RELIABILITY ANALYSIS

JULY 2023

THE EVOLUTION OF

CLEAN FUELS

IN CALIFORNIA

SoCalGas™

Recap of Clean Fuels Study

The question facing California is: What are some of the best options for reaching carbon neutrality? In October 2021, SoCalGas published the Clean Fuels Study (CFS), an analysis to find possible solutions for California to achieve clean, reliable, and affordable energy to ultimately support a carbon neutral economy by 2045.[1] The CFS explored four scenarios that could meet California's 2045 net zero emissions target and offered detailed solutions that considered the complexity of achieving carbon neutrality. The CFS found that the most feasible and affordable pathways to net zero allow for diverse decarbonization tools, including clean fuels and carbon management. Clean fuels are defined in this analysis as alternative fuels that have a net zero carbon footprint.[2] Hydrogen, biogas, synthetic natural gas (syngas), biofuels and several synthetic gaseous and liquid fuels fall in that category as long as their production process and their end use do not lead to net-positive CO_2 emissions. Clean fuels can complement electrification efforts by providing possible solutions for hard-to-abate activities and electric sector reliability.[3] This Reliability Analysis expands on the CFS scenarios to understand how each electric portfolio might evolve if required to meet reliability constraints.

ASSUMPTIONS AND METHODOLOGY

The CFS relied on detailed decarbonization modeling that integrated demand-side end-use accounting and supply-side capacity expansion modeling, similar to the modeling done to support other California decarbonization studies, including those conducted by the California Air Resources Board (CARB) and the California Energy Commission (CEC). All scenarios combined user-defined demand-side assumptions with cost optimized supply-side resource decisions to model economy-wide carbon neutrality by 2045.[4] The CFS also included a unique clean fuels infrastructure analysis layered on top of the decarbonization analysis to determine the costs associated with different potential configurations of a clean fuels network. The scenarios examined different decarbonization tools by testing different demand-side assumptions, like electric appliance adoption, and different supply-side constraints, like hydrogen pipeline blending limits or carbon sequestration.

SCENARIO DESCRIPTIONS

Resilient Electrification

Significant electrification of buildings and vehicles supported by low level of clean fuels, with carbon management

High Clean Fuels

Moderate electrification of buildings and vehicles supported by a high level of clean fuels, but no sequestration

High Carbon Sequestration

Moderate electrification of buildings and vehicles supported by a high level of carbon management but a low level of clean fuels

No Clean Fuels

Significant electrification of buildings and vehicles with no support from either clean fuels or carbon management

1 To learn more about SoCalGas' 2021 Clean Fuels Study, visit: socalgas.com/cleanfuels

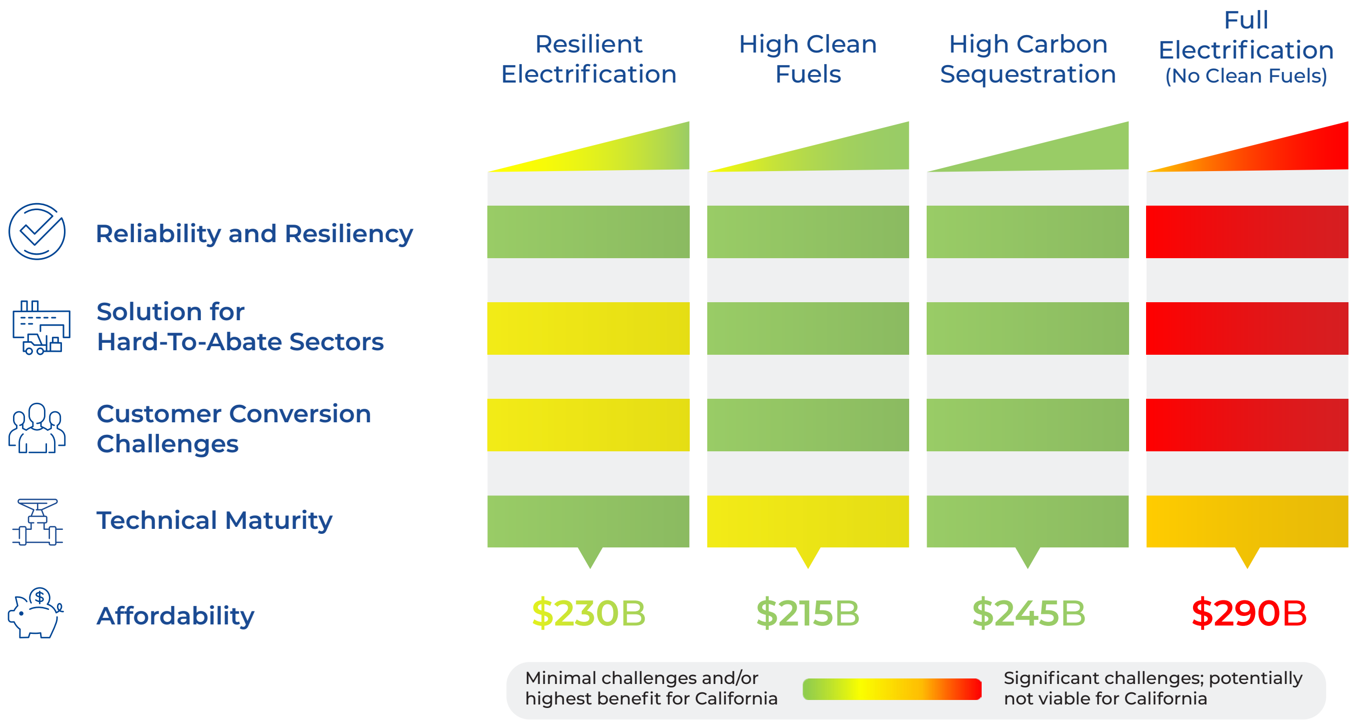
2 For the purposes of this study, "clean" is defined in this analysis as alternative fuels and/or carbon management resulting in a net zero carbon footprint. The term is not intended to suggest or imply any other environmental attribute of the fuels. References to and use of the word "clean hydrogen" in this study refer to net zero emissions hydrogen; green or blue whereby carbon emissions are captured and stored. The study's authors recognize that this definition could differ from the definitions used for "clean hydrogen" by the Department of Energy and the State of California. For the purposes of this study, "clean renewable hydrogen" is defined as green hydrogen, which is commonly understood to be hydrogen produced through electrolysis using renewable energy.

3 "Hard-to-abate sectors" of the economy, which includes heavy-duty transportation (trucking, long-haul aviation, maritime shipping) and industrial sectors, are areas in which electrification is challenged to meet the sector's needs.

4 These scenarios are designed to highlight distinctions and to test end-points for key variables. Pushing key variables to their end-points allows the model to identify and understand the impacts of and trade-offs across those variables.

Recap of Clean Fuels Study

CLEAN FUELS STUDY RESULTS



The scenarios that advance decarbonization that most successfully attain the metrics above combine the strengths of renewables, clean fuels and electrification. A clean fuels network supports:

- » System Reliability and Resiliency: Provides flexible, dispatchable power at times when renewables are unavailable.
- » Solution for Hard-to-Abate Sectors: Addresses areas that are difficult to decarbonize, like heavy-duty transportation, industrial activities, and dispatchable generation.
- » Customer Conversion Challenges: Fuel switching from natural gas appliances to electric and/or hydrogen equipment may require changes to many customers' homes and businesses. Managing this conversion is one of the most substantial implementation challenges associated with net zero efforts. A clean fuels network may provide the carbon neutral or carbon negative fuels that customers require where electrification may be challenging or inequitable to implement.
- » Technical Maturity: A diverse set of decarbonization levers reduces the risks of overdependence on any one technology.
- » Affordability: Without a clean fuels network, a larger and more expensive buildout of renewables and storage may be needed.

Reliability Analysis Findings

Expanding on the CFS scenarios, this Reliability Analysis investigates the potential evolution of each electric portfolio in response to reliability constraints.[5] SoCalGas found that up to 10 gigawatts (GW) of additional clean renewable hydrogen generation could be needed in the CFS electric portfolios for reliability purposes. **The incremental clean renewable hydrogen generation could increase the amount of fuel based generation capacity by up to 35% by 2045.**[6,7]

This Reliability Analysis reinforces and expands on key takeaways from the CFS, such as what electric resources could be needed to maintain electric grid reliability as California progresses towards net zero emissions by 2045. While the CFS highlighted the benefits of energy diversity at the macro level, **the modeling results underscored the reliability benefits of electric resource diversity and the value of clean renewable hydrogen generation.** Dispatchable generation powered by clean fuels, like hydrogen, may rely on supporting infrastructure like transportation and storage. As demand for clean fuels grows, efficiencies gained by increasing infrastructure utilization and falling marginal production costs for clean fuels could benefit multiple areas of the economy.[8] California should accelerate clean fuels infrastructure deployment to enable access to clean fuels for customers, including hard-to-abate sectors.

CLEAN FUELS STUDY

Combining the strengths of renewable electricity and clean fuels can be the most affordable and resilient path to net zero

Infrastructure that transports clean fuels and captured carbon could become essential for affordably meeting California's climate goals

RELIABILITY ANALYSIS

Resource diversity and dispatchable generation powered by clean fuels could be vital for electric reliability

Clean fuels investments to support the electric sector can catalyze clean fuels adoption in hard-to-abate areas

Stakeholders must act faster and with greater collaboration to expand and accelerate the deployment of decarbonization tools, including the clean fuels initiatives already underway.

5 To learn more about SoCalGas' 2021 Clean Fuels Study, visit: socalgas.com/cleanfuels

6 The term "fuel based generation" in this study refers to combustion generation that may be fueled by natural gas, renewable natural gas, synthetic gas, hydrogen, clean hydrogen, or clean renewable hydrogen. In this analysis, fuel based generation is referred to as "clean" when fueled by clean fuels and "clean renewable" when fueled by clean renewable hydrogen (see footnote 2).

7 CFS portfolio gas plant capacity is discussed in the 2021 Clean Fuels Study (pg. 32-33) and the Technical Appendix (pg. 11).

8 Bloomberg New Energy Finance, "Hydrogen Economy Outlook," p. 4, March 2020, available at: https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf.

Context

This Reliability Analysis examined the Clean Fuels Study electric portfolios and stress tested for reliability.

This Reliability Analysis utilizes the electric demand-side assumptions of the CFS scenarios, including high levels of building electrification. This Reliability Analysis performs a more granular electric system reliability assessment of the CFS electric supply portfolios, and further illuminates electric system reliability needs. This more granular assessment provides critical insight into reliability impacts and potential reliability deficiencies not previously reflected in the CFS.

This Reliability Analysis provides directional results that explore potential electric system attributes that could be needed under potential net zero futures.

This Reliability Analysis is directional in nature to assess a decarbonization challenge: how to provide a reliable and resilient electric system while electrification increases demand and intermittent renewables make up a larger proportion of electric supply resources.[9] This supplemental analysis provides new insight into how California may be able to achieve net zero emissions by 2045 while providing reliable electric service as electric demand grows.

	CLEAN FUELS STUDY	RELIABILITY ANALYSIS
SYSTEM RELIABILITY & RESILIENCY [10,11]	Energy system reliability provided through dual fuel service and backup power Electric system reliability evaluated with a high-level reliability screen	Leverages CFS assumptions and tests the reliability of the electric system Electric generation portfolios created in the CFS are stress tested using industry standard approach (NERC standards)[12]
SOLUTION FOR HARD-TO-ABATE SECTORS	Proposes various decarbonization tools to help reduce emissions in hard-to-abate sectors, like industry, heavy-duty transportation, and dispatchable electric generation	Focuses on understanding the future need for dispatchable electric generation under the CFS scenario assumptions
CUSTOMER CONVERSION CHALLENGES	Scenarios assume varying levels of electrification in the building and medium-duty/heavy-duty transportation sectors	Maintains electric demand assumptions from the CFS scenarios and studies how to reliably serve electric load

Modeling results from this Reliability Analysis indicate that the electric resource portfolios developed in the Clean Fuels Study would require greater levels of clean, firm dispatchable generation to meet current reliability standards.

Each of the CFS scenarios required a more diverse resource portfolio to reliably serve the range of electric demand anticipated in the CFS. While the State's actual resource procurement decisions will be influenced by technology developments and policy considerations, this Reliability Analysis identifies electric system attributes that likely demonstrate the need for clean, dispatchable generation to support a reliable electric grid in a net zero future.

9 Black & Veatch collaborated with SoCalGas and performed the Reliability Analysis modeling.

10 Reliability refers to the system operating under normal conditions. Resiliency is the system's ability to resume normal operations quickly and minimize system outages from unforeseen events such as wildfires, high winds, or unexpected and significant constraints on energy supply.

11 Stemming from the CFS, this Reliability Analysis is based on numerous assumptions extending over decades and thus is not intended to be used in or apply to any existing, pending, or future proceedings or applications.

12 NERC, the North American Electric Reliability Corporation, develops and enforces electric reliability standards.

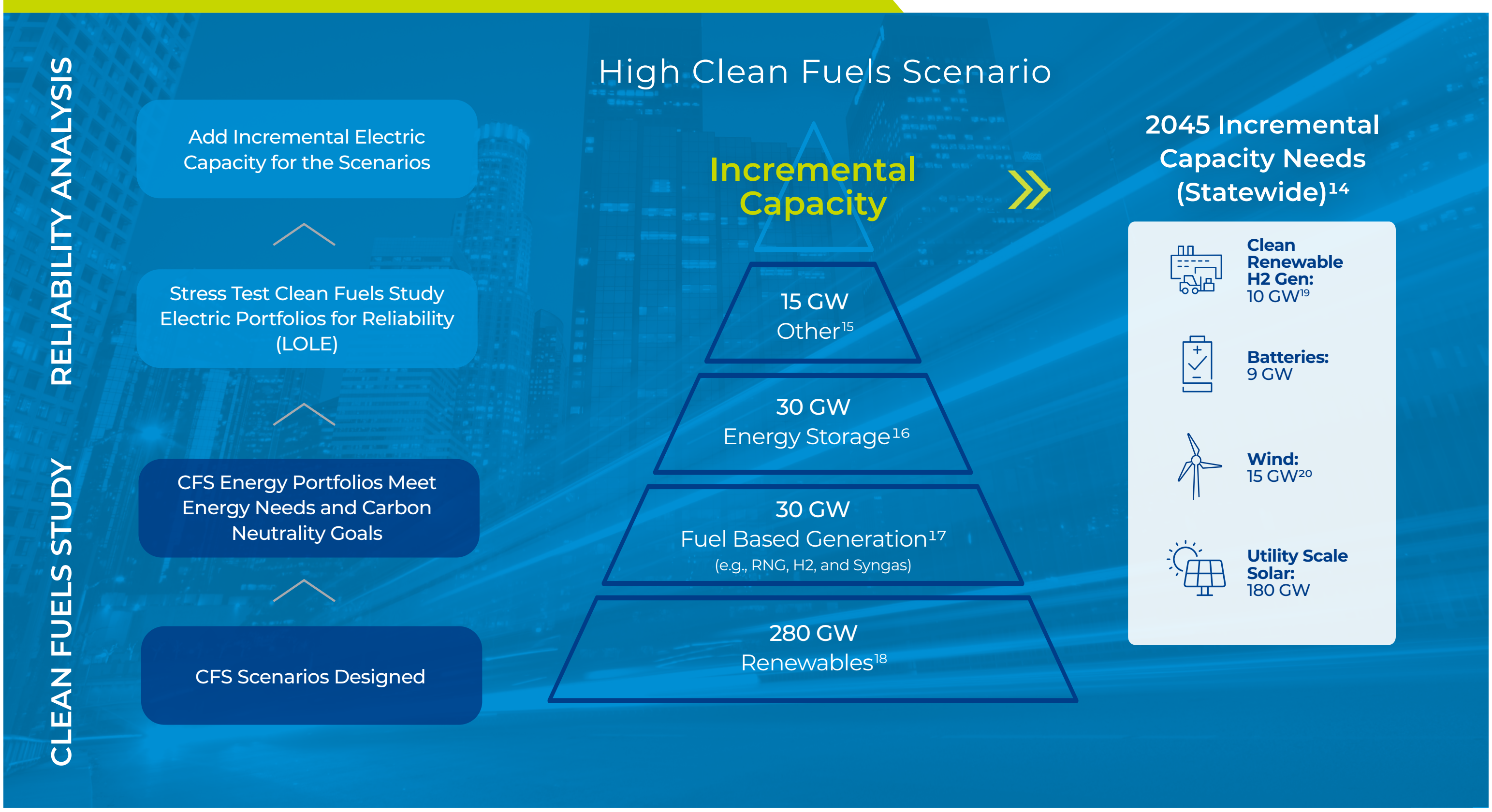
Reliability Analysis Summary

As many decarbonization pathways depend on a reliable electric grid, more robust reliability modeling is becoming a necessity for economy-wide decarbonization studies. This Reliability Analysis included a stress test on the CFS portfolios for electric reliability under NERC standards for Loss of Load Expectation (LOLE). LOLE analysis is an electricity industry standard approach that assesses reliability at a more granular level by evaluating every hour in a year to determine the potential for an electric system outage.[13] Modeling reliability at the hourly level leads to more robust results, improving insight into portfolio design.

This more granular analysis revealed that each CFS scenario required additional generation capacity, incremental to the electric portfolios designed in the CFS, to avoid electric system outages. The addition of clean renewable hydrogen generation was a potential solution and complemented incremental renewables and batteries, so that the CFS electric portfolios met the required reliability standard.

This Reliability Analysis shows that resource diversity with an enhanced role for clean fuels could deliver a more reliable electric portfolio.

Designing a Reliable Electric Portfolio for Net Zero



13 The Plexos model was used for reliability testing. NERC requires reliable electric portfolios to meet a threshold of 0.1, or a maximum of 1 day in 10 years where the generation capacity is less than the system load (i.e., outage).

14 Incremental capacity needs may represent an addition to or acceleration of capacity installations in the CFS portfolios.

15 Other includes resources like hydro and nuclear and makes up ~5% of the original CFS portfolios.

16 Energy Storage includes batteries and pumped hydro and makes up 5%-15% of the original CFS portfolios.

17 “Fuel based generation” makes up 5%-15% of the original CFS portfolios.

18 Renewables includes wind, utility-scale solar, and rooftop solar and make up 65%-80% of the original CFS portfolios. Original CFS portfolios include up to 10 GW of offshore wind.

19 For the purpose of this Reliability Analysis, “Clean Renewable H2 Gen” is combustible generation fueled by clean renewable hydrogen.

20 The directive set forth by Assembly Bill 525 (AB 525, Chiu, Chapter 231, Statutes of 2021) directed the California Energy Commission (CEC) to provide a preliminary assessment of the economic benefits of offshore wind as these potential benefits relate to seaport investments and workforce development needs and standards. The report established offshore wind energy planning goals of 2-5 GW by 2030 and 25 GW by 2045. While offshore wind may impact hydrogen demand across the State, this Reliability Analysis did not assess how the offshore wind energy planning goals could impact local and regional reliability. Incremental wind capacity by 2045 could potentially be satisfied by offshore wind.

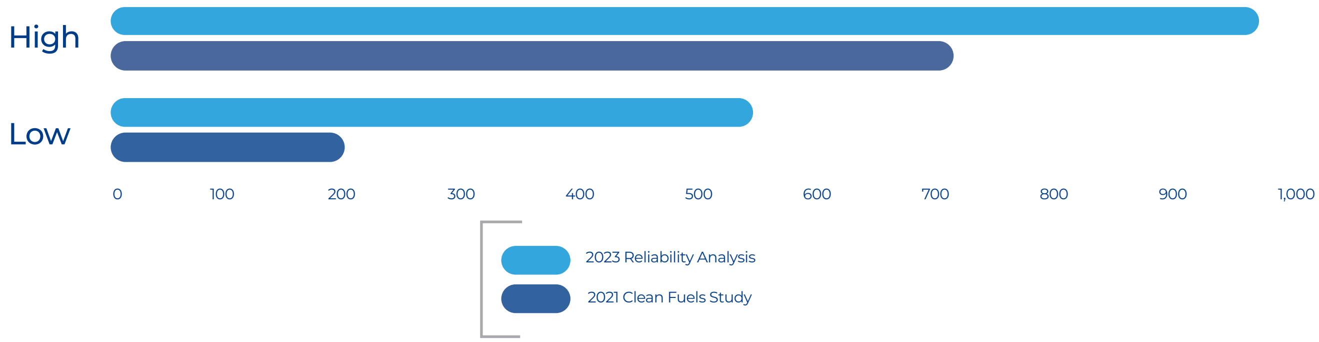
CLEAN FUELS STUDY SCENARIOS

Planning for Reliability

2045: Clean Fuels Can Play an Essential Role for Reliability

In the CFS, clean hydrogen demand primarily served end uses like fuel cell vehicles, heavy-duty transportation, and industrial activities. However, this Reliability Analysis indicates that to provide reliable electric service the State may require more clean, firm generation, and likely more clean hydrogen, than the 2021 Clean Fuels Study suggested.

Economy-wide Clean Hydrogen Demand Across CFS Scenarios (Tbtu, 2045)



In addition to supporting grid balancing and reliability, clean fuels, and especially hydrogen, is shown to be essential for serving hard-to-abate sectors. Electric sector demand for clean fuels can catalyze adoption in other sectors by contributing to the build-out of shared clean fuels infrastructure. Clean hydrogen pathways can support emission reductions for:

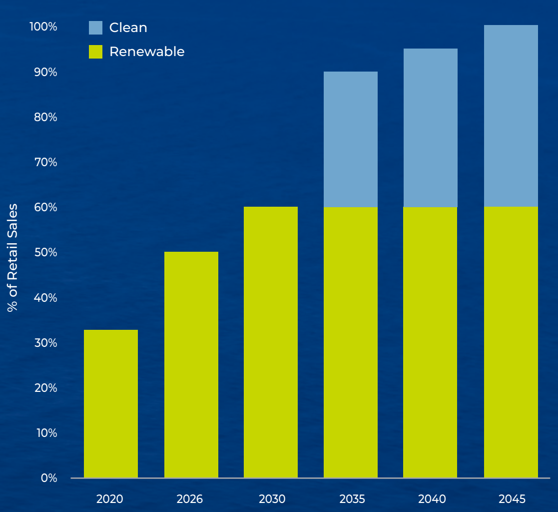
Electric Generation | **Industry** | **Heavy-Duty Transportation** | **Aviation** | **Ports + Ocean-Going Vessels**

Renewable generation combined with clean, dispatchable, fuel based generation could enable deep decarbonization while preserving reliability.

In September 2022, SB1020 accelerated California's electric grid decarbonization goals established in SB100, targeting 60% renewable and 30% zero carbon electricity by 2035. It is imperative that the State plan for a diverse portfolio to balance growing renewable generation.

Prioritizing the development of clean, flexible resources like hydrogen generation could advance the State's electric sector decarbonization goals while maintaining a reliable electric system.[21]

ELECTRIC GENERATION TARGETS



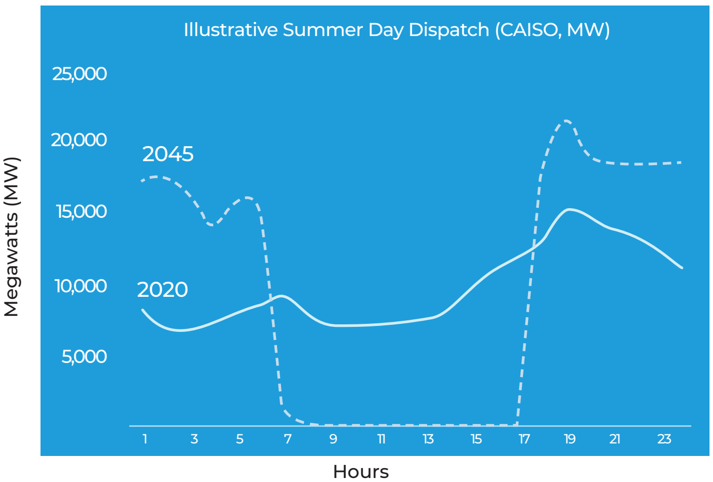
21 According to CAISO, flexible resources "can ramp up and ramp down quickly as needed, potentially starting up and shutting down multiple times per day - natural gas combined cycle plants and some energy storage devices, for example. These flexible resources will be necessary to help smooth the variability of wind and solar power" (2014, CAISO's Flexible Capacity Proposal Approved by FERC, https://sustainableferc.org/caisos-flexible-capacity-proposal-approved-by-ferc/)

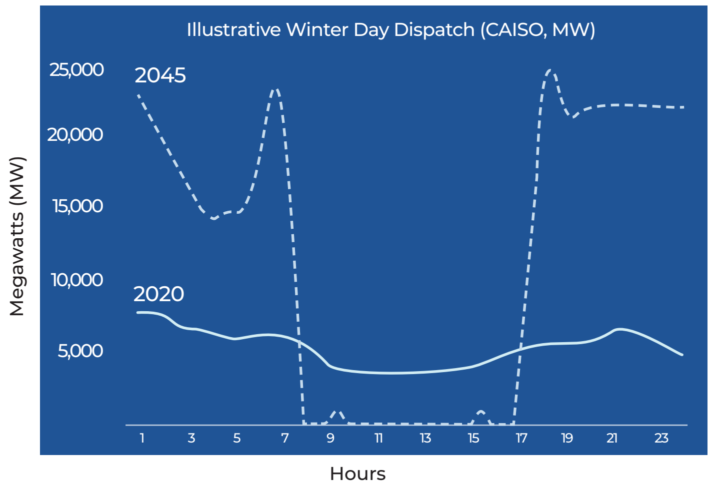
Planning for Reliability

2045: Clean Fuels Can Play an Essential Role for Reliability

Today, natural gas plants are the primary source of fuel based generation and are a critical resource for system balancing and ensuring electric reliability in California.[22] By 2045, fuel based generation could include plants that use fuels like clean renewable hydrogen, renewable gas, and synthetic gas. These plants will likely be an essential component of the State's resource mix and an integral tool in meeting the State's decarbonization goals.

2045: Fuel Based Generation





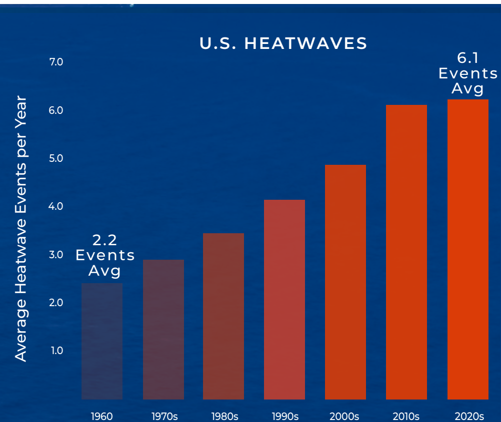
In the future, clean, dispatchable, and flexible generation could be critical for reliability.

In 2020, fuel based generation dispatch patterns were largely dictated by the availability of renewables and the need for load following resources. By 2045, a variety of factors could influence how grid needs are met, but electricity generation from clean hydrogen could help address that need, particularly if the U.S. Department of Energy's Earthshot goals are met, assuming the necessary infrastructure is built.[23]

In 2045, renewable energy will be a key part of California's clean energy future, even during the winter. The illustrative winter day dispatch graph further highlights the need to better plan for the grid's net demand peak during the winter season. While the electric system continues to peak in summer, increased electrification may present new challenges for the grid, and high renewable portfolios may need to contend with an increasing peak that may be challenged due to low renewable production in winter, underscoring the value of seasonal long-duration storage that fuels can provide.

The frequency and duration of heatwave events have increased across the U.S. Compared to the 1960s, the top 50 U.S. metropolitan areas have experienced an average of nearly three times as many heatwaves annually, and the typical heatwave lasts 35% longer.[24]

The electric grid could experience more reliability challenges as extreme heat and drought events are expected to occur more frequently and electric consumption is projected to double by mid-century. Clean, fuel based generation could provide support during extreme weather events, particularly by its ability to follow fluctuations in energy consumption.



22 California Energy Commission (CEC) Electric Generation Capacity and Energy, In-State Electric Generation by Fuel Type, available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy.

23 The US Department of Energy (DoE) aims to reduce clean hydrogen production costs to $1/kg within ten years. (U.S. National Clean Hydrogen Strategy and Roadmap, https://www.hydrogen.energy.gov/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf)

24 U.S. EPA, Climate Change Indicators, https://www.epa.gov/climate-indicators

Reliability Analysis

Planning for the Future

California remains at the forefront of climate policy and decarbonization trends. The State has called for ambitious emission reductions through electrification, and the resulting policy-driven increase in electric demand are anticipated to contribute to electric reliability concerns. These challenges will likely be amplified by continued growth in intermittent renewable resources.

This Reliability Analysis models reliability under historical weather conditions, and while the results underscore the State's acute need for resource diversity in the future, incorporating weather assumptions around climate change could further emphasize the need for clean, dispatchable generation. Viewing future reliability challenges within the context provided by extreme weather events offers the opportunity to expand upon the findings from this Reliability Analysis to help further inform policy recommendations.

Reliability Analysis

Tests Clean Fuels Study scenarios for electric reliability under normal weather conditions

Identifies future challenges that can be addressed through thoughtful planning

Focuses on 2045 scenario results

Open Questions for Stakeholders

Could extreme weather event risks continue to impact the energy system in the future?

How could the State plan for changing grid conditions with a more diverse resource portfolio?

How could the State accommodate lead times for infrastructure development?

Policy Recommendations

Near-term and long-term actions to support resource diversity and facilitate coordination between the gas and electric systems.

The challenges in meeting higher demand will likely be exacerbated by constraints around the availability of key resources that help serve load reliably today, like imports, hydro, and nuclear generation. California may not be able to rely as heavily on imports as it competes with other states that attempt to decarbonize their electric grids, changing weather patterns could reduce the availability of hydro, and policy mandates could eliminate nuclear power from the State's electric portfolio.[25]

The flexibility from clean fuels like hydrogen may allow intermittent resources like solar to contribute their maximum output while fuel based generation ramps up or down to balance the grid. Clean fuels may also provide reliability during hours when output from renewables and batteries is insufficient.

To advance California's path to carbon neutrality, energy system planning needs to look beyond historical conditions and assumptions. Near-term clean fuels infrastructure development enables the resources necessary to meet potential reliability shortfalls.

25 Grid reliability concerns and resource uncertainty were key considerations leading to California legislation that extended operations at PG&E's Diablo Canyon nuclear facilities. See SB 846 Diablo Canyon Powerplant: Extension of Operations; available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB846.

CAISO has flagged long term electric resource diversity and potential capacity shortfall concerns in California resource planning proceedings. CAISO, Comments of the California Independent System Operator Corporation, Order Instituting Rulemaking to Continue Electric Integrated Resource Planning and Related Procurement Processes, R-20-05-003, available at: http://www.caiso.com/Documents/Oct23-2020_Comments-on-Integrated-Resource-Planning-R20-05-003.pdf

Policy Recommendations

1 **The State should prioritize rapid deployment of clean, dispatchable generation, especially clean hydrogen resources.**

- Extreme weather events highlight the value of dispatchable resources, especially as the grid evolves to support more renewables and growing demand from electrification.
- The State should urgently pursue clean, dispatchable resources like clean hydrogen generation to have sufficient clean, firm power in 2045.
- An important step is to explicitly acknowledge decarbonized fuels, like clean hydrogen, as an SB100 eligible resource. Doing so could provide the appropriate market signal to electric generators and load serving entities, and encourage adoption and deployment of clean, dispatchable generation.[26]

2 **The gas system needs a rigorous, integrated planning process that factors in the impacts of climate change and evolving policy and customer needs.**

- All stakeholders must understand how climate change and aggressive decarbonization policies may affect the energy system in the long-term and create a framework that allows electric and gas system planners to coordinate closely in a long-term planning process. This can help assure that the necessary electric and clean fuels infrastructure is available when and where it is needed.
- An integrated planning process will help encourage the appropriate levels of reliability and resiliency to be built into the energy system to account for the increased frequency of extreme weather events.
- Policymakers and stakeholders need to go beyond current planning practices based primarily on historical assumptions to adequately prepare for future conditions.

3 **To support future energy needs, immediate investment in clean fuels infrastructure is necessary now.**

- Early investment in the clean fuels network is needed at scale to accommodate long lead times required for infrastructure development that is key to meeting California's long-term energy needs.
- Furthermore, the development of shared clean fuels infrastructure capable of supporting grid needs as well as other sectors, like industry and transportation, should be prioritized to facilitate the timely decarbonization of hard-to-abate sectors.
- Investments in existing gas infrastructure need to continue for the safe and reliable delivery of increasingly cleaner molecules. Leveraging the existing gas system to deliver clean fuels could allow California to achieve net zero more affordably and with less risk.

26 Clean hydrogen is consistent with the federal definition in 42 USC 16166.

Disclaimer

In general, this Reliability Analysis, including the modeling contained therein, is uncertain and speculative as it is based upon and contains hypothetical assumptions related to technology development, customer behaviors, and other large-scale trends over a 30-year time period, which in some instances were selected to test a range of potential but not exhaustive scenarios. Therefore, while the results can be useful to guide high-level strategic decision-making, neither the assumptions nor the results should be used as forecasts or estimates.

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