A Review of Selected Long-Duration Energy Storage Technologies

With a focus on closer-to-commercialization systems

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Engineer II

NM RETA Energy Storage Workshop
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Provide expertise in technical disciplines that bring answers and solutions to electricity generation, transmission, distribution, and end use.

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Energy Storage Overview

Enabler

- Energy storage is an enabler for a low-carbon future. As more renewables are installed, it will be needed to help provide grid stability and reliability.

Need

- A lot will be needed: TWs of new energy storage is projected globally by 2050

Options

- Energy storage comes in a variety of types and durations and will have different use cases

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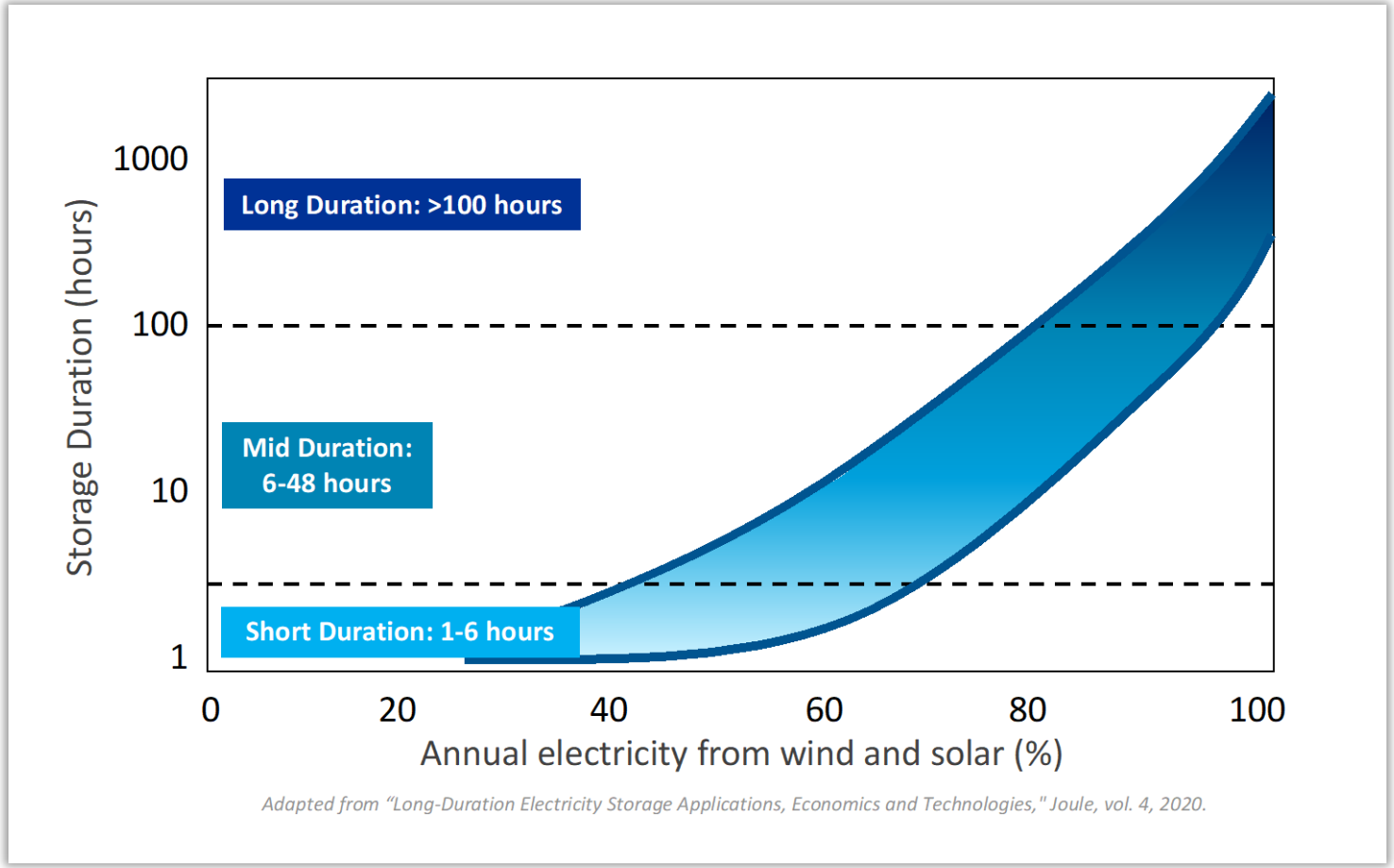
Energy Storage Evolution

- **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

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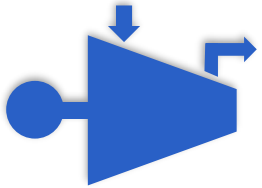
Energy Storage Types



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

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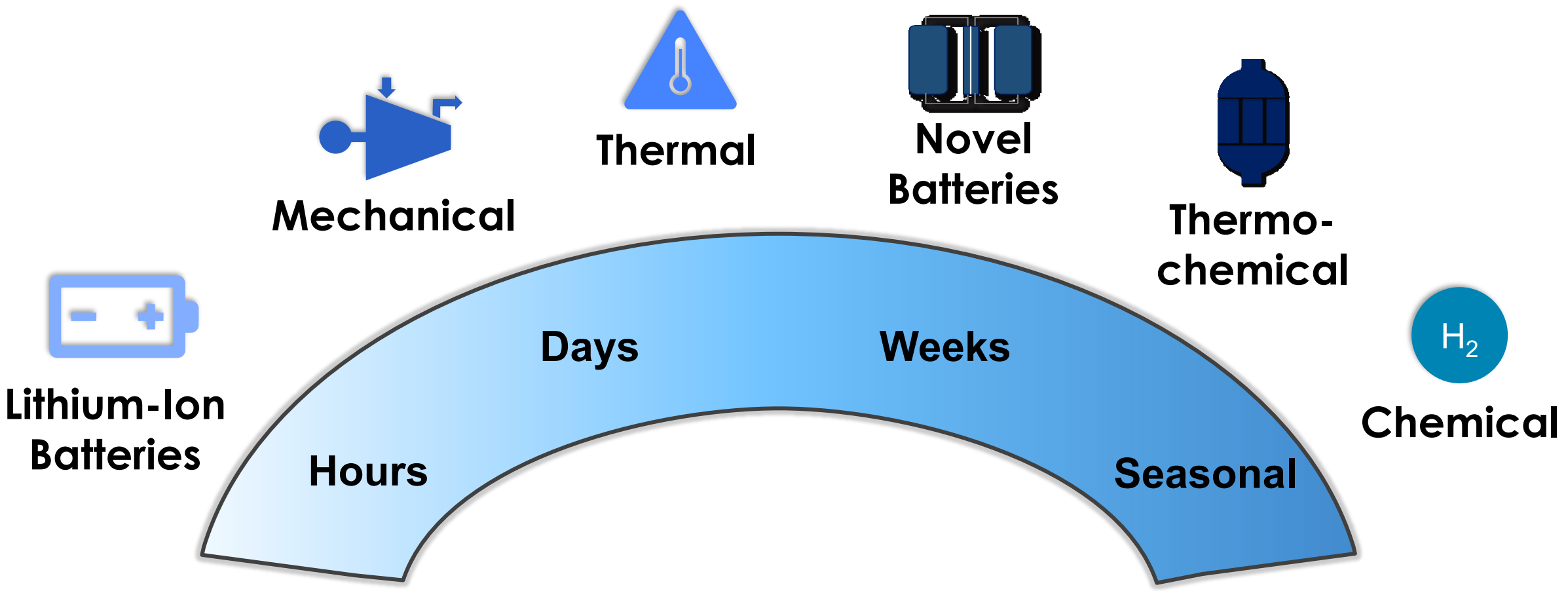
Energy Storage Spectrum

Tracking more than 100 different technologies



A range of energy storage technologies will be needed

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Selected Energy Storage Technologies

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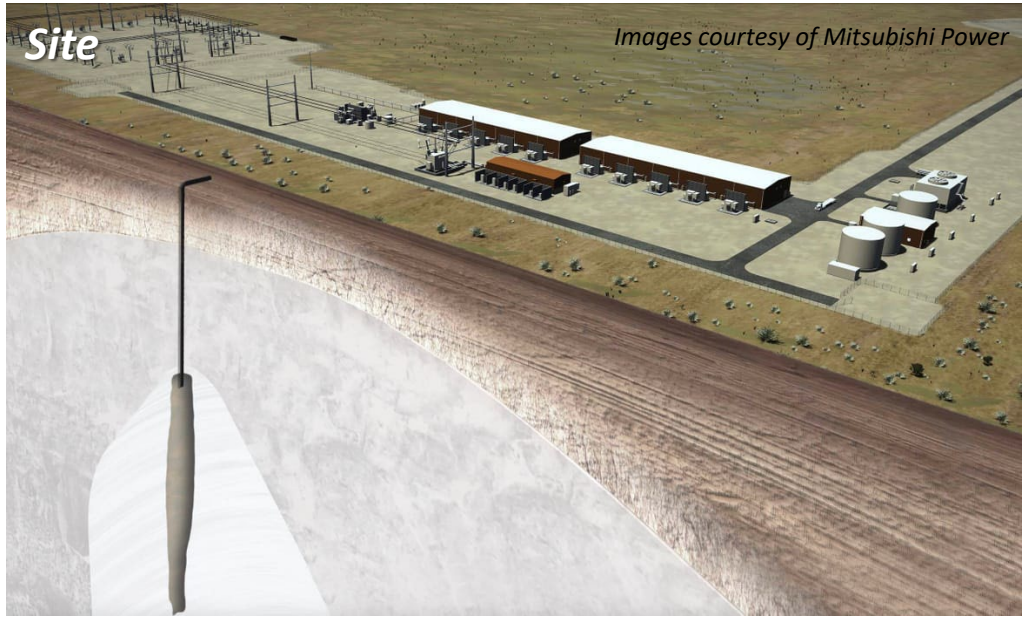
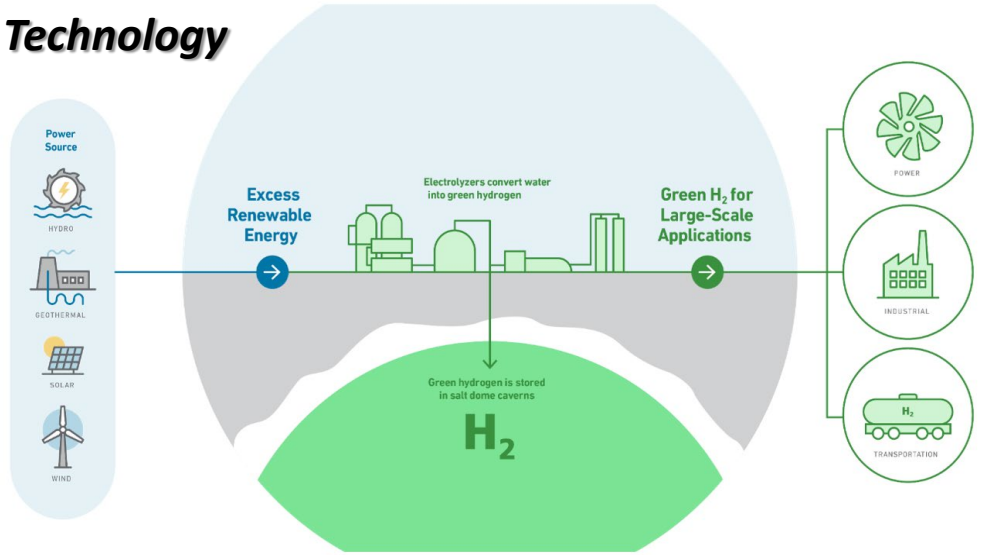
ACES Delta: Hydrogen Energy Storage

- **Site**
  - Located at Intermountain Power Project in Delta, Utah
  - $504 million DOE loan guarantee plus $650 million equity, increasing to $1.5 billion
- **Use Case**
  - Seasonal energy storage
  - Serves demand in Los Angeles via HVDC transmission line
- **Storage Technology**
  - Electrolyzers generate clean hydrogen, which is stored in salt cavern during charging
  - To discharge, the hydrogen is burned in a combined cycle system capable of up to 100% hydrogen fuel (by 2045)
  - Mitsubishi Power will provide the hydrogen equipment
  - Black & Veatch is EPC
- **System Size Profile**
  - Discharging power: 840 MW
  - Storage capacity: 165,000 MWh (~200 hours)
    - ~11,000 tonnes hydrogen storage with two caverns
  - Charging capacity: 220 MW
    - Would require ~100 days to charge completely





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Water Consumption for Hydrogen Production

- How much water will the ACES Delta consume to produce hydrogen?

$$H_2O \rightarrow H_2 + \frac{1}{2}O_2$$

- Water is 11% hydrogen by mass, so 9 kg (2.4 gal) water is consumed to produce 1 kg of hydrogen
- ACES Delta project sized to produce 100,000 kg/day of hydrogen; requires 240,000 gal/day (0.74 acre-ft) water
- For comparison, the 140 golf courses in Utah consume total of 38,000,000 gal/day water or 270,000 gal/day each!

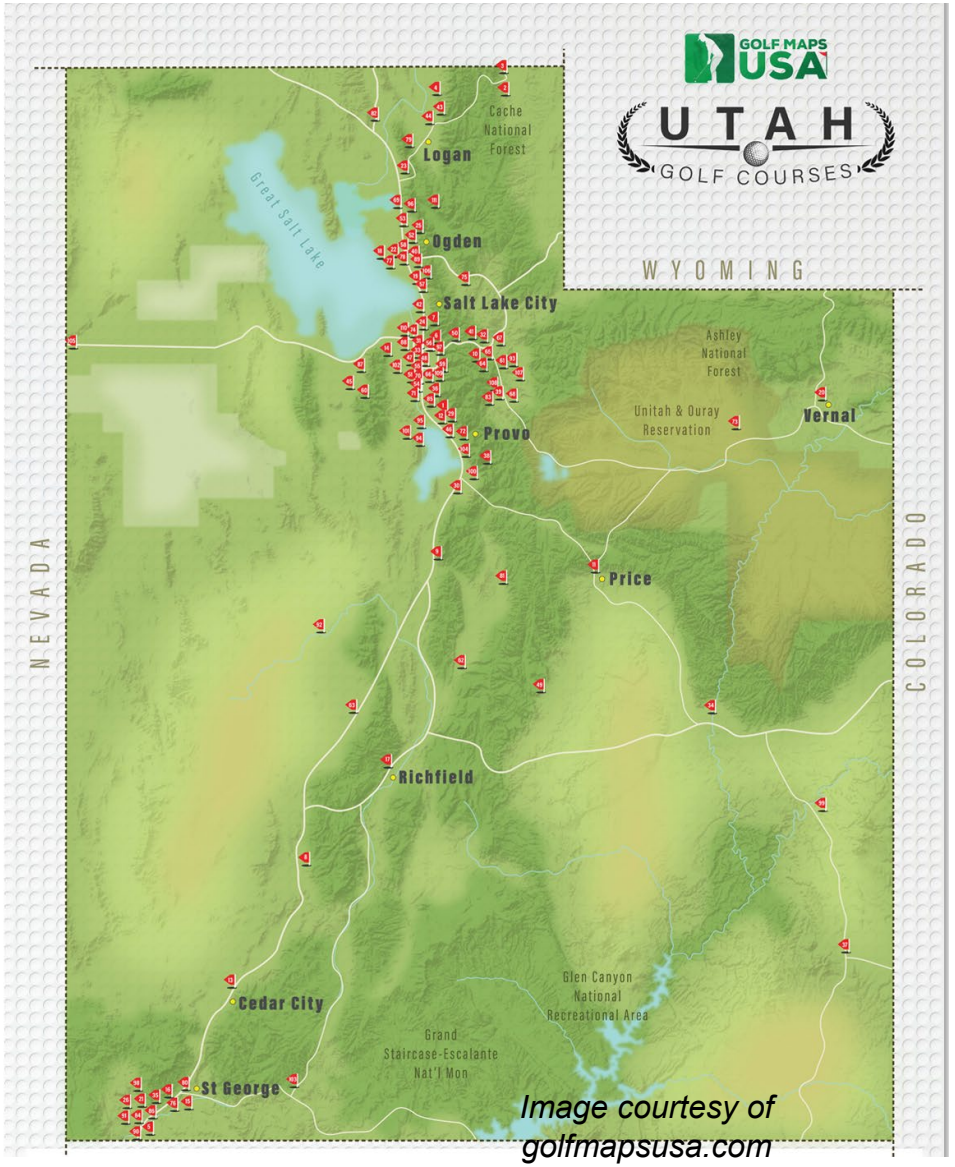

Image courtesy of golfmapsusa.com

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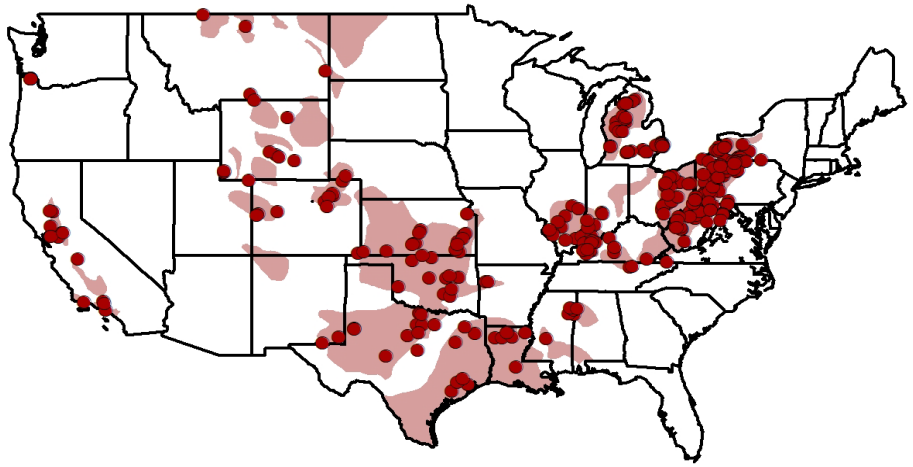
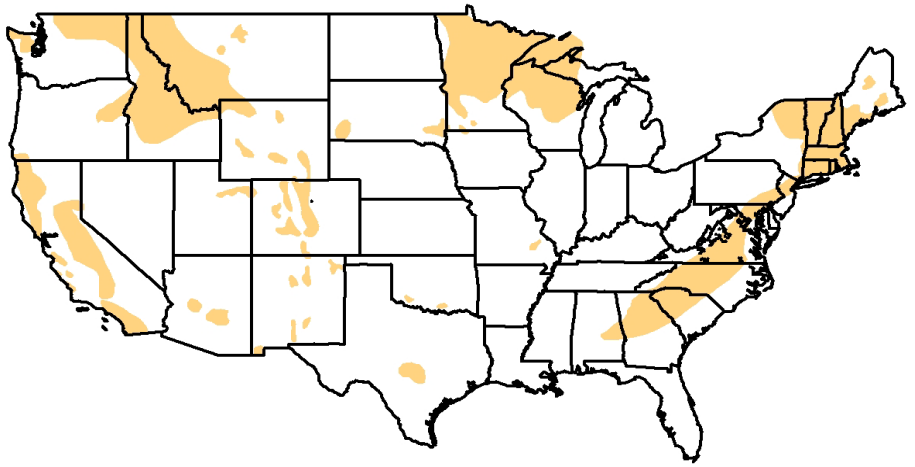
US Subsurface Maps for Hydrogen Storage

Subsurface Hydrogen Assessment, Storage, and Technology Acceleration (SHASTA)

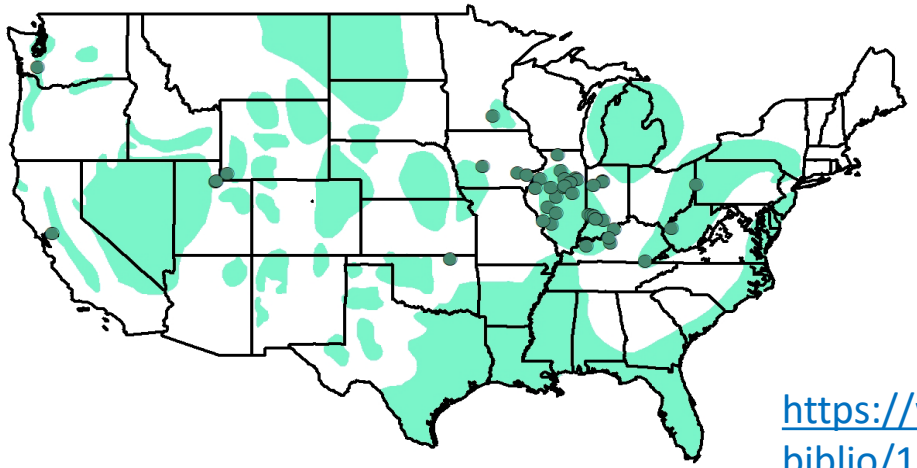
a) Oil & Gas Fields and Depleted Field Natural Gas Storage Facilities



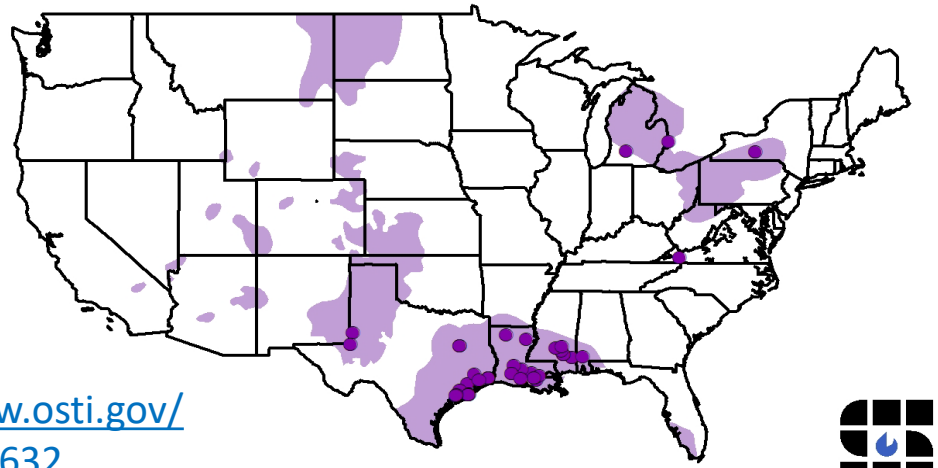
b) Hardrock Outcroppings



c) Sedimentary Basins and Aquifer Natural Gas Storage Facilities



d) Salt Deposits and Salt Dome Natural Gas Storage Facilities



https://www.osti.gov/biblio/1846632

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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:	Challenges:
• High efficiency • Low cost	• 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:**	6
Life:	30 years	**Largest Pilot:**	2.5 MWe / 4 MWhe

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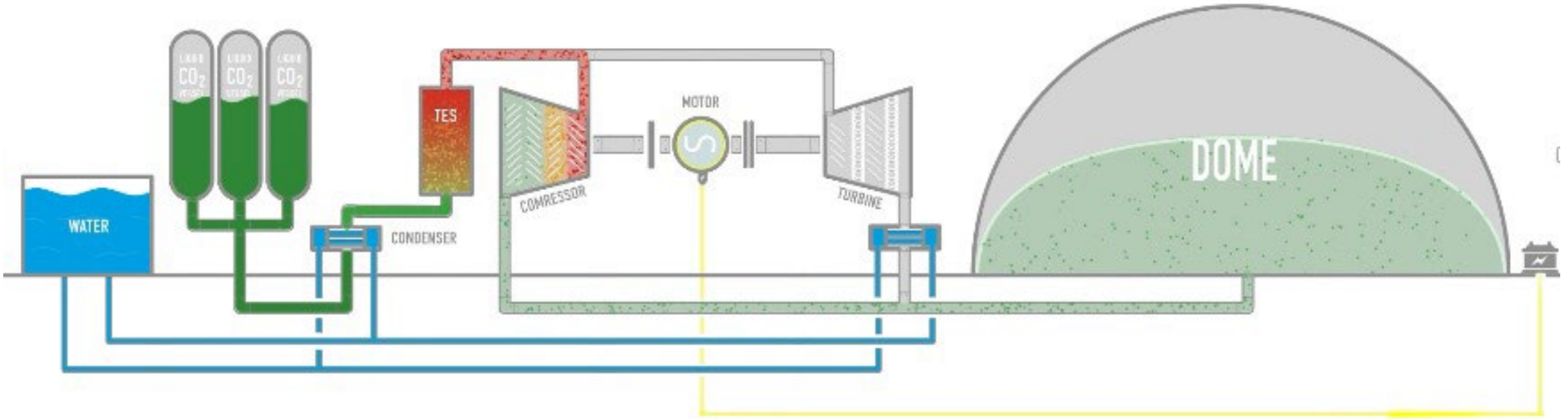
Energy Dome Schematic



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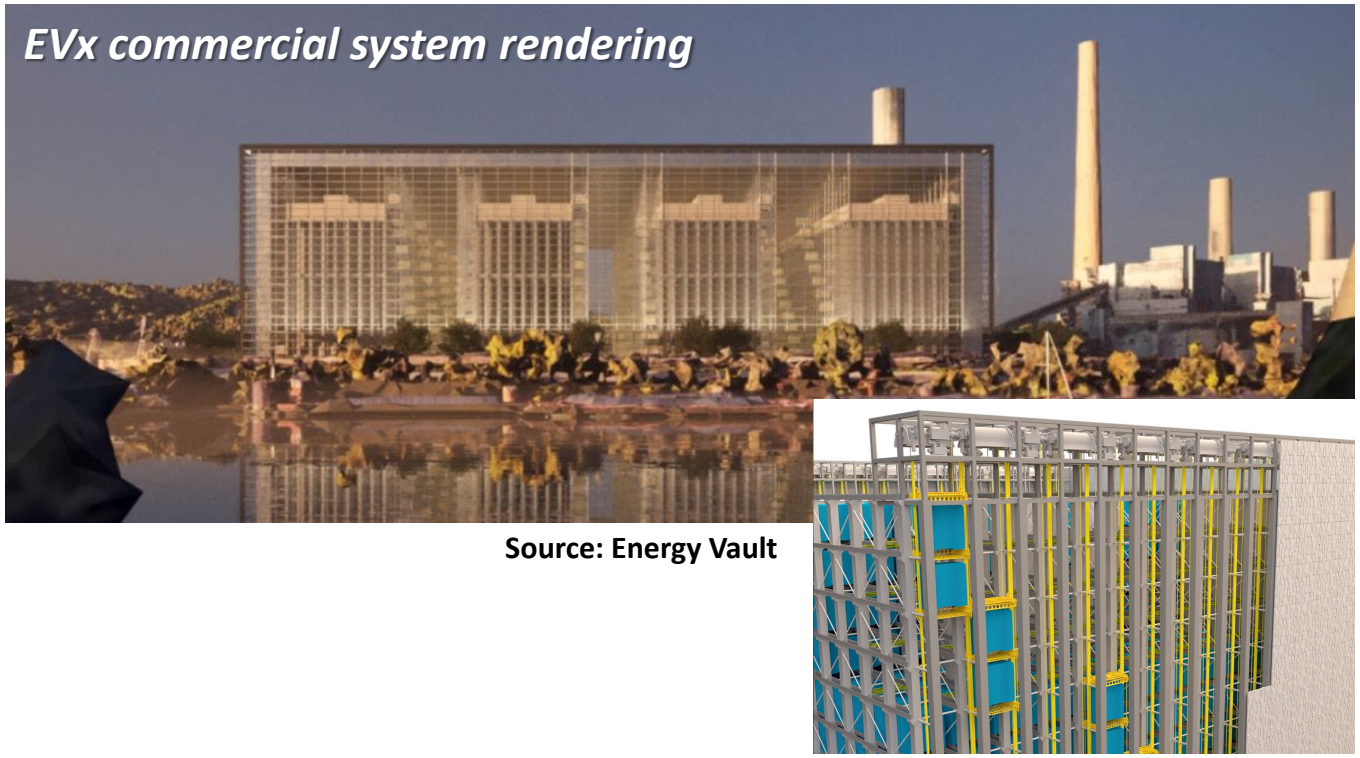
Energy Vault

How It Works:

Large blocks are raised to store energy and lowered at a controlled rate to discharge the system. Equipment is enclosed in a building.



Source: Energy Vault

Benefits:

- High efficiency
- Modular design allows sizing to fit need
- Low fire risk, no toxic materials

Challenges:

- Large footprint required for projects
- Lack of inertia
- Control systems to achieve reliable operation

Applications:

Standalone energy storage and energy shifting

Vital Statistics

AC RTE:	82%	**TRL:**	6
Life:	30 years	**Largest Pilot:**	5 MWe

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Hydrostor

How It Works:

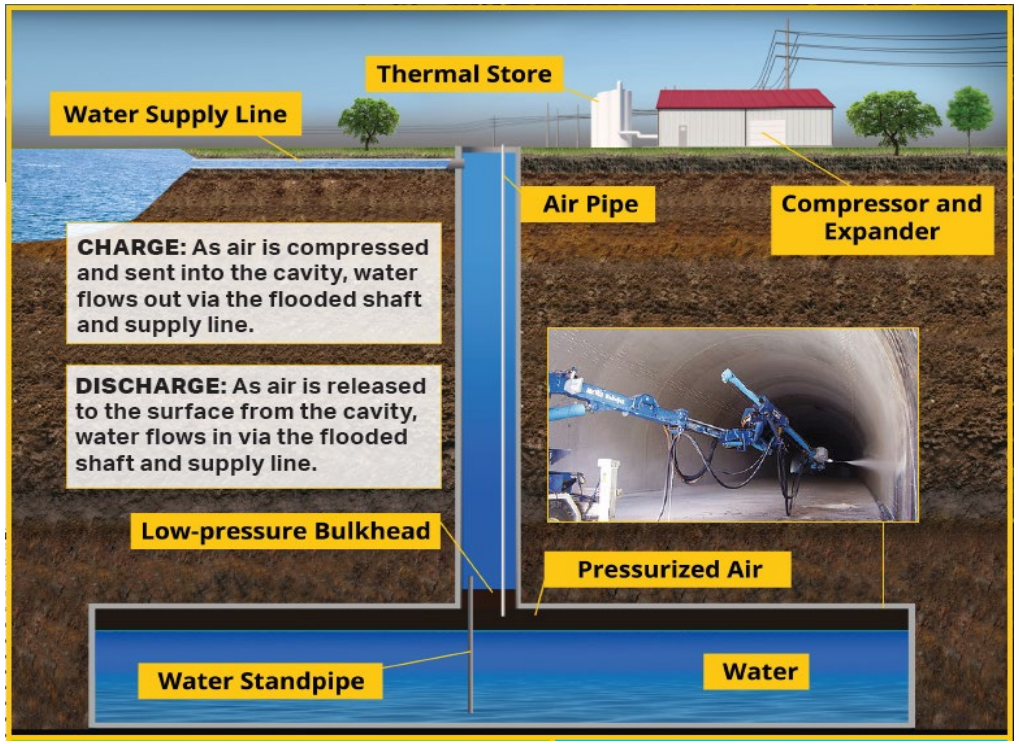
Compresses air and stores underground; stores heat of compression separately. Uses a mined cavern that holds air under constant pressure by a water reservoir and column; siting not dependent on salt domes. Discharges by expanding air and using stored heat.

Benefits:

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

Challenges:

- Constrained to favorable geological locations



Source: Hydrostor

Applications:

Standalone energy storage and energy shifting

Vital Statistics

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

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RedoxBlox

How It Works:

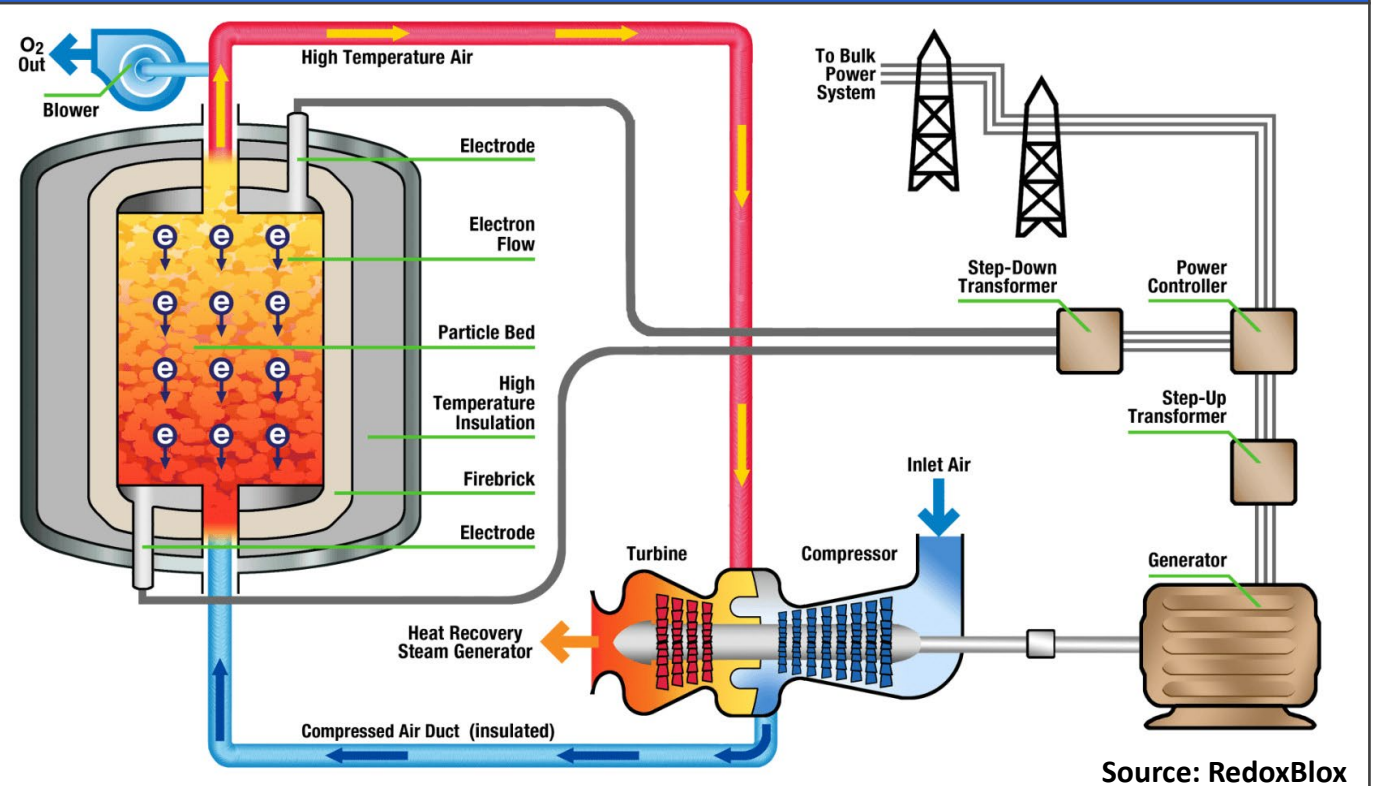
Reversible reaction adding/releasing oxygen from magnesium-manganese oxide. Pressurized pellet bed heated electrically to high temps. Discharges like a carbon-free gas turbine with 10-hours duration.

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



Source: RedoxBlox

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:**	5
Life:	30 years	**Largest Pilot:**	10 kWhth

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What Would Energy an Storage Project Look Like in New Mexico?

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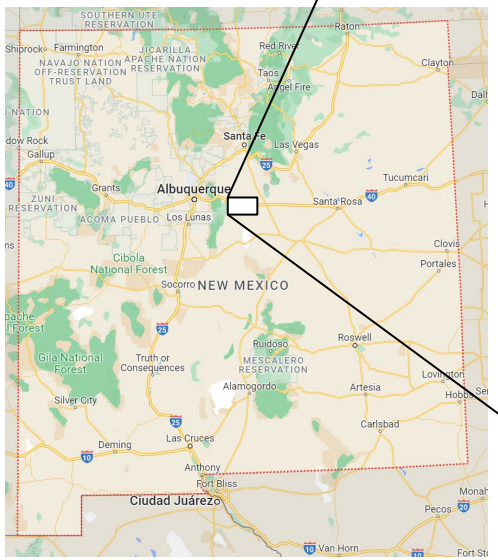
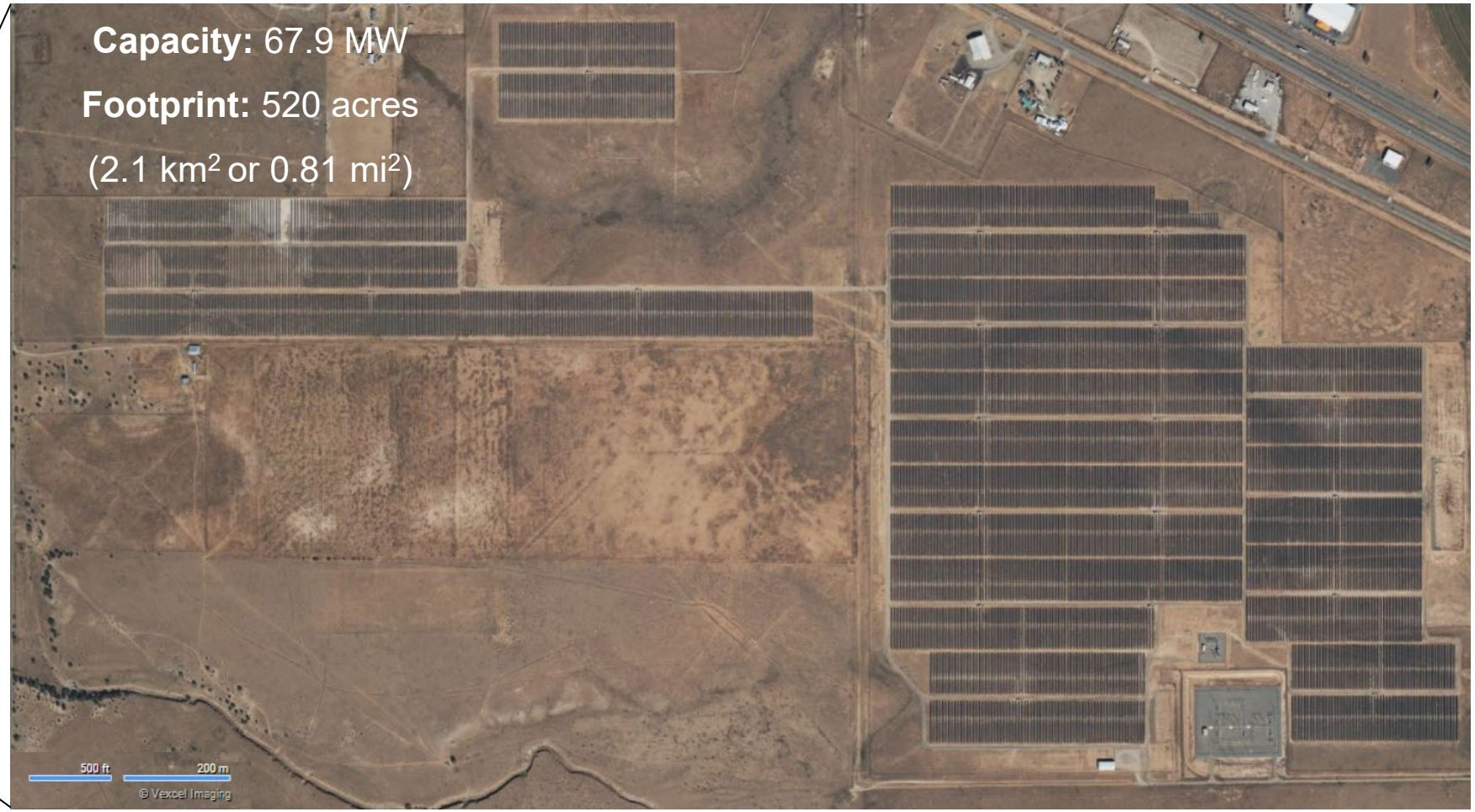
Britton Solar Energy Center – Moriarty, NM

Thought Experiment:

How would a large energy storage system look adjacent to the solar plant?

- 200 MW
- 10 hours duration





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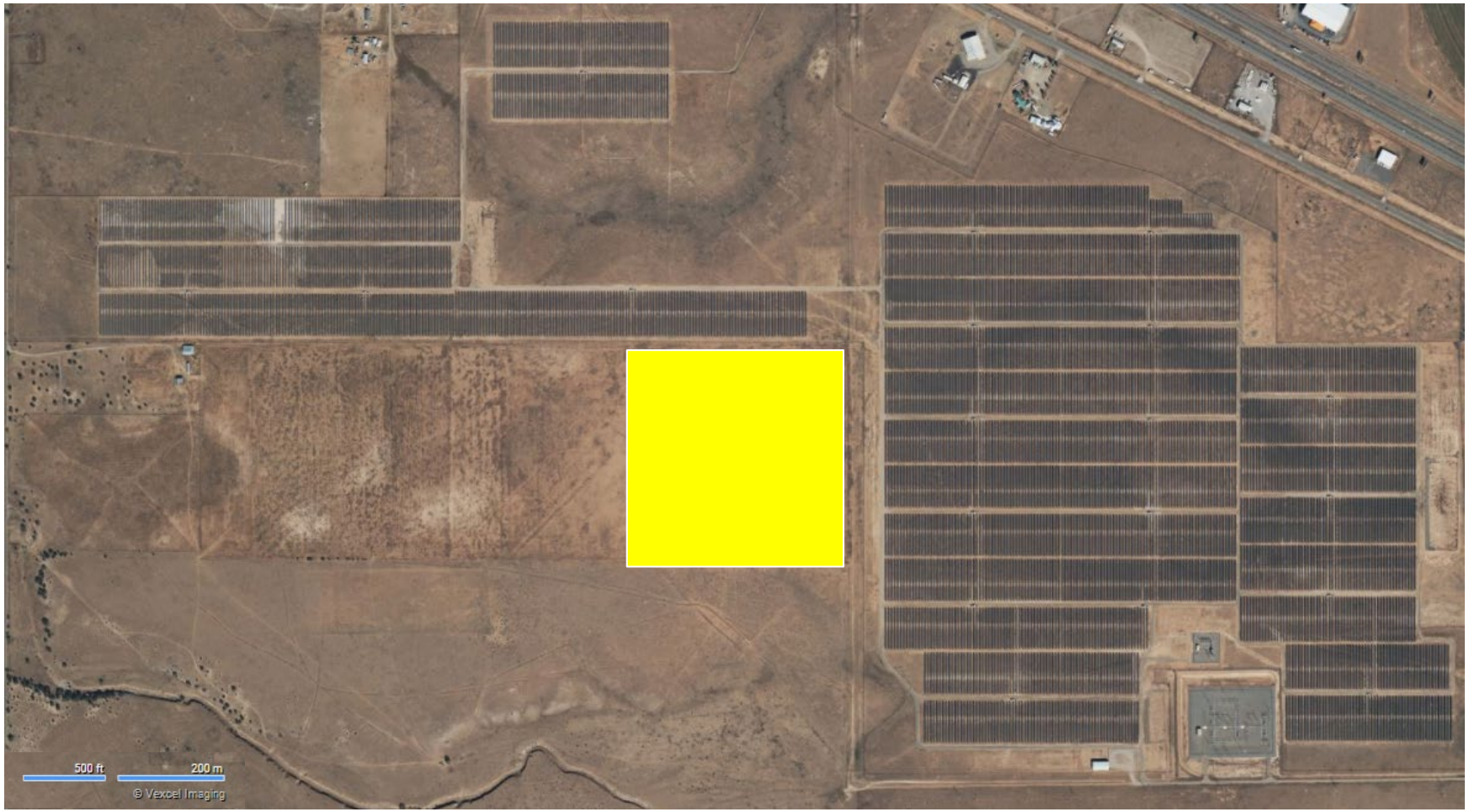
Lithium-ion batteries

- Diablo Energy Storage System
- Pittsburg CA
- 200 MW, 800 MWh
- 15 acre

For Experiment

- 2 GWh
- 37.5 acres



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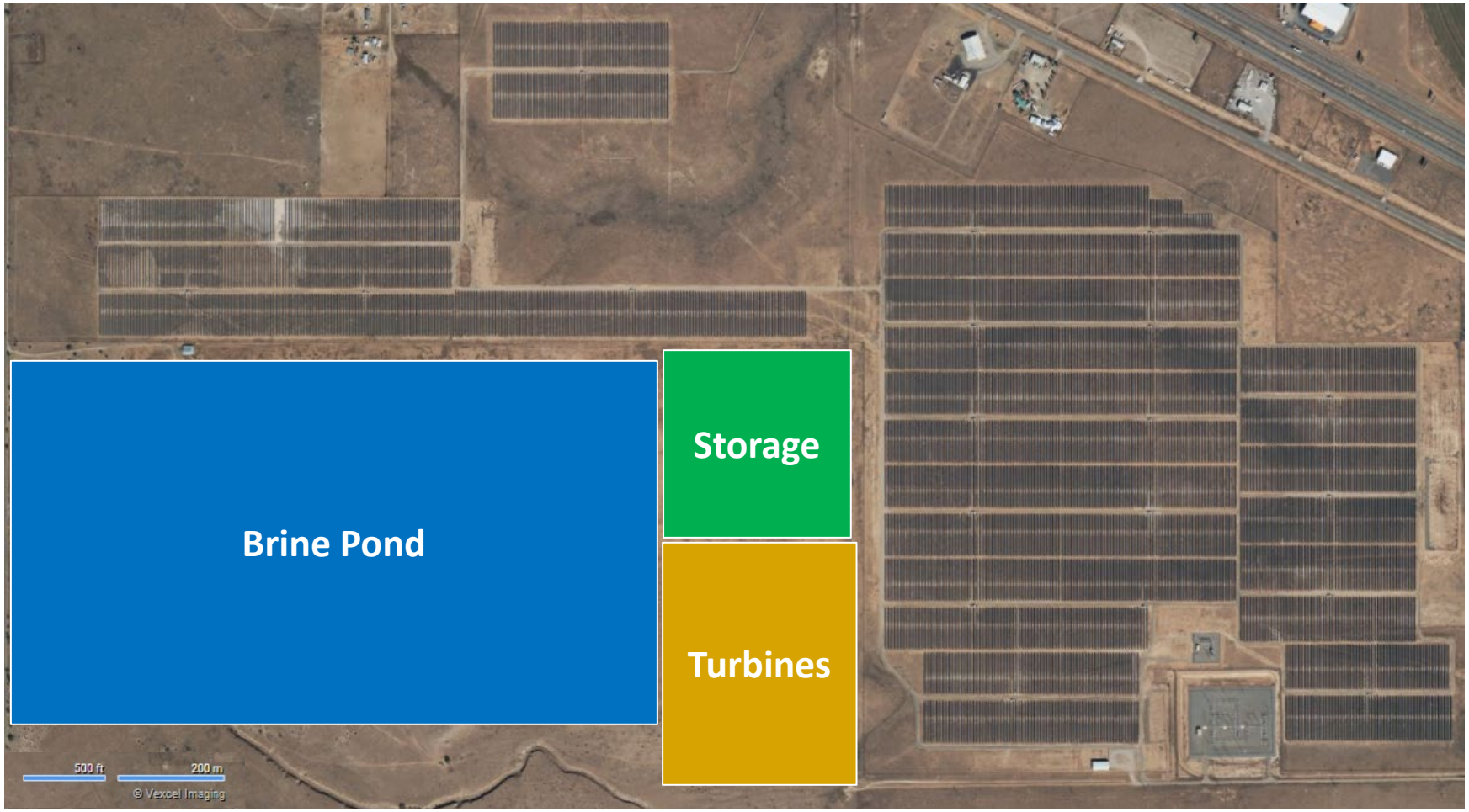
ACES Delta

- 840 MW, 200 hour
- Storage and conversion: 30 acres
- Brine pond: couple hundred acres (200)
- Turbines: 40 acres



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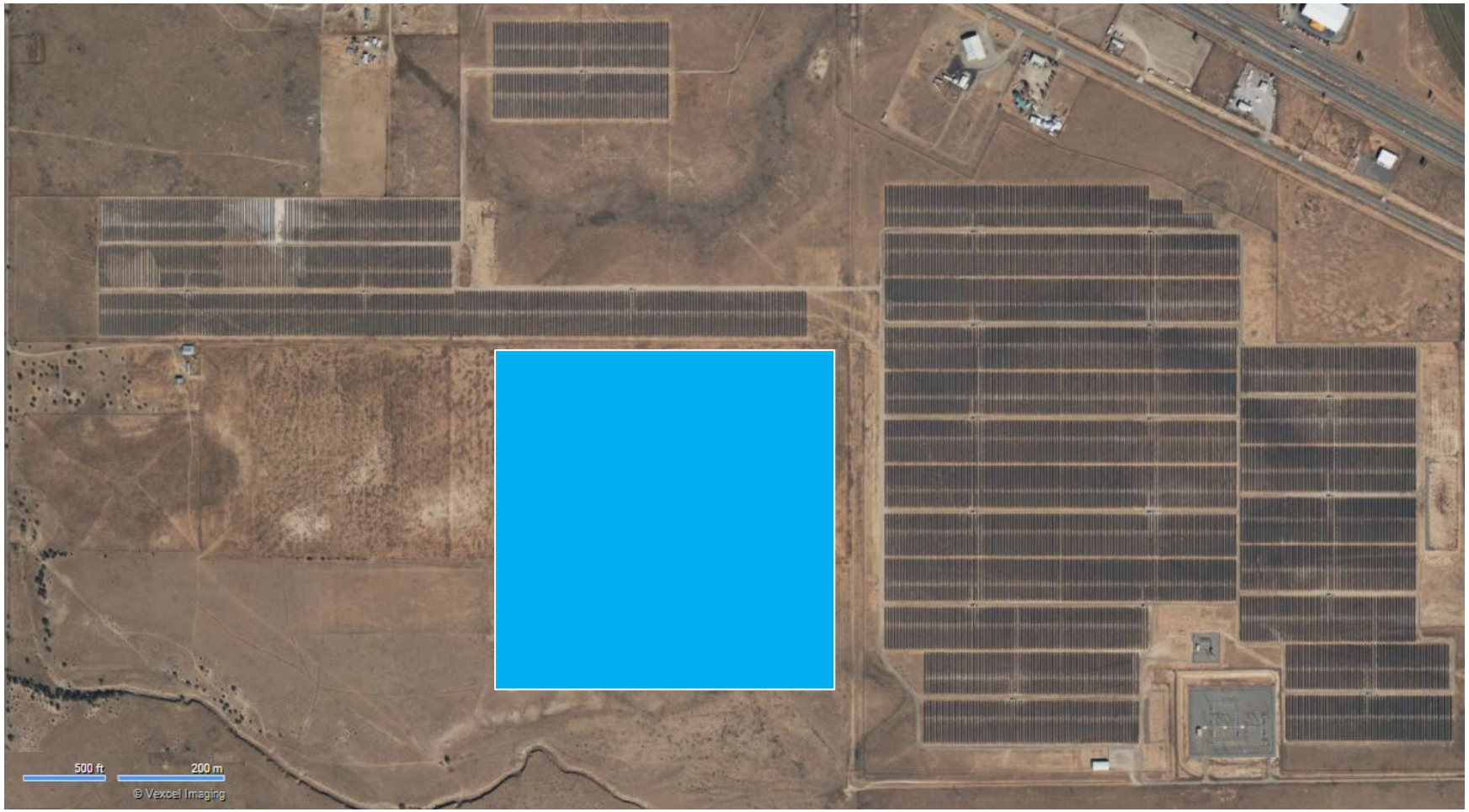
Energy Dome Baseline Plant

- 20 MW
- 10 hours
- 10 acres

For Experiment:

- 200 MW
- 10 hours
- 100 acres



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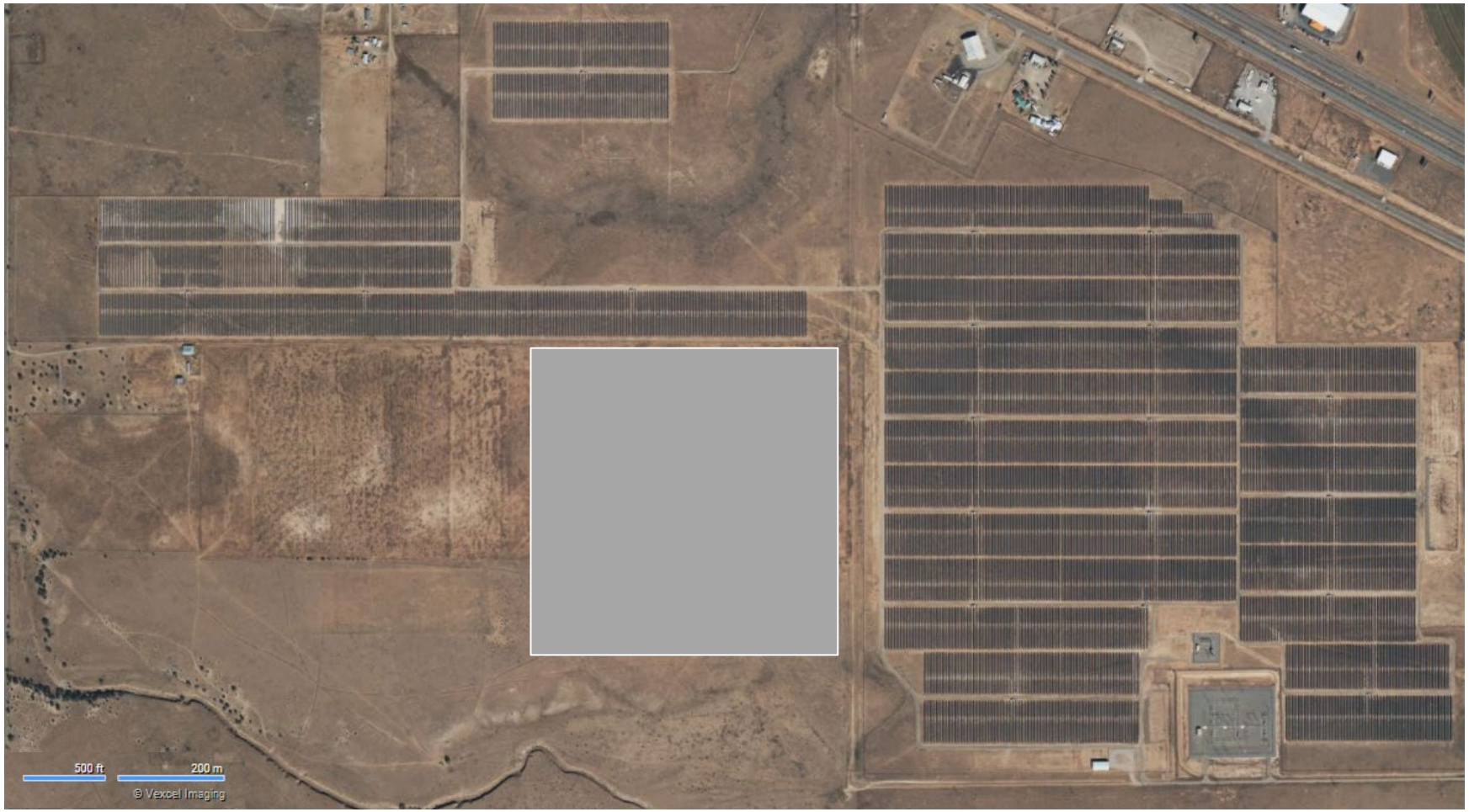
Energy Vault Baseline Plant

- 460 ft (140 m) tall
- 24 MWh/acre

For Experiment:

- 2 GWh
- 80 acres



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Hydrostor Baseline Plant

- 500 MW
- 10 hour
- 79 acres

For Experiment:

- 200 MW
- 10 hour
- 32 acres

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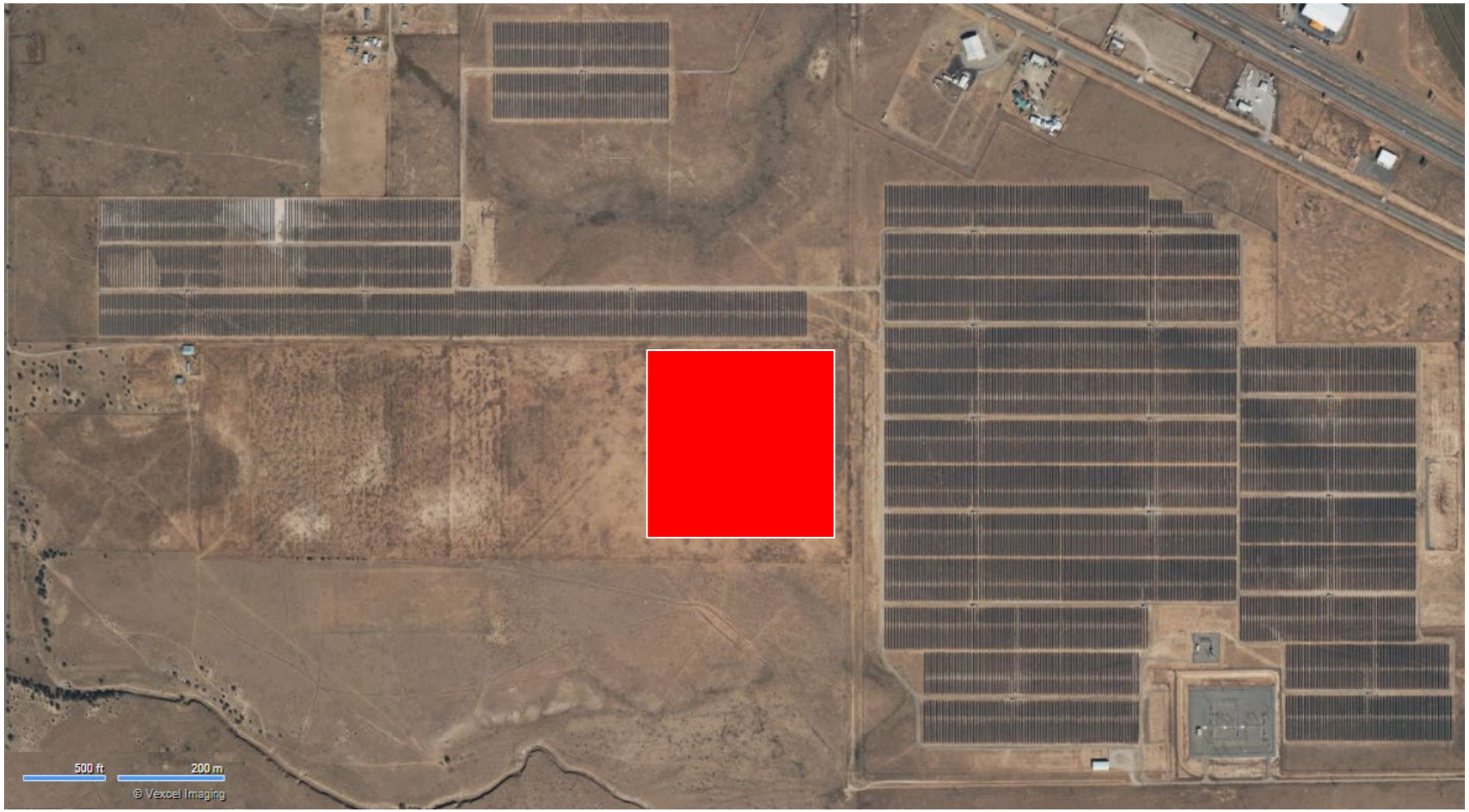
RedoxBlox Pilot Plant

- 6 MW
- 10 hour
- 40,000 ft^2

For Experiment:

- 200 MW
- 10 hour
- 30 acres



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Conclusions

- Energy storage can be used to serve multiple use cases
- There are many emerging types of energy storage
  - Hydrogen: ACES Delta
  - Compressed Air: Energy Dome, Hydrostor
  - Gravity: Energy Vault
  - Thermochemical: RedoxBlox

- Energy storage projects typically have smaller footprint compared to renewable generation
- EPRI has experience developing use cases and energy storage economics with feasibility studies, market analyses, costs, and benefits

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