MITSUBISHI POWER

WHY THE WESTERN U.S. NEEDS ENERGY STORAGE

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INTRODUCTION

California experienced record curtailment of renewable power in the Spring of 2020, but when an exceptional heat wave struck the Western United States in mid-August 2020, power supply did not meet demand, triggering two rolling power blackout events across California.

Described in a preliminary root cause report by the California Independent System Operator as a "heat storm", the event shone a spotlight on the growing imperative of storing renewable-power when it is in over-supply, to be used when power is in short supply.

This whitepaper highlights recent significant electric power challenges facing Western states, outlines existing energy storage alternatives and presents a plan to use large deployment of Li-ion Battery Energy Storage for short duration needs and "green" hydrogen for long duration storage.

THE PUSH TO DECARBONIZE

As the power grid evolves in response to climate change, the risks faced by electric power utilities and millions of customers are increasingly evident, perhaps nowhere more so than across the Western United States. There, a combination of drought, hotter summers, extended wildefire seasons and increased use of intermittent renewable resources pose a heightened threat to reliable electric power delivery to some of the most populated and economically critical parts of the country.

With climate scientists predicting even more frequent and severe weather events, policymakers in several Western states-including California, Washington, New Mexico, Nevada and Colorado-are adopting measures designed to achieve deep decarbonization while also ensuring resource adequacy throughout the year, including during challenging weather conditions.

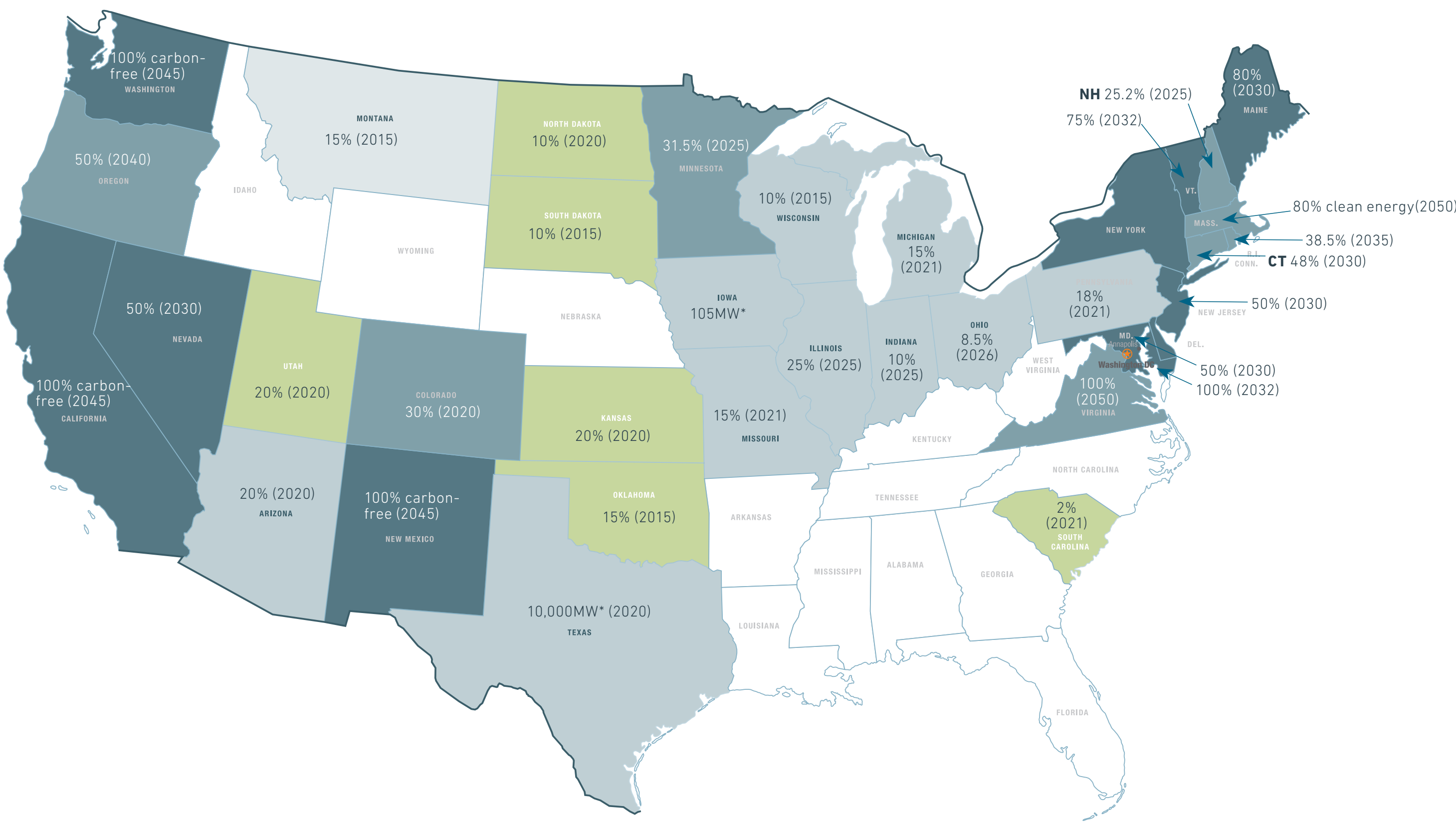


Figure 1: RPS targets in US
(S&P Global Market Intelligence

HEAT STORM AND BLACKOUT

Recent events highlight the growing imperative to move to decarbonized, electric power generating resources across the Western U.S.

FROM AUGUST 14-19, 2020, THE WESTERN UNITED STATES EXPERIENCED AN EXTREME HEAT STORM, WITH TEMPERATURES ANYWHERE FROM

10-20 DEGREES

ABOVE NORMAL

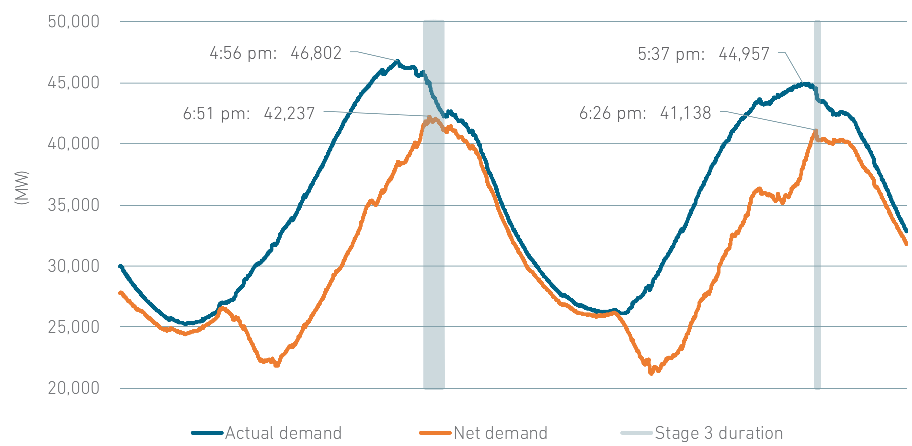


Figure 2: Net demand and blackout on August 14, 15 (source: CAISO)

As explained by the California Independent System Operator (CAISO) in a preliminary root cause analysis of the grid's performance, extreme heat affects both the demand for and the supply of electricity. During normal summer weather conditions in California, high daytime temperatures are offset by cool and dry evenings. However, during extreme heat events, hot temperatures persist into the evening and overnight hours, air conditioners continue to run and electricity demand climbs well beyond normal levels.

Faced with these converging conditions and with reserves falling below required minimums, officials at CAISO declared a Stage 3 Emergency on August 14. To comply with mandatory resource adequacy standards, they initiated rotating outages (also called load-shedding) on the evening of August 14, for the first time since 2001.

THIS AFFECTED NEARLY

500,000 CUSTOMERS

FOR ANYWHERE FROM 15 TO 150 MINUTES.

The following day, CAISO officials declared a second Stage 3 Emergency.

THIS TIME, ROTATING OUTAGES AFFECTED

321,000 CUSTOMERS

FOR ANYWHERE FROM 8 TO 90 MINUTES.

In its preliminary analysis report, CAISO found that many required resources did not, or were unable to, deliver electrical energy. Everything from conventional power plants to renewables and imports from outside of the state fell short as California struggled to cope with the effects of this extreme weather event.

The emergency occurred as the state is in the process of moving to a decarbonized future, which includes replacing conventional generating resources with carbon free and renewable sources. For example, California Executive Order B-55-18 called on the state to achieve carbon neutrality by 2045.

The California State Assembly later passed SB 100, which requires the state to meet 100 percent of retail sales with zero-carbon electricity by that same year.

Large amounts of simple-cycle and combined-cycle generating units have at least 10 hours a day between start and shutdown in a year to support California's growing volume of intermittent renewable energy resources.

AND THE STATE'S GOAL TO RETIRE

3,200 MEGAWATTS (MW)

OF NATURAL GAS GENERATING CAPACITY WILL REQUIRE CREATIVE SOLUTIONS SUCH AS LONG-DURATION STORAGE TO INCREASE PEAK DEMAND RELIABILITY.

Most of the natural gas power plants in California experience times during the year when they are required to operate for long periods of time. If natural gas power is going to be reduced over time, a combination of short duration energy storage and long duration energy storage will be required to meet resource adequacy requirements while increasing use of wind and solar energy

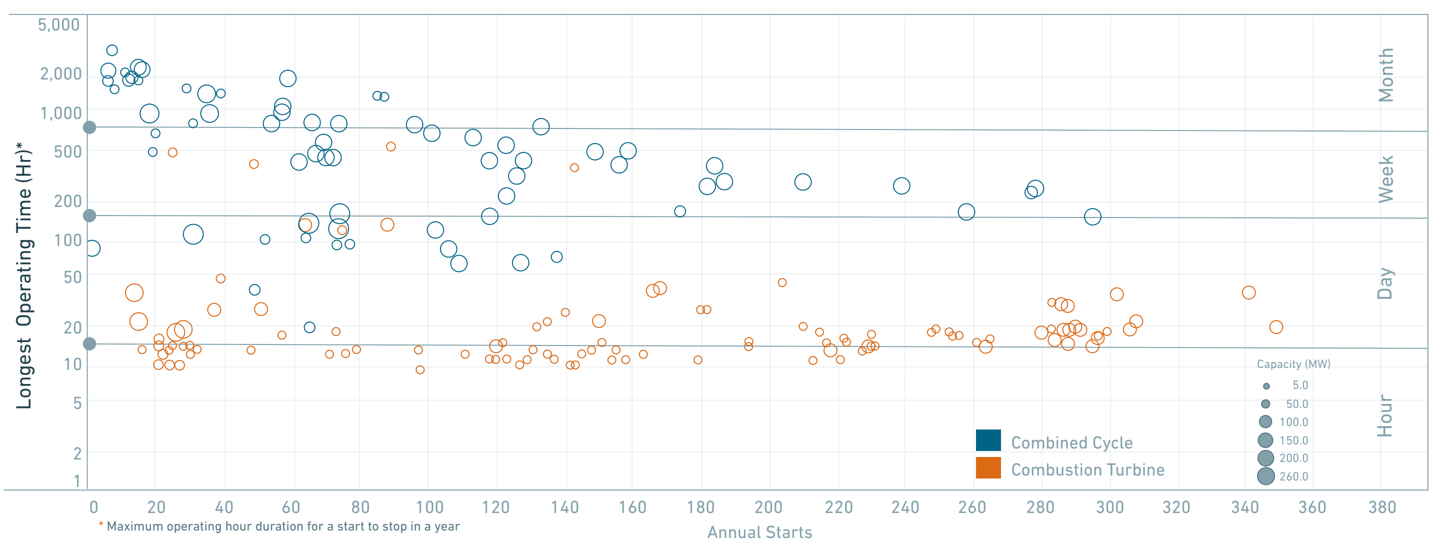


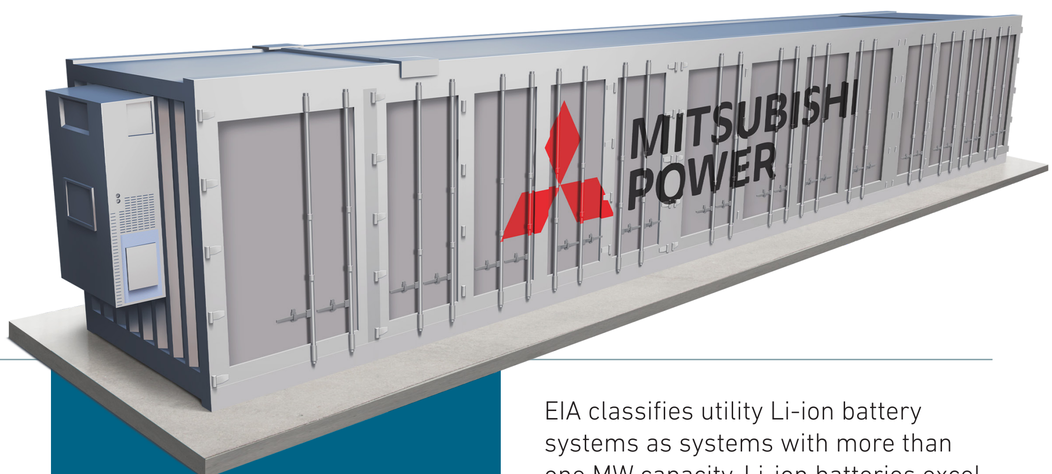
Figure 3: Natural gas replacement by batteries alone will not be sufficient (Source: Mitsubishi's analysis of all CA plant operation 2015-2019)

ENERGY STORAGE ALTERNATIVES: AN OVERVIEW

Storage Technology	Typical Size Range	Typical Storage Duration	Efficiency	Lifetime	Largest Project in US
Battery (Lithium-ion)	100 MW	4h-8h	85-95%	1000-10000 cycles	Moss Landing Energy Storage Facility, CA
Pumped storage hydro	10-3000 MW	4h-16h	70-85%	30-60 years	Bath County Pumped Storage Station, VA
Hydrogen Project	100 MW – several GW	hours-months	35-45%	30-50 years	Advanced Clean Energy Storage, UT

ENERGY STORAGE IS A KEY PATHWAY TO DECARBONIZATION BY STORING EXCESS ENERGY FOR LATER USE, WHETHER IT IS MINUTES, DAYS, WEEKS, MONTHS OR EVEN SEASONS.

Of course, the type of energy storage needed depends on many factors. Three leading technologies for energy storage are battery storage for short durations, pumped hydro for intermediate durations, and green hydrogen for longer duration storage. Each technology has a place in the energy mix.



BATTERY STORAGE

Battery storage has enabled more renewables to come online. The most common types of battery chemistry are Lithium-ion (Li-ion), nickel-based, sodium-based, lead acid and flow battery.

OVER 90%

OF UTILITY-SCALE BATTERY STORAGE POWER CAPACITY IN THE UNITED STATES WAS PROVIDED BY BATTERIES BASED ON LITHIUM-ION CHEMISTRIES.

EIA classifies utility Li-ion battery systems as systems with more than one MW capacity. Li-ion batteries excel at storing energy for short periods of time and providing instantaneous power. However, these batteries are limited by discharge duration and cannot efficiently and economically store energy for longer periods of time.

According to IHS Markit, 4-hour lithium-ion battery costs have declined 42% since 2016, primarily due to cost decline in the battery module. As the battery cost comes down, Li-ion batteries are becoming very cost-effective for short duration or diurnal storage. The batteries are often paired with renewable to smooth out generation and firm-up renewable capacity.

PUMPED HYDRO

Pumped storage is a proven technology and has been used in the United States since the 1920s. Pumped storage systems are four to 16 hour storage with approximately 60 years of life and an operational efficiency between 70 and 85 percent.

Much of this pumped storage is in vast reservoirs that typically are sited in remote areas far from load centers.

Few new hydroelectric pumped storage facilities have been built since the turn of the century. Indeed, EIA said that since 2003, installation of new large-scale energy storage facilities has been almost exclusively electrochemical, or battery energy storage.

UNDERSTANDING HYDROGEN

AT PRESENT, MOST HYDROGEN **(ANYWHERE FROM**

96% TO 99%)

is produced from natural gas or other hydrocarbon fuels. Energy is applied to separate the hydrogen from other elements.

Hydrogen, an increasingly viable, energy storage medium whose vast abundance makes it a practically inexhaustible resource for applications that include transportation and electric power generation.

Hydrogen that is derived through the use of hydrocarbons is called "gray" hydrogen and its production generates significant carbon emissions. This makes gray hydrogen ill-suited as a source of zero-emission electric power generation in places like California and elsewhere across the West.

By contrast, "green" hydrogen is produced using renewable energy resources to split water into hydrogen and oxygen. The method to do this is called "electrolysis," and uses the energy from an electric current to split water into its elemental components, oxygen and hydrogen (hence, the familiar chemical formula $H2_0$). Green hydrogen excels at storing energy for days, weeks, months or seasons.

According to the Green Hydrogen Coalition, electrolysis cells may readily be stacked and used for commercial green hydrogen production when connected to wind farms, solar plants or other renewable electricity sources. Electrolyzers interconnect to the grid in much the same way as solar or energy storage systems, with inverters. They operate with a fast response time and can provide flexible load to the grid, including important ancillary services such as voltage support and frequency regulation.

Gray and blue hydrogen provide storage of fossil fuel energy. Only green hydrogen can store renewable energy.

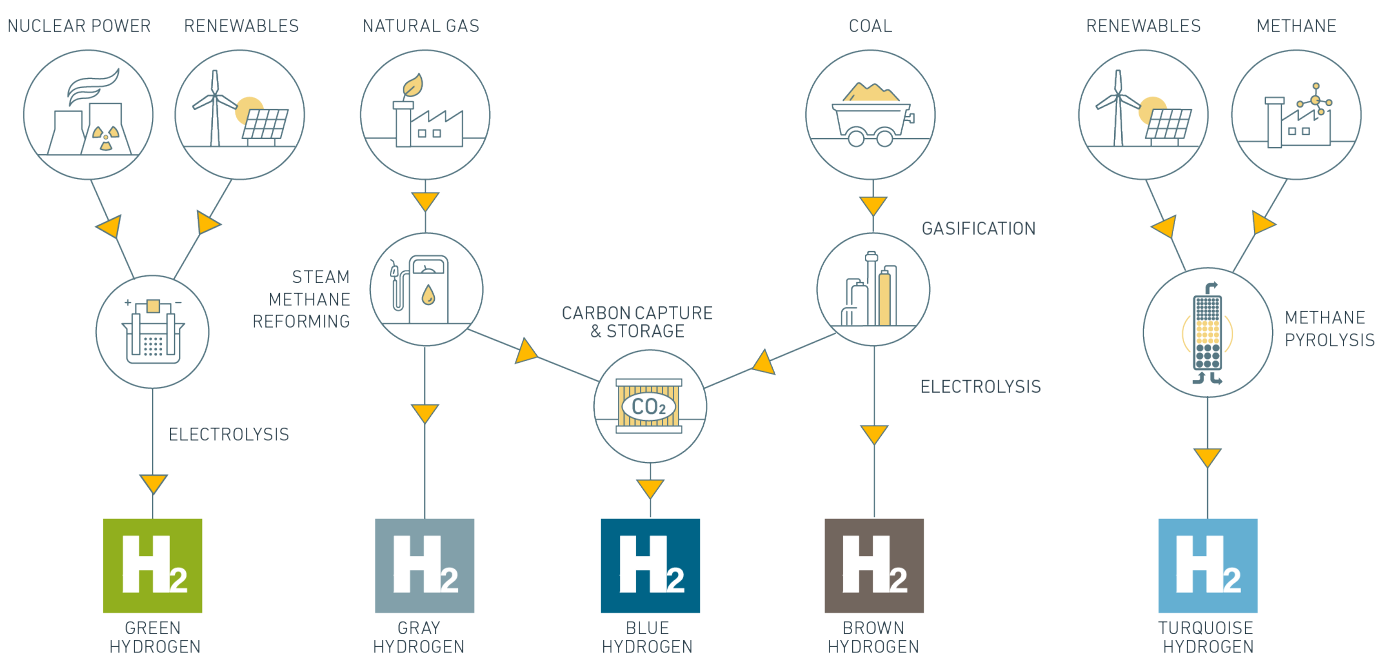


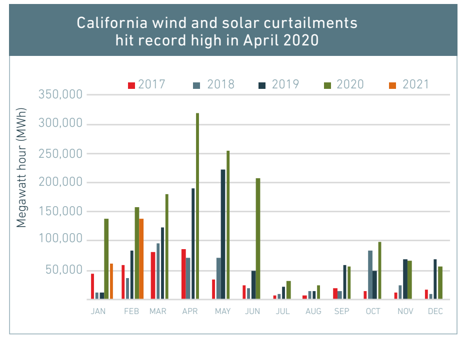
Figure 5: Types of Hydrogen
(source: RFF)

THE GREEN HYDROGEN SOLUTION

The convergence of decarbonization goals, increasing penetration of renewable energy resources and the threat of extreme weather events such as the August heat storm, all favor the deployment of a green hydrogen solution as a long-duration energy storage medium to maintain system reliability while enabling greater renewable resource penetration.

Green hydrogen can be cost effectively stored for days, weeks, even seasons and provide much needed energy arbitrage that future heavy renewable grids will need. The grid of the future will be moving "beyond the duck curve" which today only focuses on intra-daily imbalances of energy. Green hydrogen makes it possible to support the inter-daily, weekly and seasonal imbalances we already see today. This dynamic is continuing to unfold and as more renewables come online, will become even more prominent issue as shown in Figure 6.

Green hydrogen excels as a long duration storage technology and when doing a cost comparison, should be compared to other forms of long duration energy storage. When doing so, green hydrogen becomes the lowest cost option available.



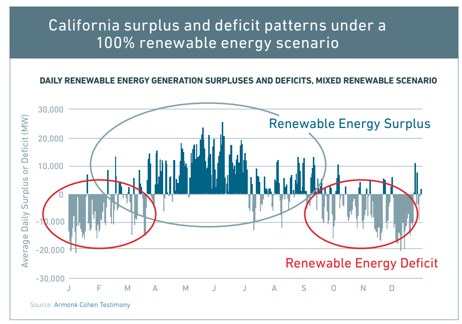


Figure 6: Curtailment and surplus in California

MITSUBISHI POWER ALREADY HAS DEEP EXPERTISE IN HYDROGEN COMBUSTION TECHNOLOGY

WITH MORE THAN

3.5 MILLION HOURS

OF EXPERIENCE CO-FIRING HYDROGEN IN MORE THAN TWO DOZEN FACILITIES SINCE THE EARLY 1970S.

THE COMPANY ALSO RECENTLY ANNOUNCED ITS FIRST **100%** CLEAN ENERGY PROJECT WITH THE INTERMOUNTAIN POWER AGENCY AT THE INTERMOUNTAIN POWER PLANT (IPP) IN DELTA, UTAH.

A GIANT LEAP FORWARD

The IPP Renewal project will replace existing coal-fired units with 840 MW of blended natural gas and hydrogen power generation to customers that include the Los Angeles Department of Water and Power and municipalities across both California and Utah.

TWO M501JAC POWER TRAINS WILL INITIALLY USE A MIX OF

30% HYDROGEN AND

70% NATURAL GAS AS FUEL FOR POWER GENERATION BY 2025

This blend will cut carbon emissions by more than 75% compared to the retiring coal-fired boilers. Then no later than 2045, the power plant's capability will rise to 100% hydrogen, reducing carbon emissions entirely.

An important energy storage component integral to the facility is the Advanced Clean Energy Storage project, adjacent to IPP, which will produce green hydrogen on a massive scale. This project, jointly developed by Mitsubishi Power and Magnum Development, will store 150 gigawatt-hours (GWh) of renewable energy in an underground salt cavern as part of the first phase of the project. There is enough room for an additional 99 salt caverns for future phases. The relatively low cost of hydrogen storage in geologic formations will allow large amounts of energy to be stored at low cost.

This will be particularly useful in providing firm zero-carbon electricity during multiday periods with low wind and solar power generation for future phases.

OPERATIONAL COST OF HYDROGEN AND NATURAL GAS BLENDED IN TURBINES

In the early years, blending higher concentrations of natural gas with hydrogen offsets the higher cost of hydrogen keeping operating costs low.

Over time, as more renewables are added to the grid and electrolyzer capital costs improve, the cost of green hydrogen will significantly decrease.

Thus the gas turbine can capture these costs downs by blending increasing amounts of hydrogen, decreasing natural gas use, and ultimately keep operating costs flat or declining without adding additional hardware.

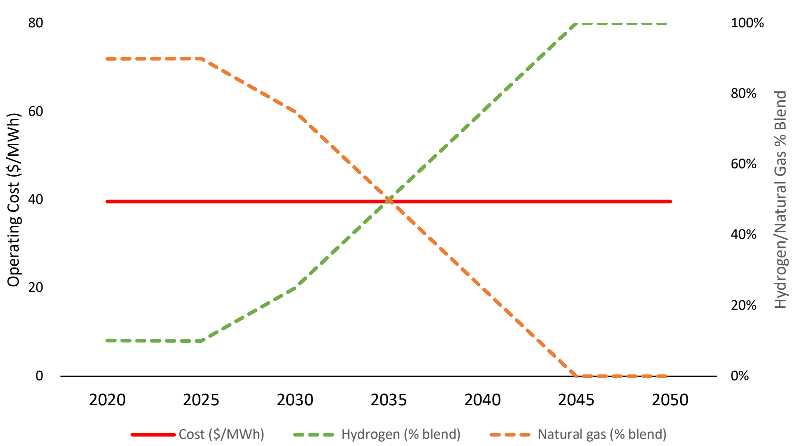


Figure 7: Operational cost of gas turbine with hydrogen and natural gas blend

EVENTUALLY AT

100% HYDROGEN

UTILIZATION, FORECASTS SHOW THE OPERATING COSTS OF SUCH A UNIT CAN BE LESS THAN OR EQUAL TO

$40/MWH.

CONCLUSION

Both short- and long-duration energy storage are critical components to reaching the ambitious climate goals set in several Western states. Green hydrogen is an increasingly viable energy storage medium whose vast abundance makes it well suited to decarbonize the power sector. Green hydrogen excels as a long duration storage technology and when compared to other forms of long duration energy storage, green hydrogen becomes the most cost effective option available today. The Intermountain, Power Plant and the Advanced Clean Energy Storage project is the first step in creating the necessary infrastructure to scale hydrogen production and storage to accelerate the pace of decarbonization.

MITSUBISHI POWER

Mitsubishi Power Americas, Inc.
amer.power.mhi.com
407-688-6800