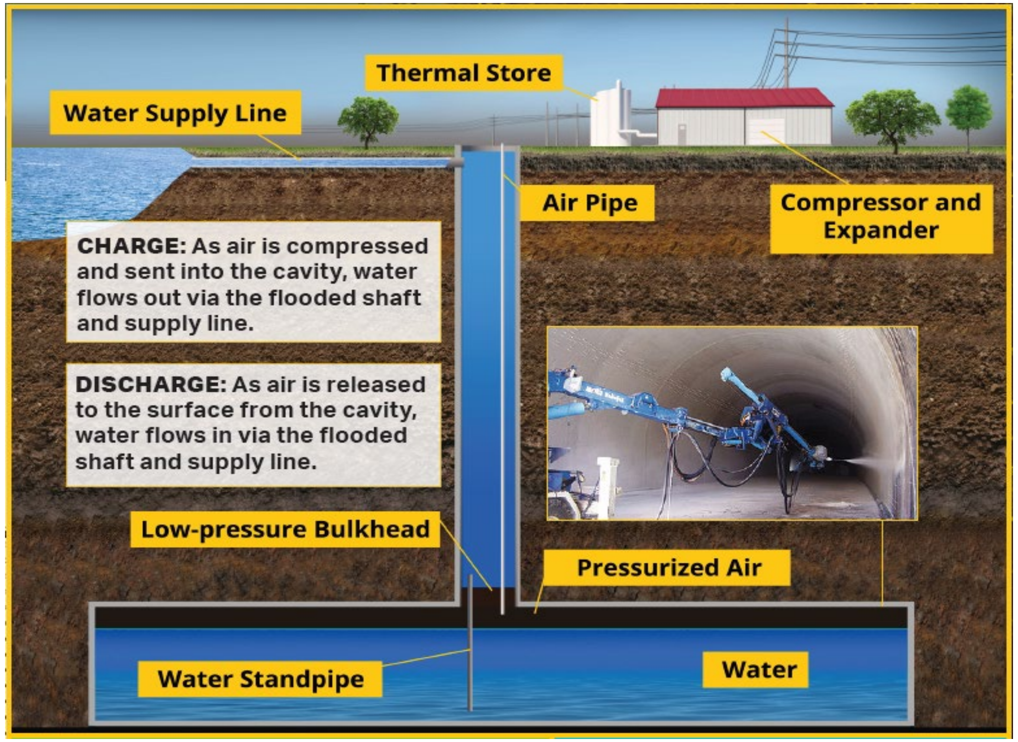
## Vital Statistics

| | | | |
|---|---|---|---|
| **AC RTE:** | >30% | **TRL:** | 4 |
| **Life:** | 30 years | **Largest Pilot:** | 10 kWhth |

# Hydrostor

## 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.




Source: Hydrostor

## Benefits:

- Capable of large sizes and longer durations
- Low fire risk, no toxic materials

## Challenges:

- Constrained to favorable geological locations

## Applications:

Standalone energy storage and energy shifting

## Vital Statistics

| | | | |
|---|---|---|---|
| **AC RTE:** | 60% | **TRL:** | 6 |
| **Life:** | 30 years | **Largest Pilot:** | 1.75 MWe / 7 MWhe |

# EPRI Government Projects

- DE-FOA-2804: Industrial Efficiency and Decarbonization (pending)
  - RedoxBlox (metal oxide thermochemical), Dow Chemical

- DE-FOA-2867: Long-Duration Energy Storage Demonstrations (pending)
  - Urban Electric Power (metal oxide batteries), NYPA (New York)
  - Energy Dome ($CO_2$ cycle), Alliant Energy (Wisconsin)
  - Echogen (separate hot and cold storage), Golden Valley Electric Association (Alaska)

- DE-FOA-2997: Industrial Efficiency and Decarbonization (selection in progress)

- DE-FOA-3036: Energy Storage Demonstration and Validation (selection in progress)

- CEC-GFO-22-307: Optimizing Long-Duration Energy Storage to Improve Resilience and Reliability in Disadvantaged and Low-Income Communities and Native American Tribes (selection in progress)

**EPRI is supporting many grants for pilot funds**


Together…Shaping the Future of Energy®