

# Exploring Renewable Hydrogen Production Pathways:

The Advanced Clean Energy  
Storage Project and IPP Renewal  
Case Studies

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## Our Mission in the Americas

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We will provide profitable power generation and storage solutions to our customers, empowering them to affordably and reliably combat climate change and advance human prosperity.



# Solutions for a Change in Power

**Hydrogen Ready  
Gas Turbines**



**Lithium Ion  
Batteries**

**PV Solar**



**Hydrogen Energy  
Storage Systems**

**Offshore Wind**



**Carbon Capture,  
Utilization &  
Storage**

# Magnum Development, LLC: *Leading Energy Storage*

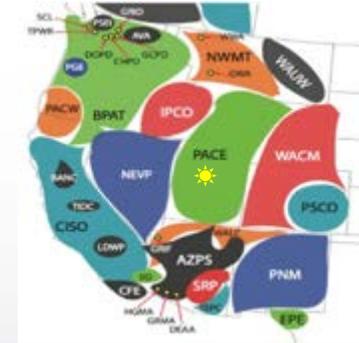
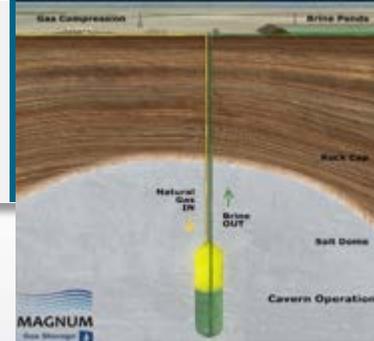


founded  
**2008**

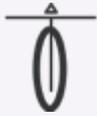


Invested ~  
**\$100M**

Salt Dome  
Storage



Central in  
the WECC



operating Caverns  
**5**



located  
**WECC**

Direct Access to  
Power  
Transmission



Hydrogen  
Storage



business segments  
**7**



west energy storage  
**Goal: #1**

Abundant Natural  
Resources



Carbon Capture,  
Utilization &  
Storage

# Advanced Clean Energy Storage



ADVANCED  
CLEAN  
ENERGY  
STORAGE

## What

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- We Produce and Store Green Hydrogen from excess renewables
- We deliver green hydrogen to support decarbonization of power, transportation, and other verticals
- We provide utility scale storage technologies and carbon-free fuels to support broader integration of renewable energy to meet our regional and national climate goals

## Size

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- Each cavern is 40x larger than the entire US installed base of lithium ion batteries
- The potential amount of energy storage in the salt caverns is virtually limitless
- The bulk of our energy capacity can be measured in MW-days, or MW-months, not in MW-hours

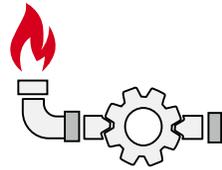
## Where

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- Initiative relies on the United States' only "Gulf Coast" style salt dome
- Location adjacent to intermountain Power project allows integration into western U.S. power grid

## Phase 1

The retirement and replacement of coal-fired power plants with:



Natural Gas



Renewables

## Phase 2

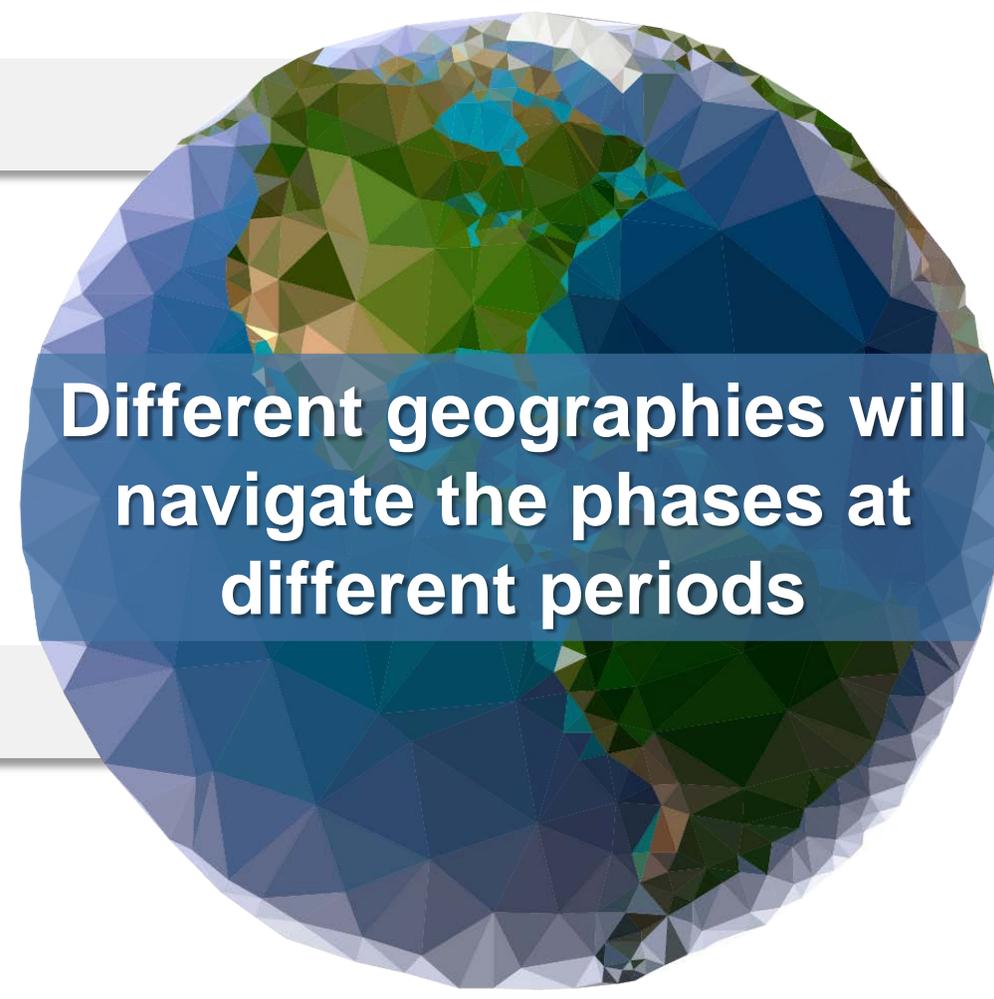
Tackle Long-term Intermittency, currently managed by natural gas power generation:



Energy Storage



Renewables



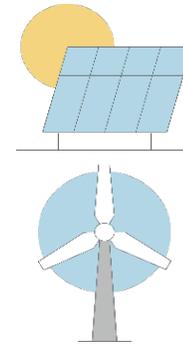
Different geographies will navigate the phases at different periods

## Regulatory



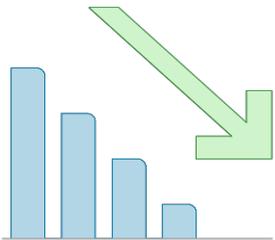
Does the regulatory and legislative environment exist to promote zero carbon targets?

## Need For Storage



Does your power grid have enough intermittent renewable power that curtailments are becoming a problem?

## H<sub>2</sub> Production & Storage



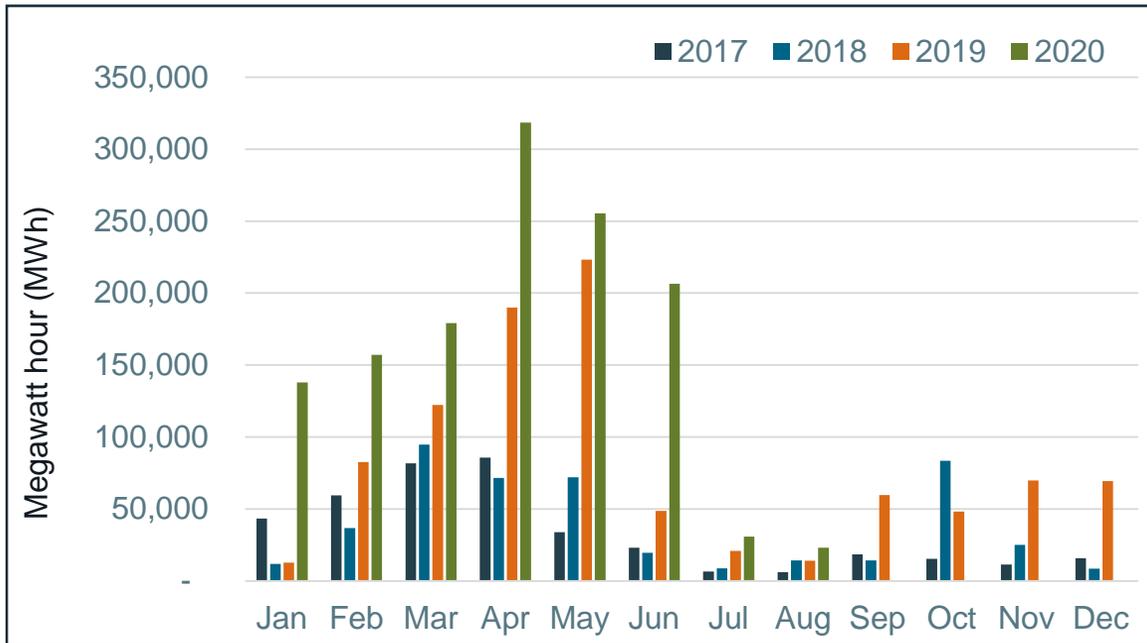
Is the cost of green hydrogen low enough to be the economic alternative for long duration storage?

## Technology



Is there a reliable, affordable and scalable solution to convert hydrogen back to electricity?

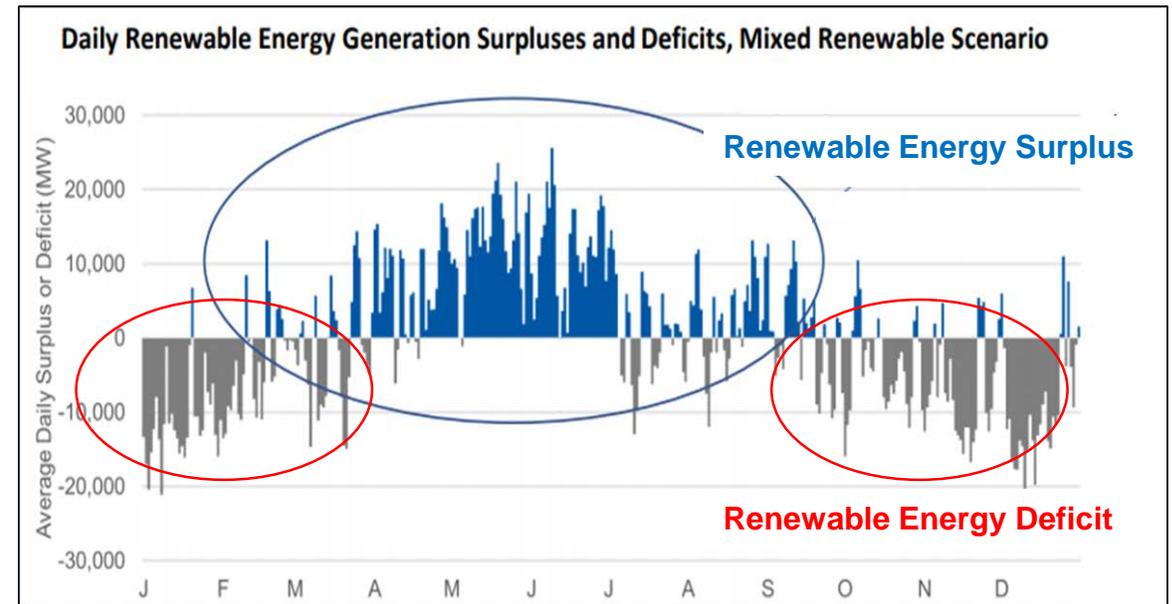
## California wind and solar curtailments hit record high in April 2020



Source: CAISO  
 Data compiled September 2020  
<http://www.caiso.com/informed/Pages/ManagingOversupply.aspx>

At just 30% renewable integration,  
 Peak monthly curtailment exceeds 300,000 MWh

## California surplus and deficit patterns under a 100% renewable energy scenario

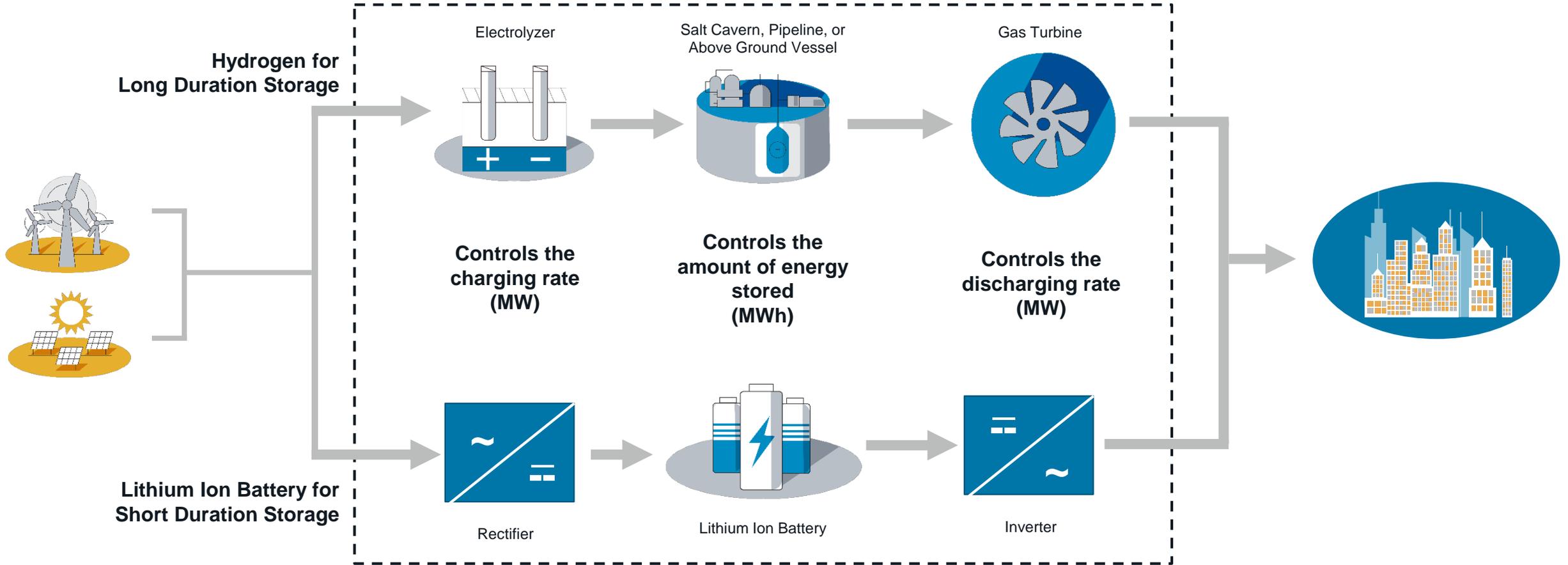


Source: Armonk Cohen Testimony

Seasonal surplus and deficits signal need for long-duration energy storage “beyond the duck curve”

# To Store Energy via Hydrogen or to Store via Lithium?

## Comparison of Green Hydrogen Energy Storage Systems and Battery Energy Storage Systems



March 10, 2020 - MHPS contract award and FNTF  
**\$1.9B Investment Announced by IPA**

The **1<sup>st</sup> Advanced Class Gas Turbine project**  
specifically **designed for green hydrogen fuel**

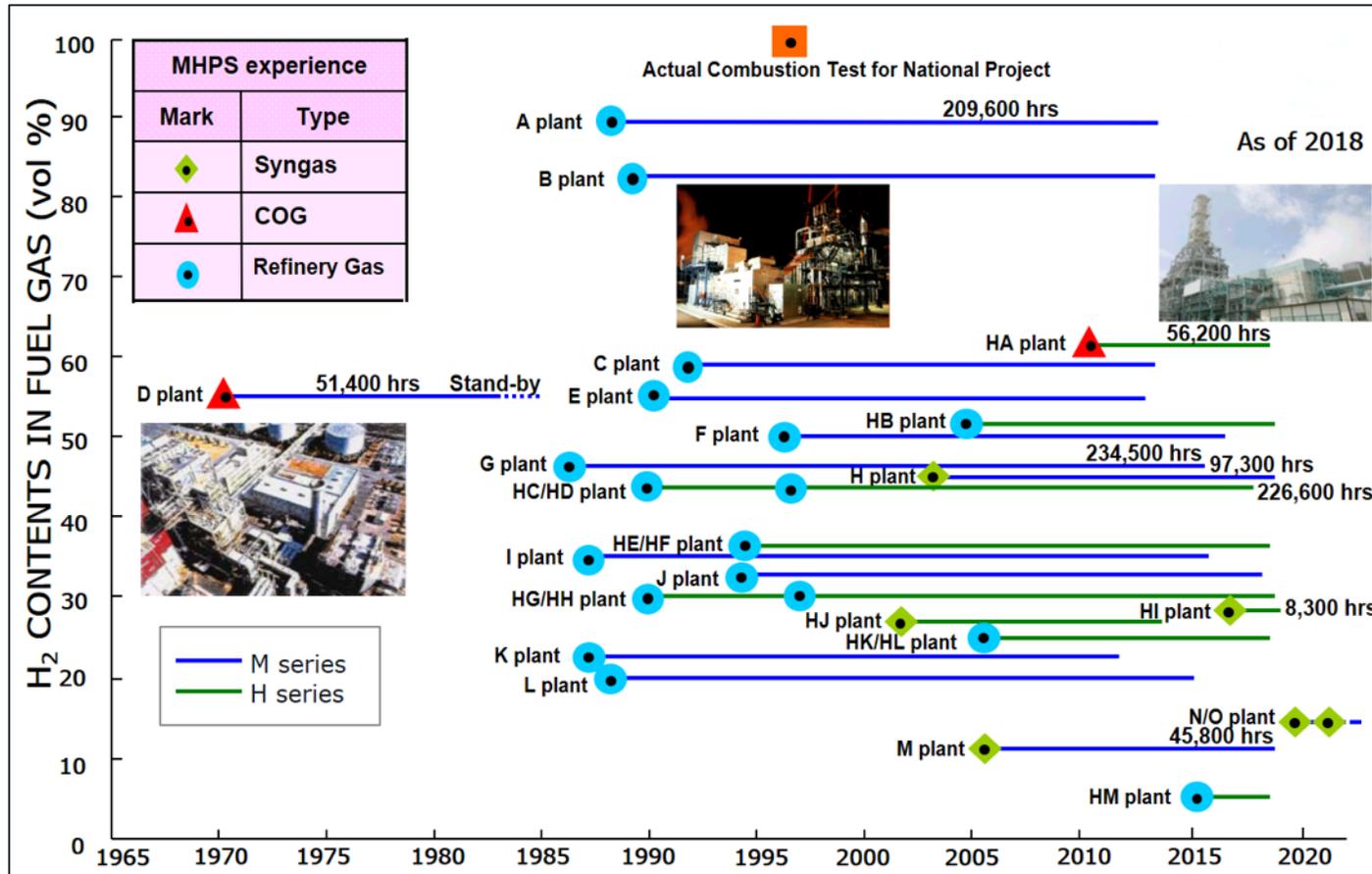
Providing **840MW of reliable energy** to Los Angeles  
and municipalities in other parts of California and Utah

Commercial Operation in **2025** using mix of  
**30% hydrogen & 70% natural gas fuel**

No later than **2045**, capability will be increased to  
**100% Green Hydrogen** to support California  
carbon-free goals



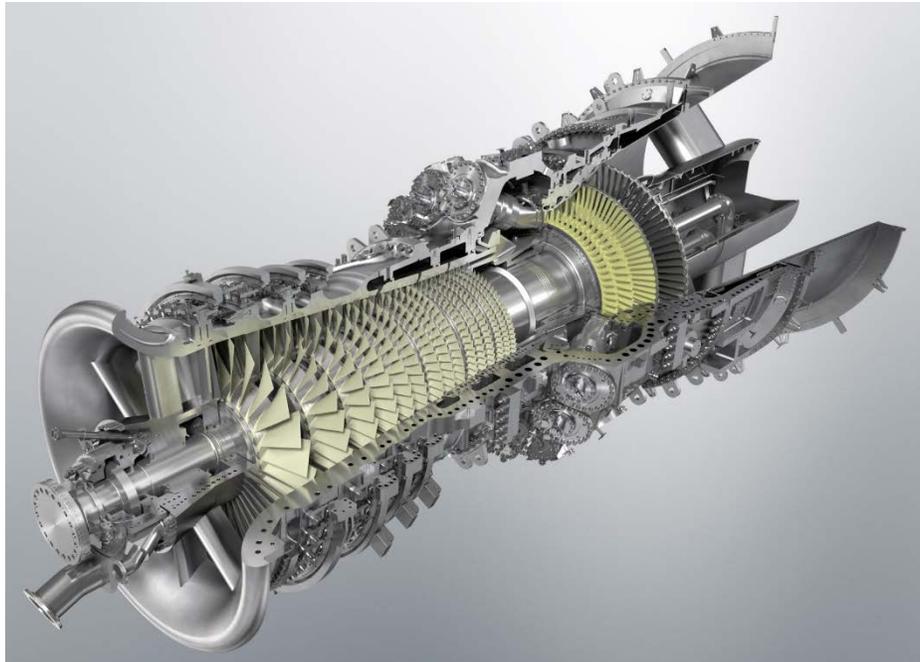
Hydrogen combustion is a mature technology with a proven track record dating back to the 1970s



## Fast Facts: Hydrogen Firing

- Long history (50 years) of operating on Hydrogen fuels in gas turbines
- Many projects with fuels greater than 50%
- Many different projects with different fuel characteristics
- Over 3.5 million hours of experience with hydrogen fuels

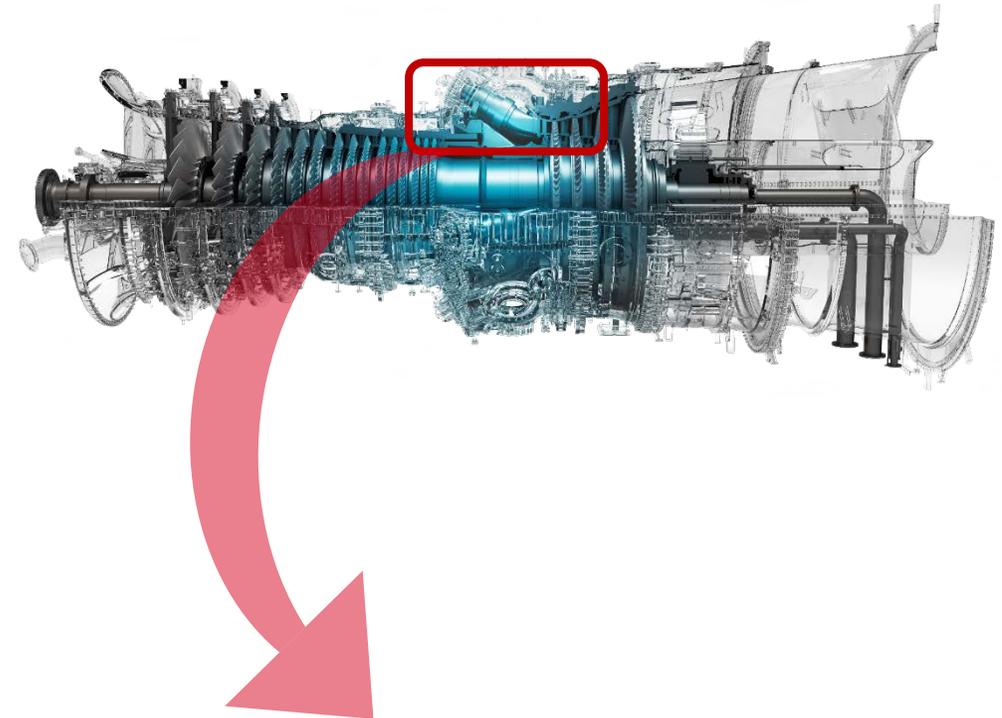
## Advanced Technology



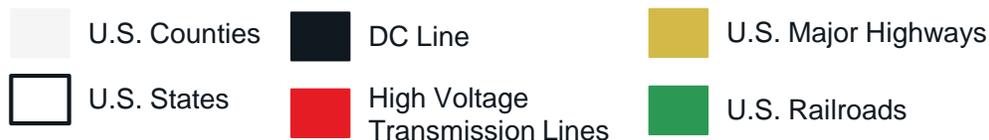
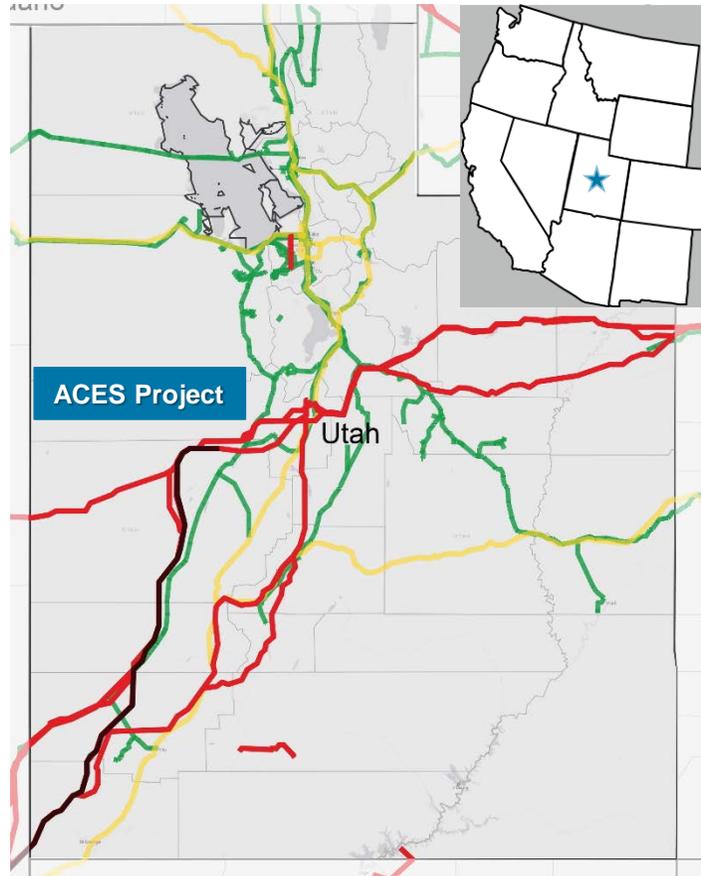
### MHPS J-Series

**CCGT Efficiency : ~65%**  
**Reliability: 99.5%**  
**39 in Commercial Operation**

## H<sub>2</sub> Gas Turbine



**Modifications are only required on the  
combustion components of the GT**



## ACES has exclusive rights to Delta Salt Dome

- Only known “Gulf Coast” style domal-quality salt in the west capable of large caverns
- Large-scale storage necessary for the west coast to decarbonize via green hydrogen

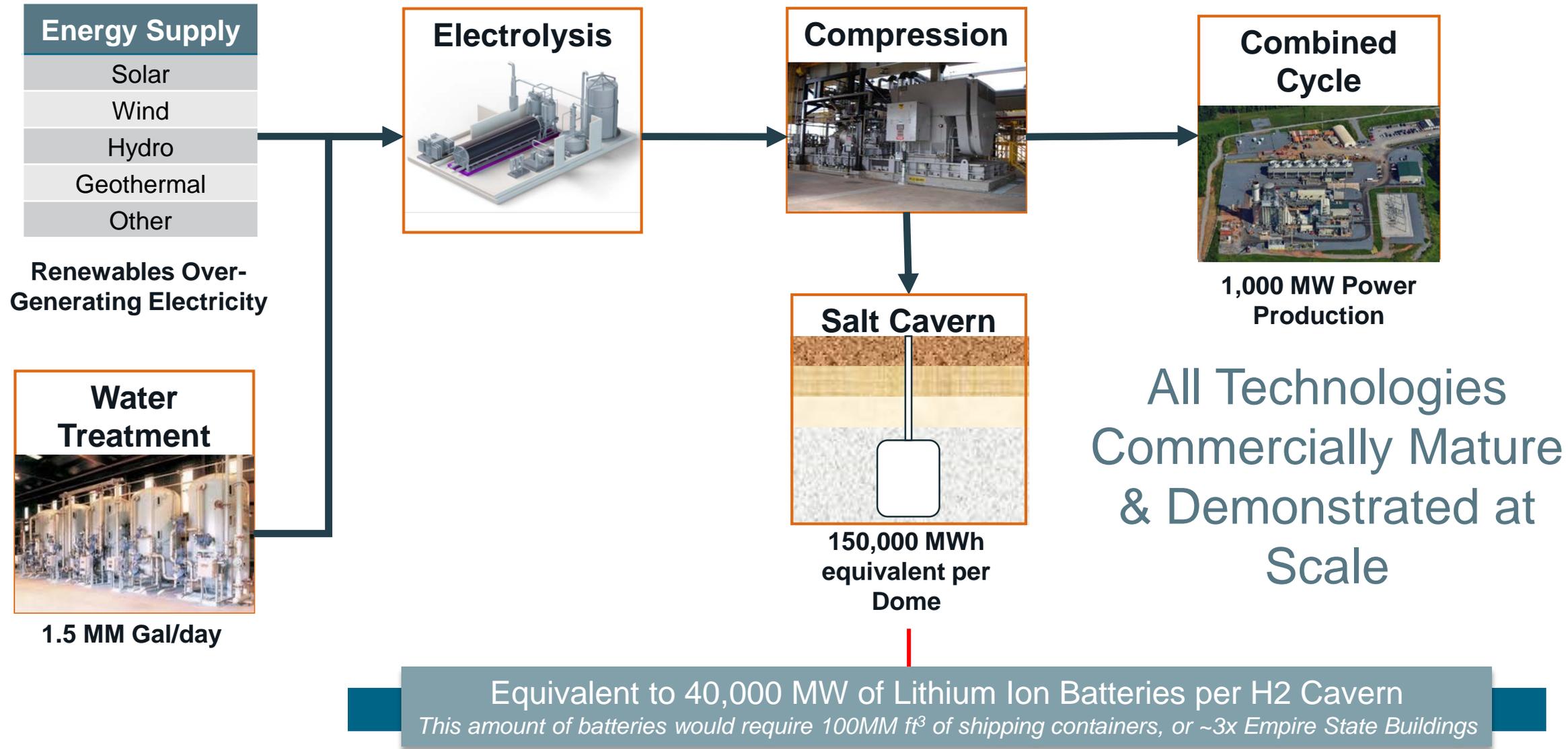
## ACES site Centrally Located to WECC

- California through HVDC Transmission Line
- Major WECC Utilities through AC Tie
- TransWest Express Transmission Line will tie site into WY and Las Vegas

## H<sub>2</sub> Infrastructure to Decarbonize “Hard to Electrify” Verticals

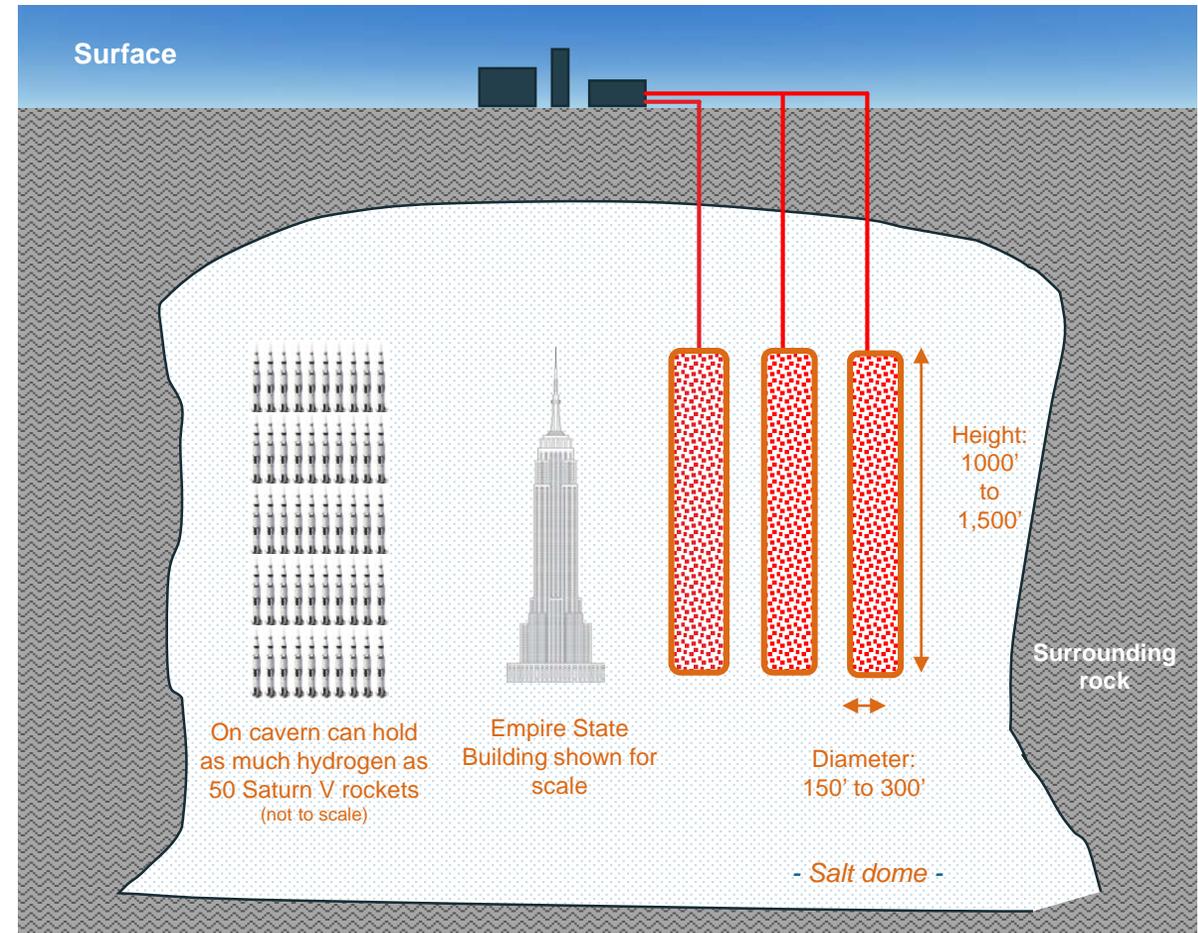
- Transportation (Heavy Duty/Long Haul Vehicles, Rail, Aircraft, Maritime)
- Datacenters
- Military
- Industrial and Manufacturing
- Ammonia and Derivatives
- Pipeline Injection
- Shipping and Exports (including to Asia)

# Integrated Green Hydrogen Energy Storage System



# The Advanced Clean Energy Storage Site in Utah is Unique

- Salt domes are unique geological structures which provide an economic form of bulk storage
- There are over 400 such sites in the US where oil, natural gas, helium and hydrogen is stored
- Caverns once created can easily be expanded by injecting water
- Site can support 100 caverns
- 5 caverns have already been successfully created and are in operation storing liquid fuels



# Existing Hydrogen Salt Caverns in US



**Clemens Dome  
(ConocoPhillips)**

**Moss Bluff  
(Praxair)**

**Spindletop  
(Air Liquide)**

## Combining Over 50 Years Safe Operations

	<b>Clemens Dome*</b>	<b>Moss Bluff</b>	<b>Spindletop</b>
<b>Salt Formation</b>	Salt Dome	Salt Dome	Salt Dome
<b>Operator</b>	Chevron Phillips	Praxair	Air Liquide
<b>Commissioned</b>	1986	2007	2016
<b>Amount of H2/t</b>	2,400	3,690	8,230

\* Praxair & Phillips 66 developing 8 BCF Cavern at Clemens Dome



**1,600 miles of Privately  
Operated Hydrogen  
Pipelines currently in  
operation across the U.S**

100% Hydrogen Fuel =  
**Zero CO<sub>2</sub> Emissions**

Based on Proven and  
Commercially Deployed Technologies

Over  
**3.5 MILLION**  
hours of H<sub>2</sub> turbine operation

First H<sub>2</sub> pipelines  
**1930's**

Large-scale electrolysis  
systems since  
**1940's**

First H<sub>2</sub> storage in salt caverns  
**1980's**



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**MITSUBISHI  
HEAVY  
INDUSTRIES  
GROUP**