MOVE THE WORLD FORWARD

MITSUBISHI HEAVY INDUSTRIES GROUP

TMCES STORAGE WORKSHOP

The First Step Towards the Realization of Integrated Hydrogen Technologies from Production to Power Generation

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July 30, 2025

MITSUBISHI POWER

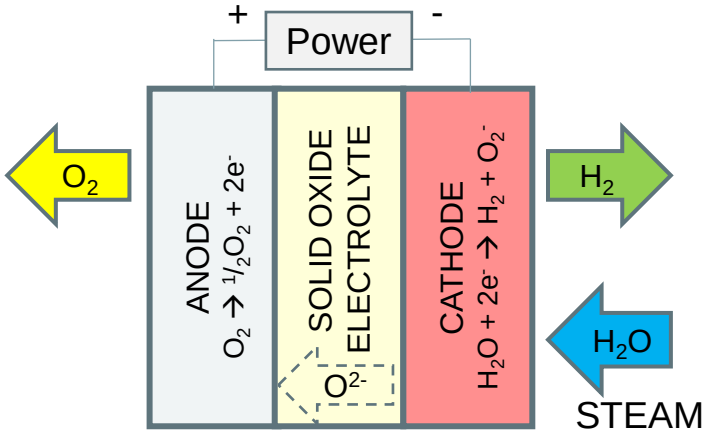
1. Hydrogen Production Validation
2. Hydrogen Storage
3. Advanced Clean Energy Storage (ACES) Update

VALIDATION

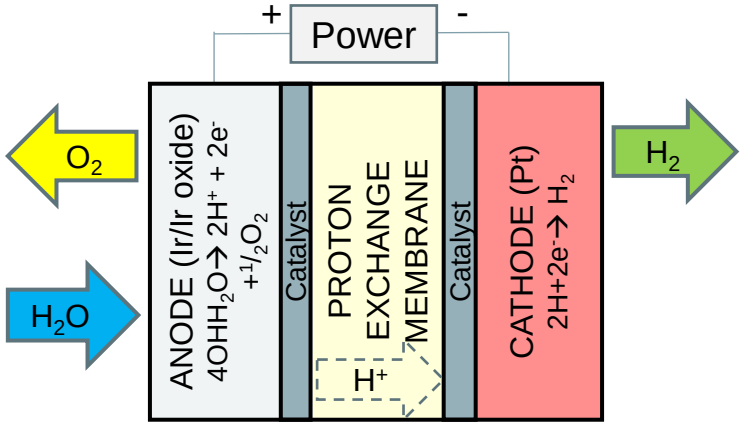
Hydrogen Production

Green Hydrogen Production Technologies

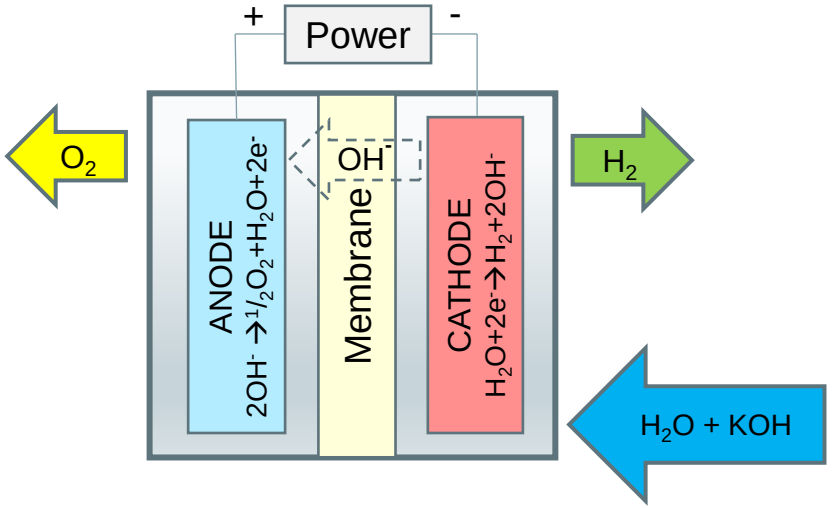
Solid Oxide Electrolyzer Cell



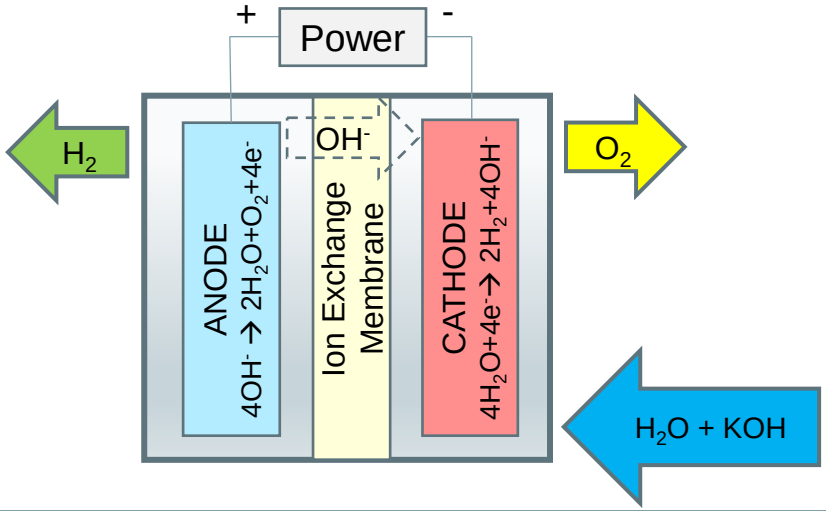
Proton Exchange Electrolyzer



Alkaline Electrolyzer



Anion Exchange Electrolyzer



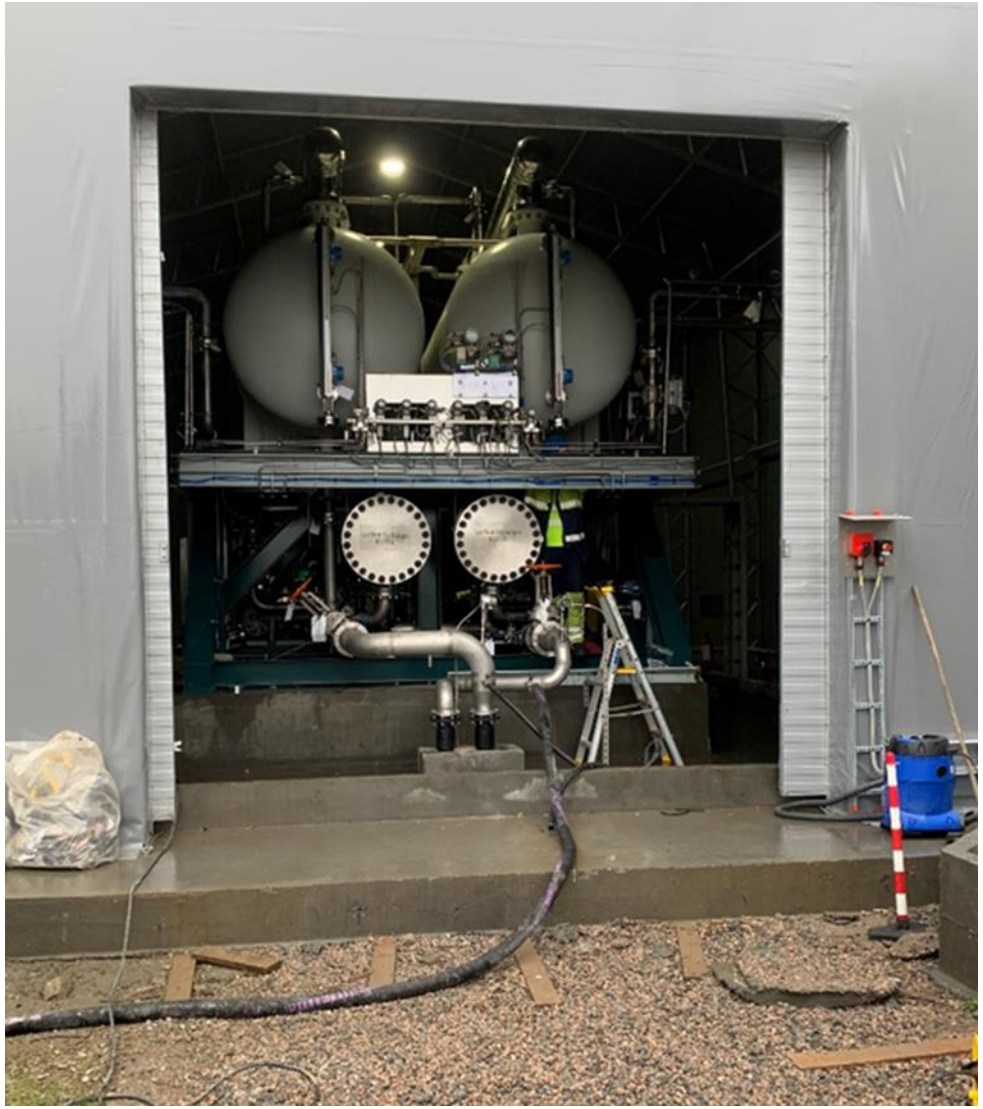
Electrolyzer Rapid Validation (ERV): Project Overview

- **First of Kind Validation:** 5.5MW pressurized alkaline electrolyzer and gas separator
- **Equipment:** Specifically built to validate hardware, controls, operation, and performance
- **Location:** Installed and tested in Porsgrunn, Norway
- **Timeline:** October 2022 – March 2023

Electrolyzer Rapid Validation: Benefits from the Validation

- First piece qualification for factory.
- Designs created to meet worldwide codes & standards (ASME, NEC, PED, ATEX).
- Develop quality procedures and documentation.
- Improve understanding of system integration and BOP.
- Develop operations, start-up, and installation instructions.
- Develop understanding of operational performance.
- Test Operation, Controls, and Performance

Electrolyzer Rapid Validation: Lessons Learned



Produced with over 50 items

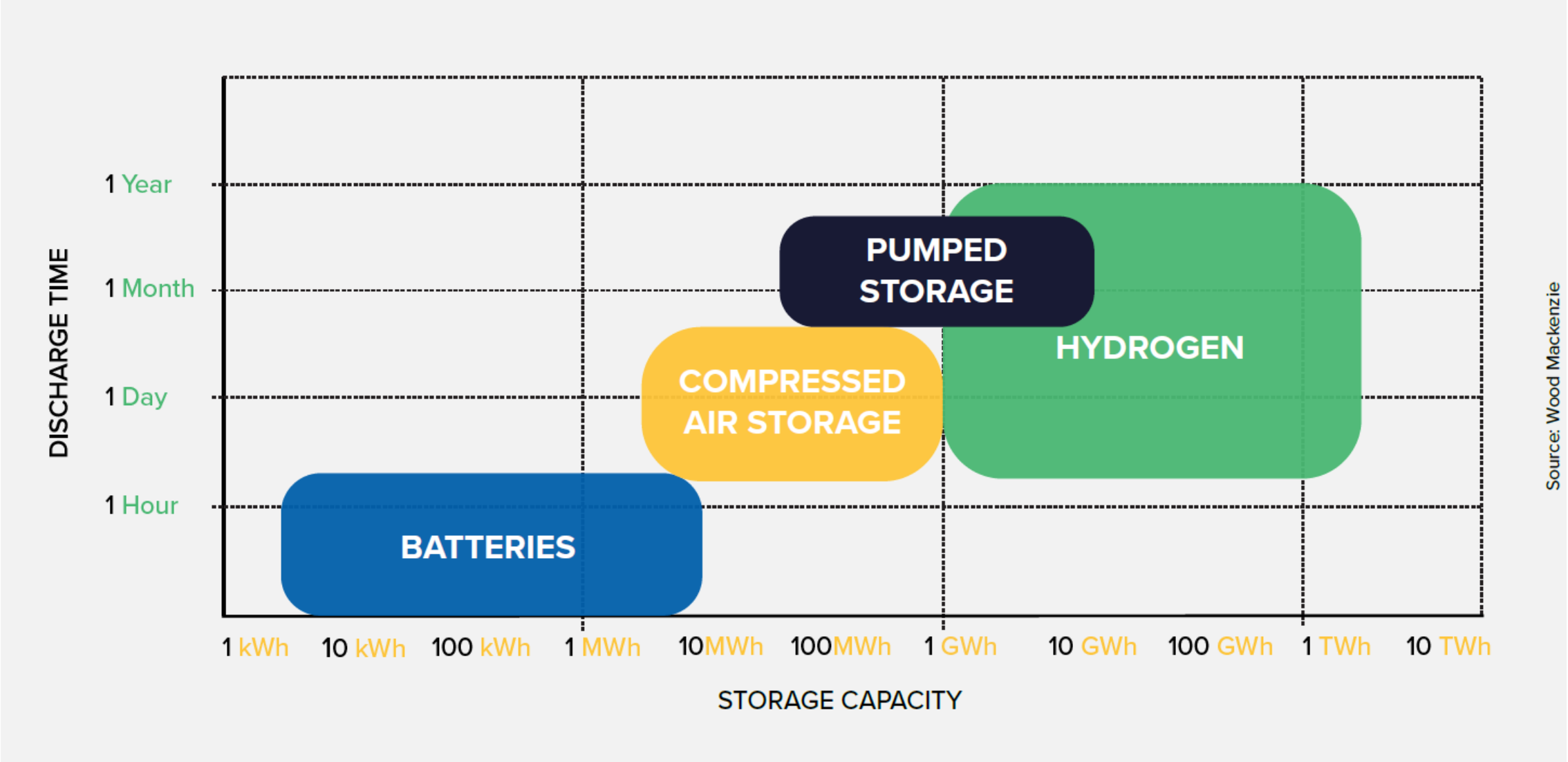
- Improved control, instrumentation (locations, drains, configuration)
- Improved manufacturing procedures, quality, and tooling.
- Flushing & passivation procedures improved.
- Better methods for performance testing & gas sampling.
- Temperature management and extreme weather effects.
- Constructability & Maintainability.
- Improved commissioning procedures.
- Design changes to improve performance.

Takasago Hydrogen Park – Accelerating Decarbonization - MISSION NET ZERO

Storage

Hydrogen Storage

Comparison of Capacities of Energy Storage Technologies

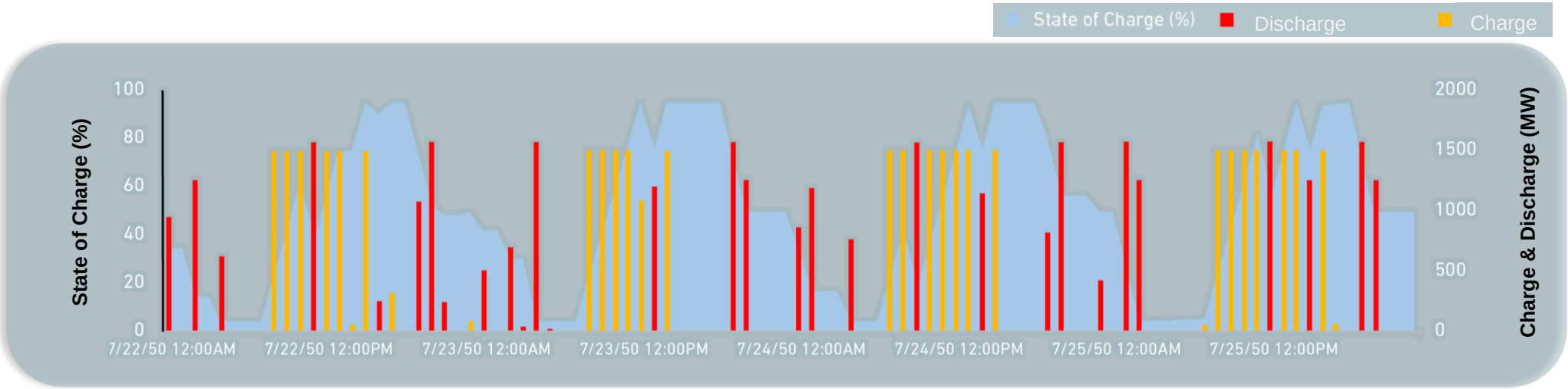


Reference: Green Hydrogen Coalition Handbook

Hydrogen Provides Seasonal Storage, Li Ion BESS Provides Daily Storage

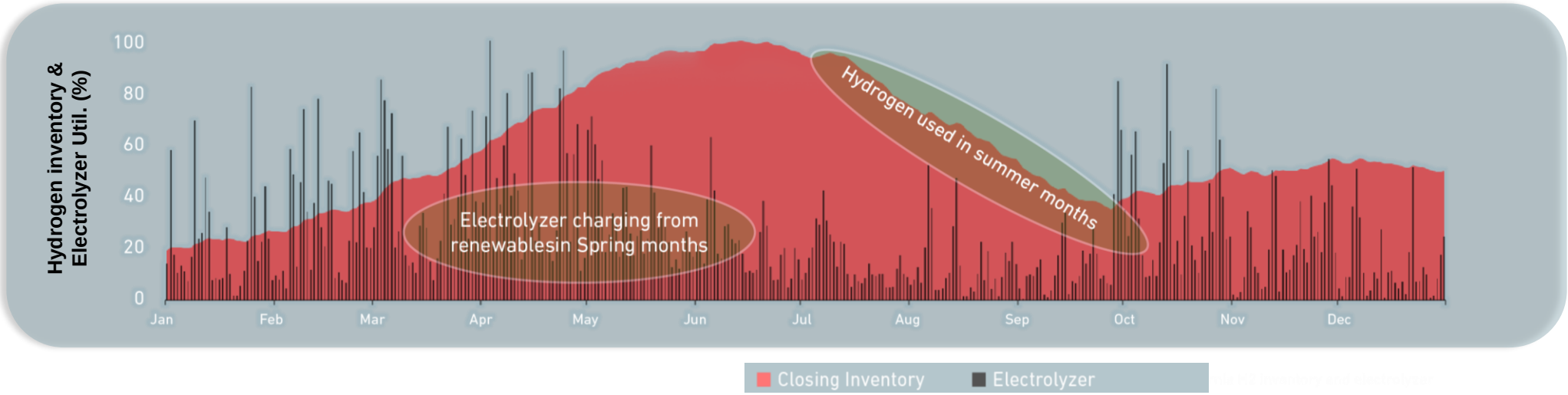
LIB Operation

(California)



Hydrogen Production and Electrolyzer Utilization

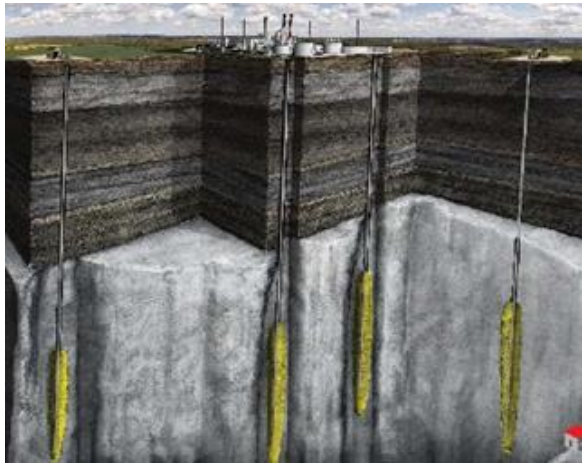
(California)



Hydrogen Storage Technologies

Geological Storage

- Salt Caverns
- Hard Rock Caverns



Pipeline Storage

- Steel Pipeline-24”
- Horizontal Pipeline Segments
- Vertical Wells
- Composite Pipeline (future evaluation)

Pressure Vessel Storage

- Steel Concrete Composite Vessels
- Vertical Underground Silos
- Modular Hydril Tubes
- Large Diam Horizontal Vessels
- Spherical

Other

- Liquid Organic Hydrogen Carrier (LOHC)
- Ammonia
- Boron/Sodium liquid solutions
- Liquefaction

Update

Advanced Cavern Energy Storage (ACES)

Advanced Clean Energy Storage Project Update

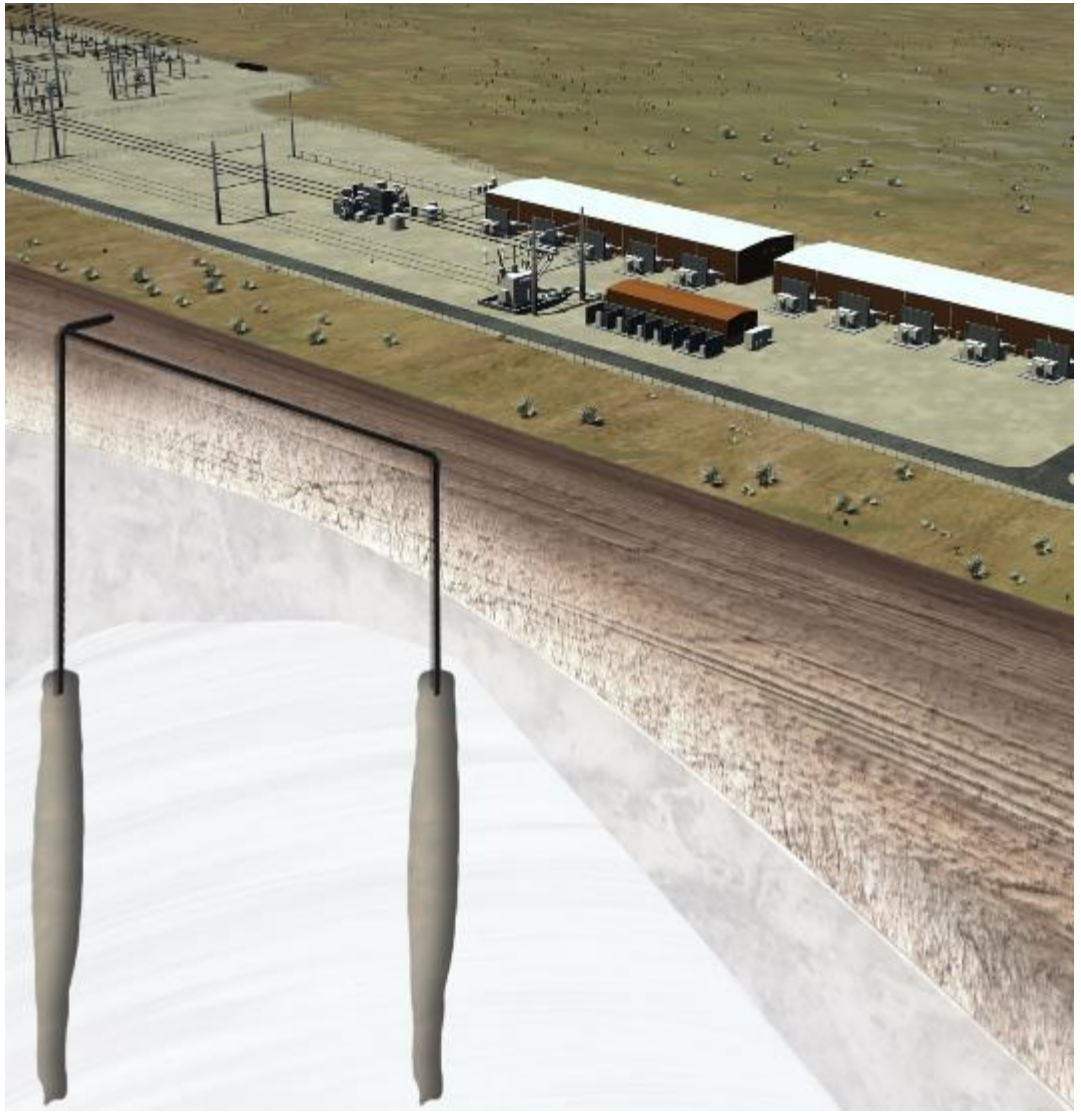
Startup planned for August

Two salt caverns for Hydrogen storage
Each cavern has a storage capacity of **150 GW hours of energy**. This salt dome has the ability to house up to **70-100 caverns**.

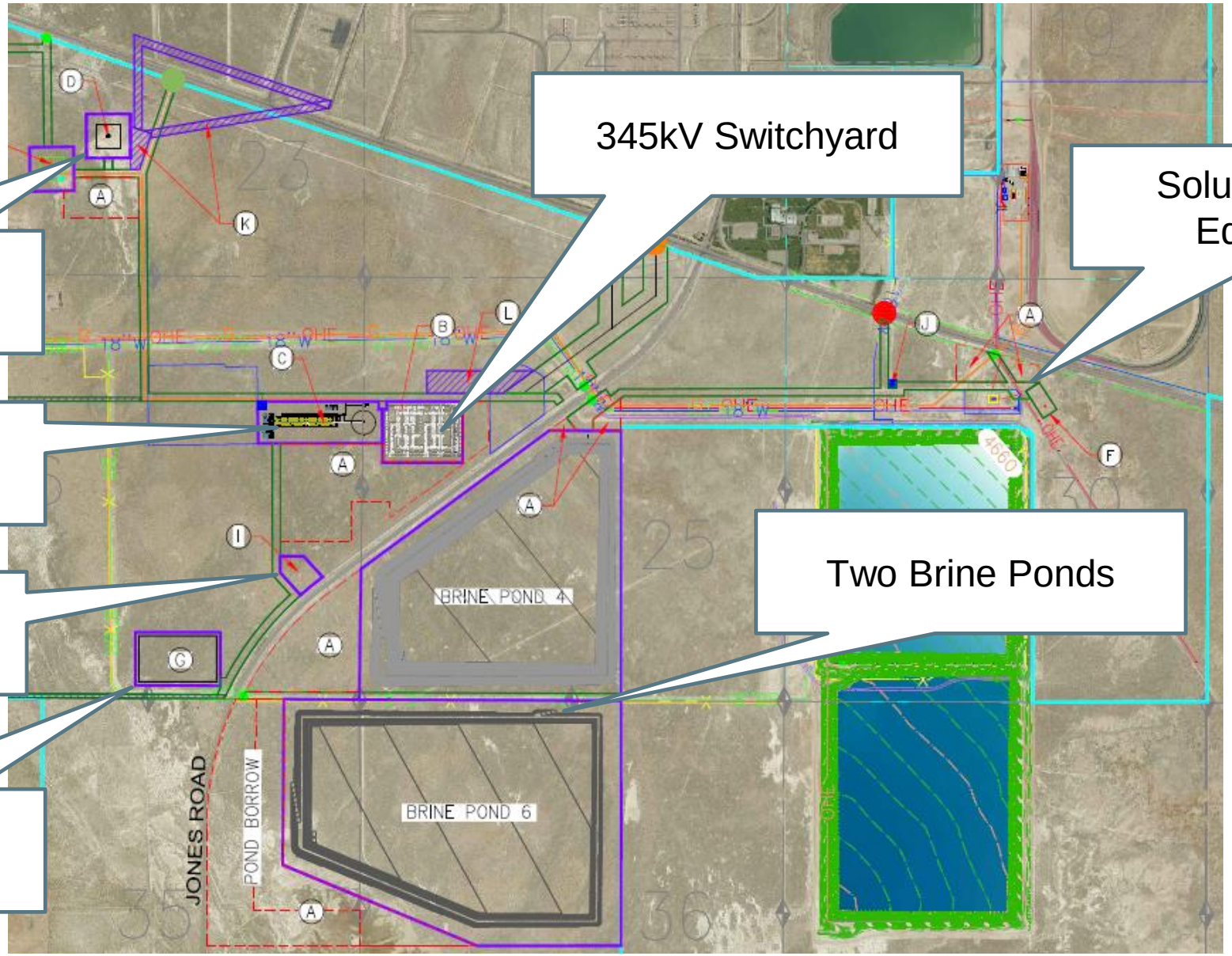
Convert more than 220 MW of renewable energy to 100 metric tonnes per day of green hydrogen.

The ACES Delta Hub received a **$504.4 million loan guarantee** from the U.S. Department of Energy's (DOE) Loan Programs Office to develop the world's largest industrial green hydrogen facility.

In 2023, Chevron U.S.A. Inc. company through its Chevron New Energies Division, became a **new strategic partner** of the ACES Delta Hub by acquiring Magnum Development, now a wholly-owned subsidiary of Chevron.



Scope of Conversion and Storage Systems



Two Caverns

345kV Switchyard

Solution Mining Equipment

220MW/4TPH Electrolyzer Plant

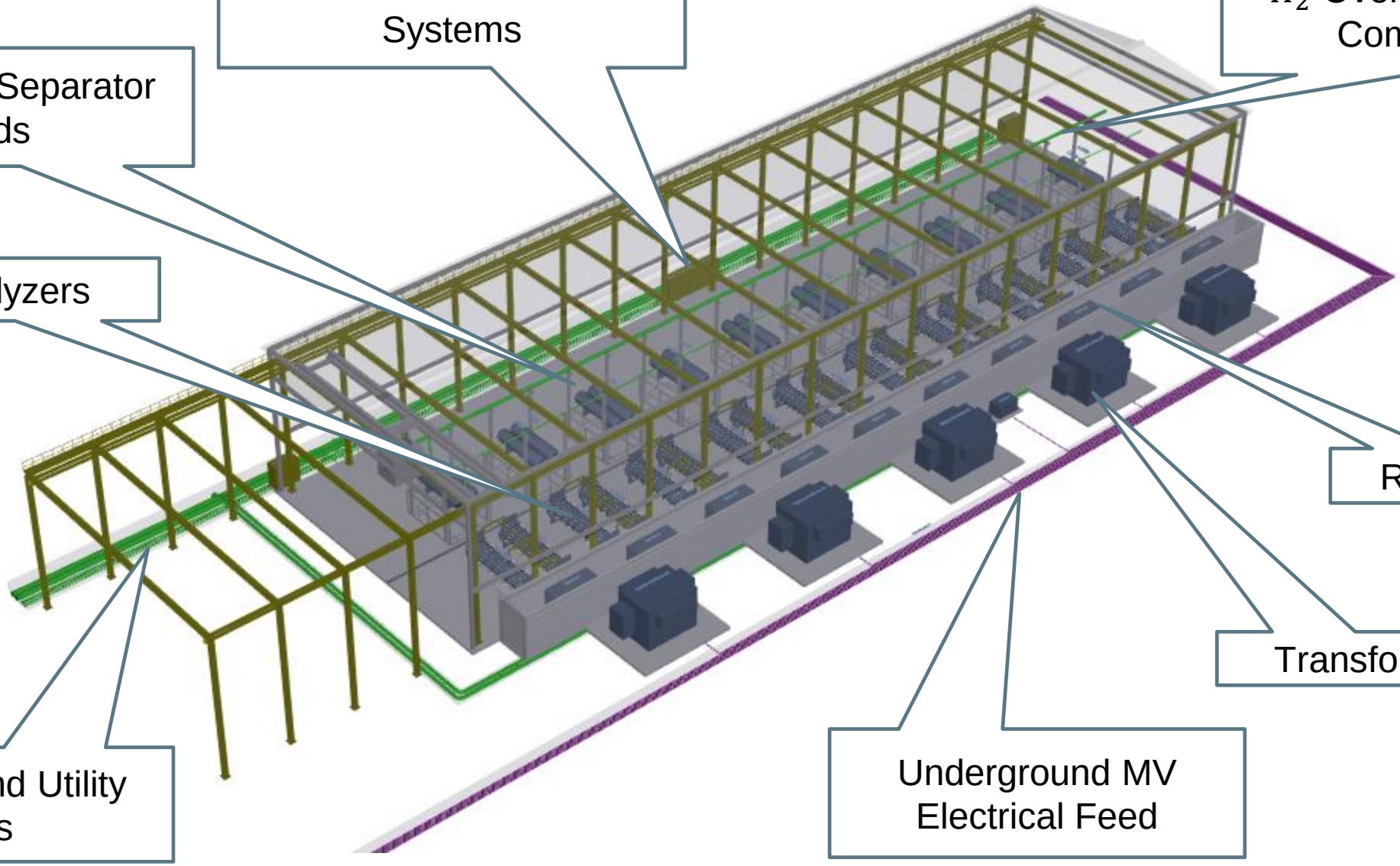
Two Brine Ponds

O&M Building

Evaporation Pond

Actual Site from Google Earth

Utility-Scale Deployment of Technology Selected



Project Progress

Storage Facility

- Solution mining near completion - cavern 23 (10/18/2025 completion).
- Cavern 2 is set to finish 3/25/2028.

Conversion Facility

- Installation complete
- Hydrogen Generation ESD Interlock Testing complete
- Load testing of rectifiers complete
- Flushing and system leak checks complete (July 2025)
- Startup and substantial completion (August 2025)

ACES Delta Progress July 2025

ACES Delta Progress July 2025

Electrolyzer Building A
20 electrolyzer cell stacks and 10 gas separator skids

Electrolyzer Building B
20 electrolyzer cell stacks and 10 gas separator skids

ACES Progress 2025

Compressor Area

Cavern 2 Wellhead

Cavern 23 Wellhead

Summary

ENERGY STORAGE

- Energy storage is a critical component of a transition to Green Energy.
- Hydrogen storage is key to long term energy storage.
- A wide variety of new technologies for storage are needed, from short to long duration. There is no one solution.
- Economical means to store energy and reconvert it require development across all segments.

GREEN HYDROGEN KEY CONSIDERATIONS

Green Hydrogen enables cost effective achievement of climate goals as an energy storage resource (power industry) and as a decarbonized fuel (“hard to electrify” verticals).

Green Hydrogen value chain – including electrolysis, storage, transport, and use in power plants – is commercially mature.

Sector Coupling of green hydrogen infrastructure enables even more cost effective achievement of economy-wide, decarbonization goals.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Back Up

Hydaptive™ Benefits

Core Technology Supply by MPWA

- Electrolyzer
- Gas Separator
- Rectifiers
- Transformers
- Controls

Standard Package Offers

- Documentation packages for:
  - Hydrogen Production or Hydrogen Integrated with Power
  - Includes – General Arrangements, One-Line Diagram, P&IDs, PFD's, Equipment lists
  - Provided via a License or other mechanism.

Benefits

- Reduces schedule and cost by eliminating FEED study for layout plant, preliminary design, cost estimates…
- References to a plant under construction/operation
- Upfront estimate of CAPEX, OPEX
- Improved financeability

Hydrogen Storage – In Summary

[1] *"Discharge" capability based on hydrogen GTCC*
[2] *Assumes ~3,000 psig to 1,000 psig working gas*
[3] *Assumes 500+MW H2-GTCC @ 100% H2 operation*
[4] *Assumes 500+MW H2-GTCC @ 30% H2 operation*

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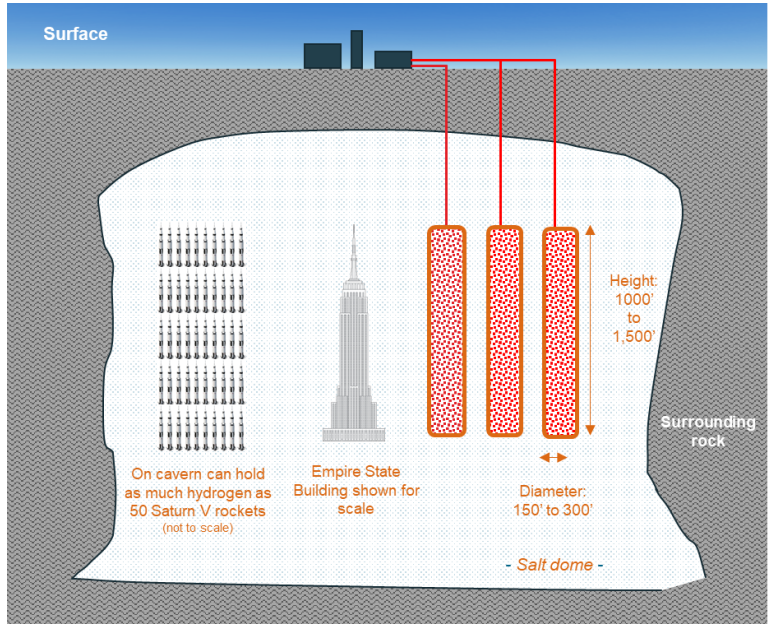
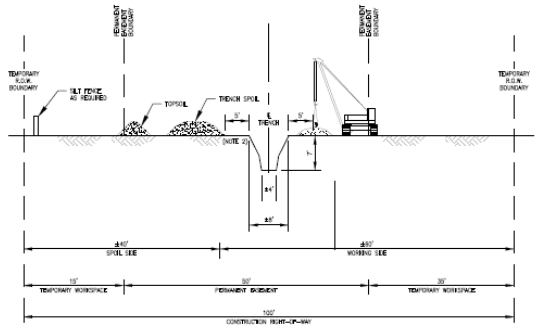
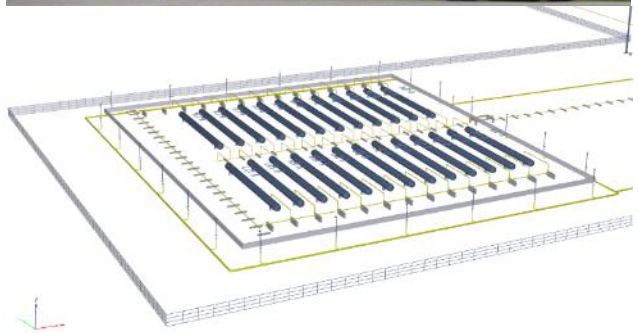
Salt Cavern



Hydrogen Pipeline Pack



Pressurized Vessels



Per 1 Cavern Stats

- >100,000 MWh[1]
- 5,500 tonnes[2] H_2
- 10 days[3] to 1 month[4]

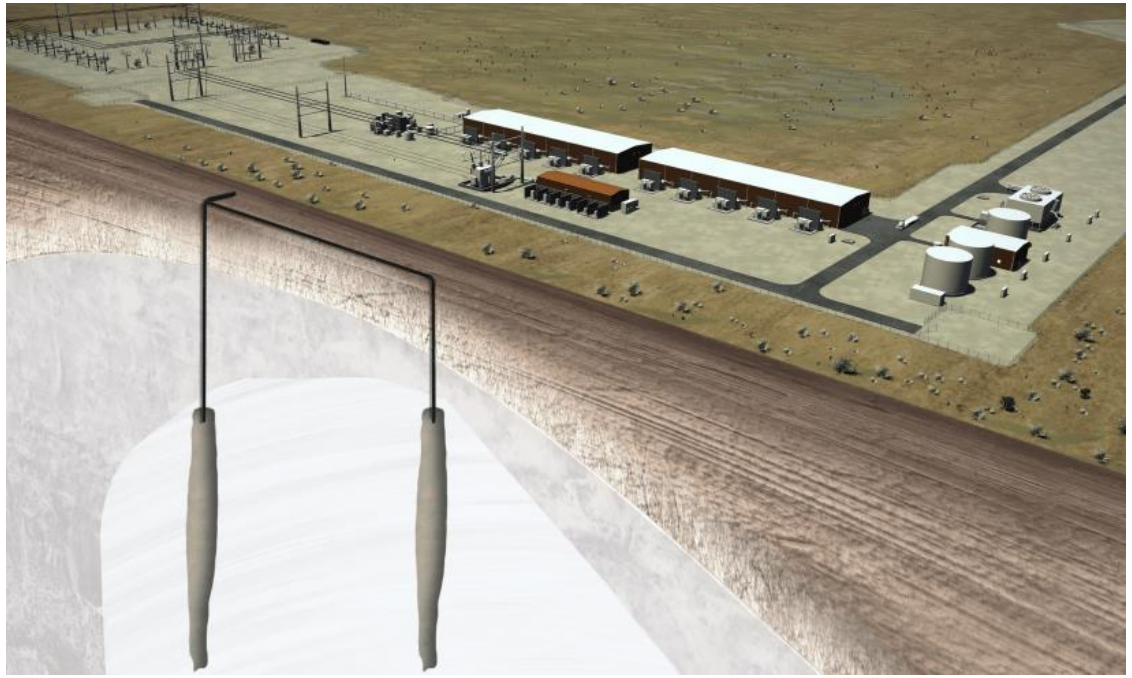
Per 10-mile Stats

- >1,000 MWh[1]
- 45 tonnes[2] H_2
- 2 hours[3] to 16 hours[4]

Per 10-Bullet Stats

- >200 MWh[1]
- 10 tonnes[2] H_2
- 0.5 hours[3] to 4 hours[4]

Advanced Clean Energy Storage Update



TECHNOLOGY INNOVATION

Advanced Clean Energy Storage uses a 220-megawatt bank of electrolyzers and intermittent renewable energy to produce hydrogen, store it in salt caverns, and deliver that hydrogen for future dispatchable generation. The scale of deployed electrolyzers as well as the use of salt caverns to store hydrogen are both significant innovations.

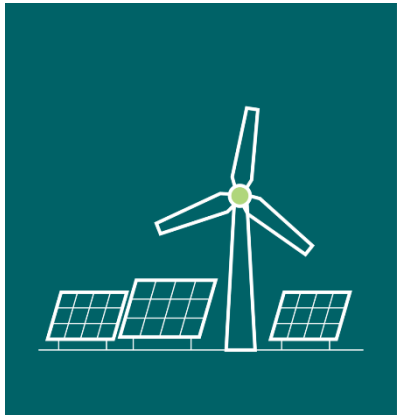
CLIMATE BENEFIT

Advanced Clean Energy Storage may contribute to grid stabilization and reduction of curtailment of renewable energy by using hydrogen to provide long-term storage. The stored hydrogen is expected to be used as fuel for a hybrid 840 MW combined cycle gas turbine (CCGT) power plant that will be built to replace a retiring 1,800 MW coal-fired power plant. The project is estimated to help prevent 126,517 metric tons of carbon dioxide emissions annually based on the difference in the emission profiles of the IPP turbines between 100 percent natural gas fuel to a 70 percent natural gas and 30 percent hydrogen fuel blend.

Hydrogen Storage ACES

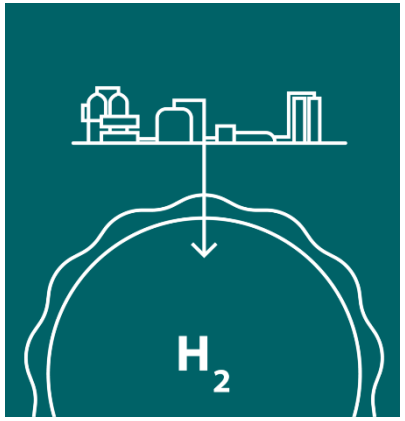
CONVERT GREEN HYDROGEN

The Advanced Clean Energy Storage hub will capture excess renewable energy, such as wind and solar, during off-peak hours to inexpensively power electrolyzers that convert water molecules to “green” hydrogen and oxygen. Representing one of the world’s largest orders for electrolysis equipment, the Advanced Clean Energy Storage hub will nearly double the global installed capacity for electrolysis.



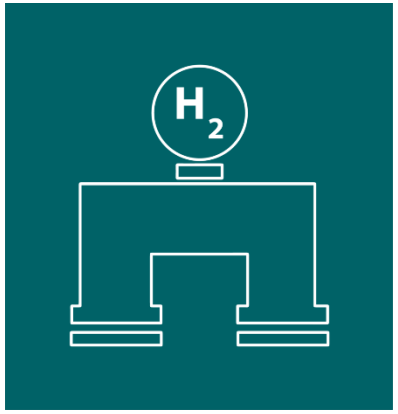
STORE GREEN HYDROGEN

The hydrogen will be stored in two massive, subterranean salt caverns, each capable of storing 5,500 metric tonnes of working capacity. The salt cavern storage capacity will make it possible to store excess renewable energy produced in the spring when energy demand is low and use it to generate energy in the summer when demand is high.



DELIVER GREEN HYDROGEN

The Advanced Clean Energy Storage hub’s central Utah location can seamlessly integrate with the Western power grid and interstate gas transmission system. This project will serve as a green hydrogen gas and storage hub for the Western United States, delivering green hydrogen for the power generation, industrial, and transportation sectors.



GENERATE POWER FROM GREEN HYDROGEN

The stored green hydrogen will then be used to fuel hydrogen-capable gas turbine combined cycle power plants that will initially run on a blend of 30% green hydrogen and 70% natural gas starting in 2025 and incrementally expanding to 100% by 2045.

It would take more than 80,000 shipping containers of lithium-ion batteries to produce the equivalent megawatt-hours of energy that one hydrogen salt cavern can store. Just one of the salt caverns at the Advanced Clean Energy Storage site has the capacity to store the entire state of California’s monthly curtailed energy.