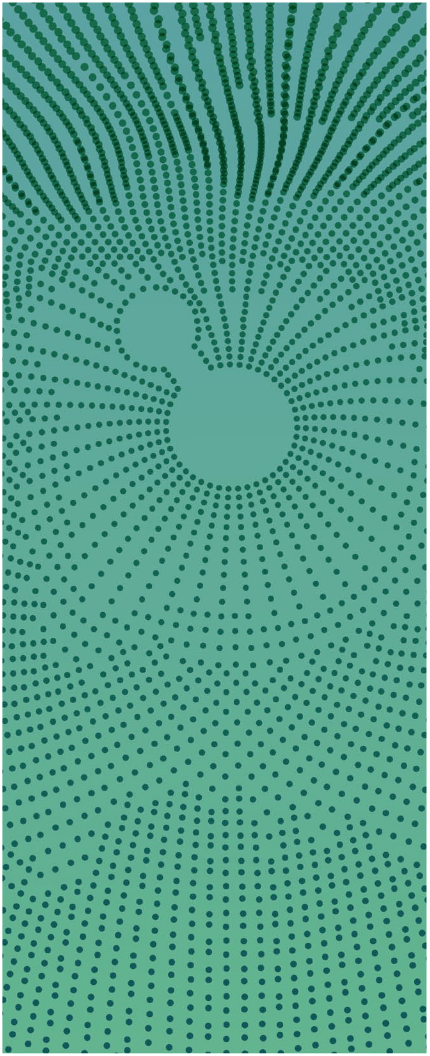


GREEN
HYDROGEN
COALITION

WESTERN GREEN HYDROGEN INITIATIVE

Clean Hydrogen and Grid Reliability

Overview of Potential Use Cases and Considerations for States

CLEAN HYDROGEN IN THE ELECTRIC SECTOR

As states strive to reduce emissions while ensuring a reliable and resilient electric sector, clean hydrogen has emerged as a potential solution, particularly in applications such as long-duration energy storage (LDES) and microgrids. With the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) playing pivotal roles in stimulating investment in scaled hydrogen production and use across the United States, states have a plethora of use cases to consider for clean hydrogen. The IIJA allocates funds specifically for creating regional clean hydrogen hubs and enhancing hydrogen production, processing, delivery, and end-use. Complementarily, the IRA offers tax credits for clean hydrogen production, making projects more financially viable. Together, these Acts are foundational in fostering a national network of hydrogen hubs and supporting the transition to a lower-carbon energy system.

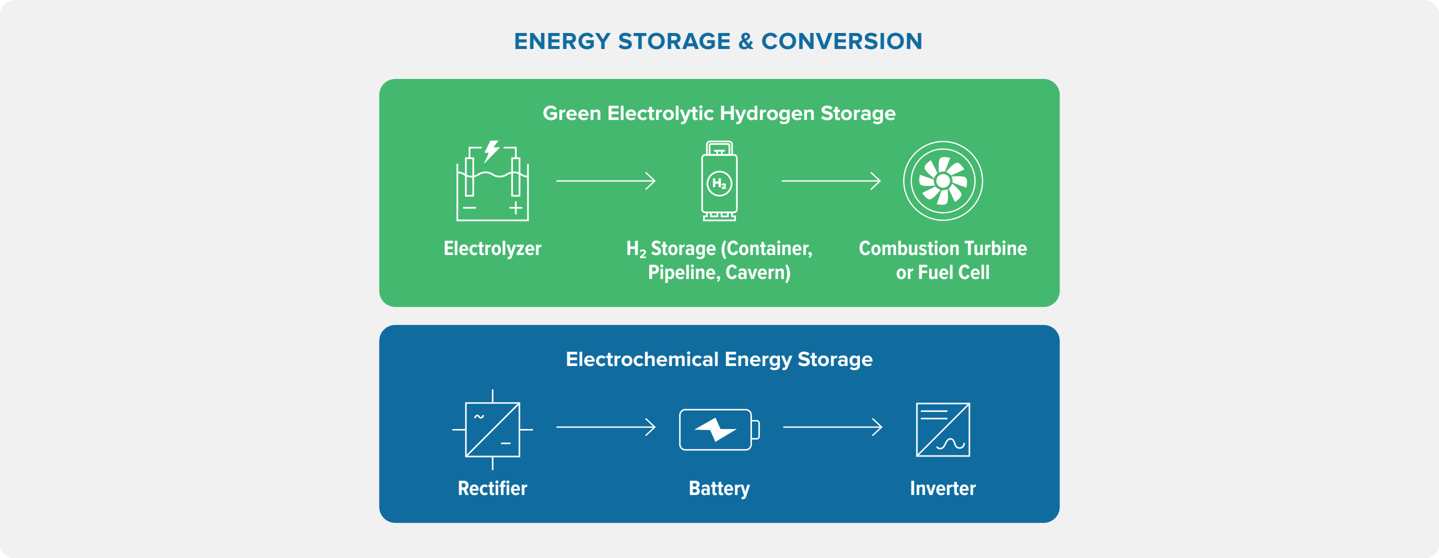
This issue brief offers an overview of the benefits and challenges associated with clean hydrogen for two specific electric sector use cases—LDES and microgrids—with the aim of aiding state leaders in evaluating clean hydrogen initiatives as part of their statewide planning efforts. It is important to clarify that this brief does not perform a cost-benefit analysis of clean hydrogen and its alternatives; rather, it focuses on elucidating key use cases of clean hydrogen for informed consideration.

USE CASE: HYDROGEN AS LONG-DURATION ENERGY STORAGE

OVERVIEW

As many states and utilities advance their strategies to achieve a low- and zero-carbon electric grid, studies have found that up to 80-90% of decarbonization can be achieved using existing technologies.[1] However, the variable nature of renewable generation poses a challenge to reaching a fully decarbonized grid for states with these requirements. This necessitates the deployment of new technologies capable of providing clean, flexible capacity over increasingly long periods. Operators will need vast quantities of clean energy stored for long durations for peak demand and multi-day use to even seasonal energy balancing. To meet the need for a clean, dispatchable energy supply, clean hydrogen has emerged as a LDES solution, as it can offer storage durations ranging from weeks to months.

Figure 1 | Electrolytic Green Hydrogen Energy Storage Compared to Electrochemical Energy Storage



Source: Janice Lin et al., “Green Hydrogen Guidebook,” Green Hydrogen Coalition, April 2022.

---

[1] Bharath Ketineni and Bhavana Katyal, “Long-Duration Energy Storage Assessment,” WECC, February 3, 2023. https://www.wecc.org/Reliability/LDES_Final_Report.pdf.

Storing hydrogen as a gas or liquid enables it to be kept in large quantities for extended periods, facilitating its use on-demand to balance the electricity grid. This attribute is particularly advantageous in circumstances of longer-duration energy need, where hydrogen storage becomes more cost-effective compared to electrochemical batteries.

BENEFITS

The use of hydrogen for LDES provides a multitude of economic, environmental, and grid benefits. Utilizing hydrogen for energy storage helps prevent the economically inefficient curtailment of renewable energy sources and is a commercially viable way of storing bulk amounts of energy for long periods, multiple days, weeks, and even seasons. Clean hydrogen can be generated from organic waste or water electrolysis using renewable electricity, including excess renewable energy generated during peak production hours. By storing abundant, low-cost renewable energy as hydrogen, it can be converted back to electricity during periods of high demand or low production from renewable sources via a number of different technologies, including fuel cells, gas turbines, or linear generators. Most gas turbines can combust a blend of hydrogen and natural gas without modification, and all major turbine manufacturers have announced plans to commercialize turbines that can operate on 100% hydrogen. The ability to utilize existing gas turbines and upgrade them to ultimately combust 100% renewable hydrogen is an opportunity to ensure clean firm dispatchable power by utilizing existing thermal asset fleets.

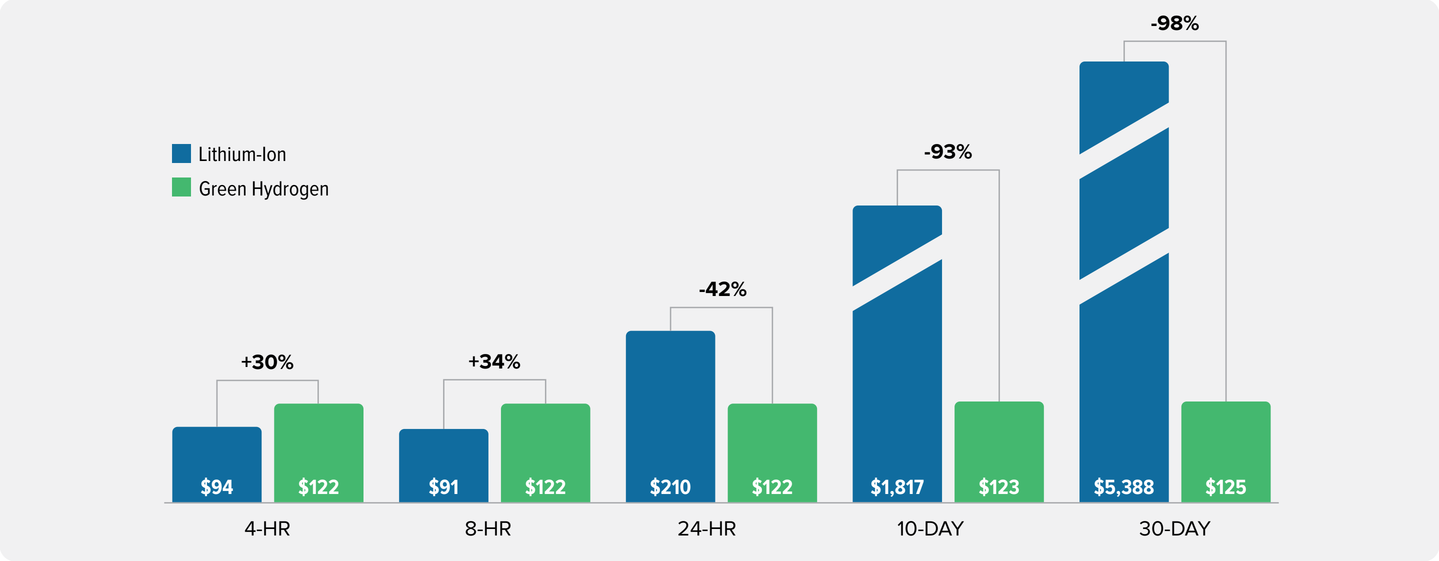
Additionally, electrolytic hydrogen production contributes significantly to grid flexibility, absorbing and managing energy demand and supply fluctuations. It allows for greater integration of renewable energy sources by providing a reliable backup that can store energy at times of surplus and be deployed as needed, thus supporting continuous energy supply even during variable weather conditions.

LDES is crucial for achieving deeper decarbonization in the electric sector. Because natural fluctuations in wind and solar power do not match fluctuations in power demand, increased concentration of variable renewable energy in the generation mix will inevitably lead to prolonged periods of power surplus and shortage. By enabling very long duration, including seasonal storage duration and capacity via pipeline and geologic storage underground, hydrogen can help smooth out the intermittency of renewable energy sources and help meet demand throughout the year.

IMPLEMENTATION CHALLENGES

The availability and cost of implementing hydrogen-based energy storage solutions is a significant barrier. Current expenses associated with hydrogen production, storage, and conversion back to electricity remain higher than traditional storage methods for short durations, such as electrochemical batteries, though technological advancements and scale could reduce these costs over time. For very long duration and large-scale energy storage, hydrogen has been commercially stored for decades in underground purpose-built salt caverns on the Gulf Coast, in support of oil refineries. Additional geologic storage is needed throughout the country, paired with scaled demand and transport infrastructure.

Figure 2 | Levelized Cost of Energy ($/megawatt-hour) of Energy Storage by Discharge Time



Source: Janice Lin et al., "Green Hydrogen Guidebook," Green Hydrogen Coalition, April 2022.

POLICY AND PROGRAM CONSIDERATIONS FOR STATES

As states continue to navigate the landscape of energy policy and decarbonization, several key considerations should be taken into account, particularly in the context of planning for and deploying LDES. This will enable the deployment of LDES paired with renewable resources to support grid reliability.

To enable effective integrated resource planning, there is a critical need for the development of standardized inputs and methodologies that account for the characteristics of LDES and, in the case of stored hydrogen, how it can be utilized in existing and new assets to supply clean firm dispatchable power and assist with grid reliability and resiliency as part of ongoing integrated resource planning. This standardization will ensure that the assessments and forecasts regarding energy storage needs and capabilities are consistent and comparable across utilities and states, facilitating more cost-effective and reliable resource deployment.

State energy offices can also undertake statewide decarbonization roadmapping exercises to assess and plan for the integration of LDES solutions accurately. This involves detailed analyses to understand the specific needs and potential roles of LDES in achieving emissions targets, as well as where scaled hydrogen electricity storage can be deployed synergistically with other hydrogen uses in transportation, industry, agriculture, and other sectors. Such roadmapping will help accelerate the commercial viability of hydrogen in the power sector because of the ability to aggregate demand for hydrogen across sectors and share needed transport and storage infrastructure. In some regions, the power sector may serve as an important first mover and anchor off-taker to aid in scaling aggregated demand and scaled production and need infrastructure.

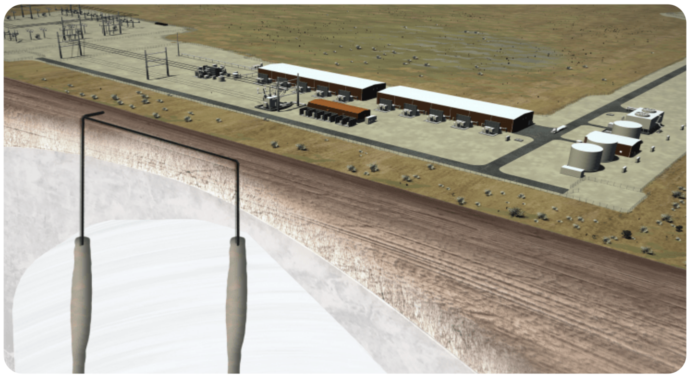
There are also important emissions implications for a developing hydrogen ecosystem. Combusting hydrogen as a fuel produces nitrogen oxides (NOx), a pollutant that contributes to air quality issues and health problems. While hydrogen combustion generates lower carbon dioxide emissions than gas, coal, or oil, the resulting NOx emissions necessitate regulatory oversight. Therefore, any new hydrogen plant should adhere to existing NOx and other emissions standards as part of its permitting process.

Finally, it is essential to create robust market valuation mechanisms for storage systems that can provide energy for durations exceeding four hours. Currently, compensation mechanisms for energy storage, such as resource adequacy frameworks and net energy metering, do not appropriately differentiate between four-hour battery storage and longer-duration solutions. By establishing mechanisms that recognize and compensate for the unique value provided by longer-duration storage, states can encourage investment and development in technologies like hydrogen.

CASE STUDIES

The examples of Nine Mile Point Nuclear Station in New York and the Advanced Clean Energy Storage Project in Utah demonstrate the versatile applications of LDES across different market contexts aimed at emissions reduction, minimizing renewable curtailment, and enhancing reliability. In 2022, a collaborative initiative involving New York and the U.S. Department of Energy provided funding to Nine Mile Point Nuclear Generating Station to pioneer hydrogen fuel cell technology. This project, the nation's first 1 megawatt (MW) demonstration of a scaled nuclear-powered clean hydrogen facility, commenced clean hydrogen production in May 2023. Utilizing electricity from the nuclear plant, it produces hydrogen that is then stored within the site's existing infrastructure, supporting emission reductions on the New York Independent System Operator electric grid.[2]

In Delta, Utah, the Advanced Clean Energy Storage Project is set to establish a groundbreaking hydrogen production and storage facility boasting 220 MW of electrolyzers. These electrolyzers will generate hydrogen, which will be stored in two natural salt caverns with a combined capacity of 300 gigawatt hours of dispatchable clean energy. The facility is designed to leverage surplus renewable energy to produce hydrogen, which will subsequently fuel an 840MW hydrogen-capable gas turbine combined cycle power plant, illustrating a strategic approach to utilizing excess renewable energy and providing long-term seasonal energy storage.[3]



---

[2] Constellation Energy, "Constellation Starts Production at Nation's First One Megawatt Demonstration Scale Nuclear-Powered Clean Hydrogen Facility," March 7, 2023, https://www.constellationenergy.com/newsroom/2023/Constellation-Starts-Production-at-Nations-First-One-Megawatt-Demonstration-Scale-Nuclear-Powered-Clean-Hydrogen-Facility.html.

[3] ACES DELTA, "Advances Clean Energy Storage Hub," Accessed May 2, 2024, https://aces-delta.com/hubs.

USE CASE: FUEL CELL MICROGRIDS

OVERVIEW

Microgrids represent a transformative approach to energy management, capable of operating independently from the main power grid. This feature is particularly beneficial in remote areas where connectivity to the central grid is either impractical or prohibitively expensive but can also provide value in the case of grid outages. The core infrastructure of a microgrid combines power generation, storage, and sophisticated energy load management systems to establish a reliable and efficient power supply.

The integration of fuel cells and electrolyzers can enhance the functionality of microgrids. Fuel cells, utilizing chemical energy from hydrogen or other fuels, generate electricity in a clean and efficient manner. When hydrogen is used, the only by-products are electricity, water, and heat, thus supporting environmental sustainability. Unlike batteries, fuel cells continuously produce electricity and heat as long as fuel is supplied, without the need to recharge.

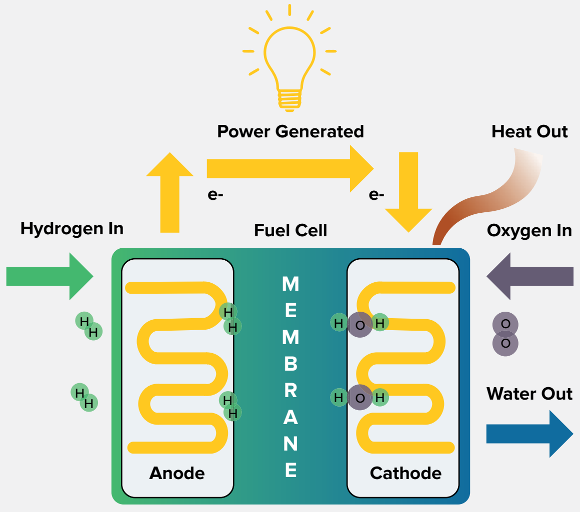
BENEFITS

The incorporation of fuel cells into microgrids leverages hydrogen's potential as a LDES resource and also ensures a consistent and reliable power supply, which is crucial for maintaining a microgrid's operational independence and resilience. This capability allows microgrids to "island" or disconnect from the traditional utility power grid and operate autonomously, enhancing grid resilience and stability, especially valuable during outages and grid disturbances.

Additionally, when paired with renewable energy sources, fuel cells in microgrids can prevent the uneconomic curtailment of renewables. By storing excess renewable energy in the form of hydrogen, these systems utilize low-cost energy that would otherwise be curtailed due to grid capacity limits or supply-demand mismatches, thereby enhancing economic efficiency.

Furthermore, fuel cell microgrids offer utilities a compelling non-wires alternative, deferring or eliminating the need for costly infrastructure upgrades necessary to meet growing energy demands or replace aging equipment. This approach provides reliable and efficient energy solutions without the extensive capital expenditures associated with traditional grid expansions, offering a cost-effective and flexible solution that aligns with modern energy needs.

Figure 3 | Diagram of a Fuel Cell



Source: Janice Lin et al., "Green Hydrogen Guidebook," Green Hydrogen Coalition, April 2022.

IMPLEMENTATION CHALLENGES

While microgrids with fuel cells offer numerous advantages, several significant challenges impact their deployment and effectiveness. The durability and reliability of fuel cells and electrolyzers will be critical, as these systems will be expected to operate under varying conditions and potentially over extended periods. Currently, hydrogen electrolyzers and fuel cells face durability challenges, primarily due to the degradation of components such as membranes and electrodes over time. This degradation can be accelerated by factors like fluctuating loads, impurities in the hydrogen or the oxygen used, and thermal cycling. These issues can lead to increased maintenance costs and reduced lifespan, which are barriers to the widespread adoption of hydrogen technologies.[4]

Microgrids also face considerable financial and regulatory hurdles. The high capital costs for setup and the technical complexity of integrating microgrid systems pose financial barriers. Additionally, regulatory challenges, which include a lack of clear guidelines for microgrid integration and operation, complicates the scalability and practical deployment of microgrid technologies and thus require detailed strategic planning and adjustments to existing frameworks.[5]

POLICY AND PROGRAM CONSIDERATIONS FOR STATES

States can implement measures such as tailored microgrid grant and loan programs to overcome implementation challenges and accelerate the adoption of microgrids. For example, California's Self-Generation Incentive Program offers financial incentives for developing and deploying microgrids, effectively lowering the initial capital barriers for organizations aiming to develop these projects.[6] Similarly, New York's NY Prize initiative provides funding specifically for designing and constructing community microgrid projects, which enhances resilience to local energy demands and emergencies.[7]

Policy frameworks focused on enhancing grid reliability and resiliency might include mandatory standards for utilities to incorporate microgrid capabilities in their emergency response strategies or to develop regional microgrid hubs that can provide critical support during outages. By integrating these regulatory measures, states can unlock the full benefits of microgrids, making them a viable solution for sustainable energy management. This approach not only supports the transition towards renewable energy but also enhances the reliability of the power supply during peak times and emergencies.[8]

CASE STUDIES

The following successful implementations below demonstrate how microgrids can be leveraged as a key component of modern energy strategies to enhance community resilience and promote sustainable energy use.

The PG&E Calistoga Resiliency Center in California was established to provide reliable power during natural disasters such as wildfires, ensure a continuous electricity supply, and enhance community resilience. The facility utilizes hydrogen as a fuel source to provide over 48 hours of continuous energy and a peak instantaneous power output of 8.5 MW during regional Public Safety Power Shutoff events.[9]

Similarly, the microgrid at Amity Regional High School in Woodbridge, Connecticut, utilizes a 2.2 MW fuel cell to secure a dependable power supply and serve as an educational resource, teaching students about advanced energy solutions and sustainability.[10]

---

[4] Iain Staffell et al., "The Role of Hydrogen and Fuel Cells in the Global Energy System," Energy & Environmental Science, January 1, 2019, https://doi.org/10.1039/c8ee01157e.

[5] Sulman Shahzad et al., "Possibilities, Challenges, and Future Opportunities of Microgrids: A Review," Sustainability, April 7, 2023, https://www.mdpi.com/2071-1050/15/8/6366.

[6] California Public Utility Commission, "Self-Generation Incentive Program," Accessed May 6, 2024, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/self-generation-incentive-program.

[7] New York State, "NY Prize Microgrid," Homes and Community Renewal, Accessed May 6, 2024, https://hcr.ny.gov/ny-prize-microgrid-competition.

[8] Sulman Shahzad et al., "Possibilities, Challenges, and Future Opportunities of Microgrids."

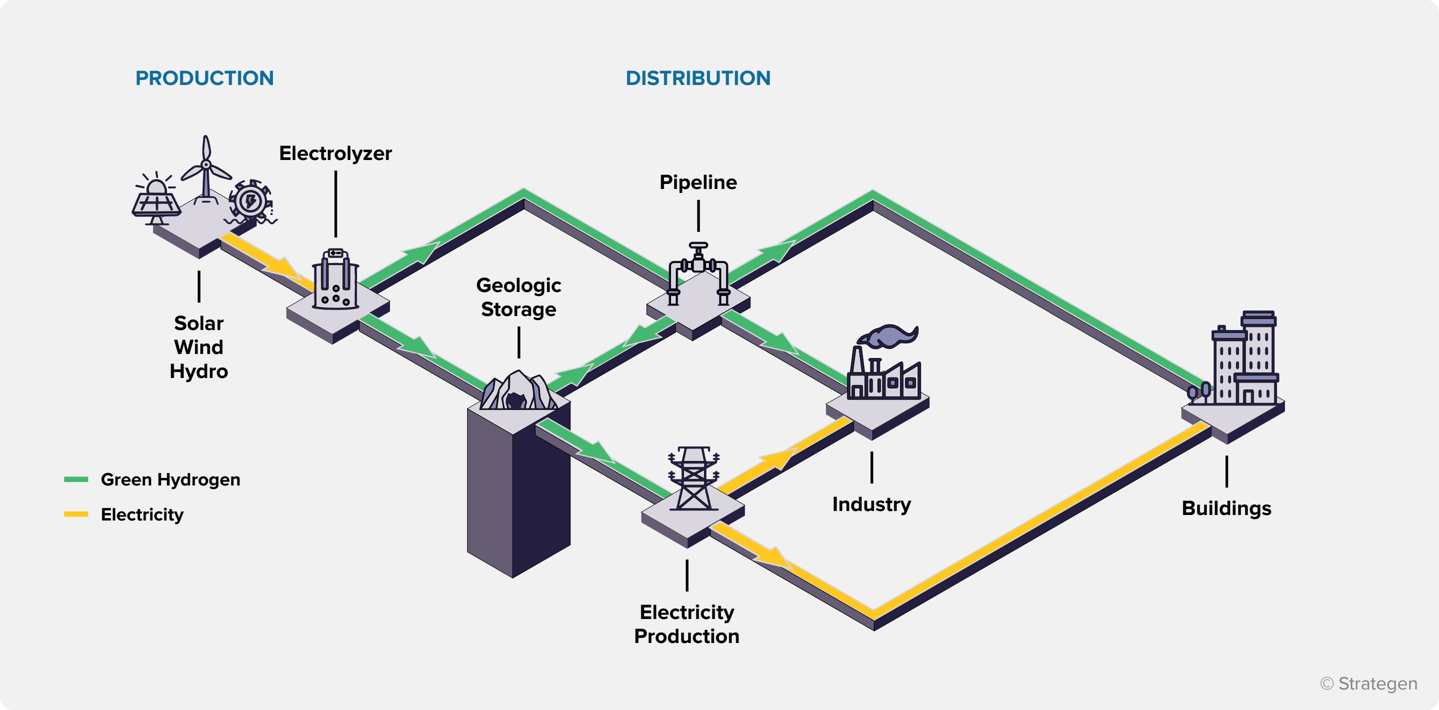
[9] Energy Vault, "Calistoga Resiliency Center," Accessed May 10, 2024, https://www.energyvault.com/projects/calistoga.

[10] AVANews, "Woodbridge, CT: A First of its kind microgrid," AVANGRID, February 25, 2022, https://avanewsblog.com/2022/02/woodbridge-ct-a-first-of-its-kind-microgrid.

ELECTRIC SYSTEM COORDINATION

Electrolyzers, the equipment that converts electricity into hydrogen, provide a link between hydrogen production and larger electric systems and represent an additional load that may be connected to the electric grid. Strategic planning is needed to align their deployment and usage with grid conditions and optimize the use of renewables, balancing environmental benefits and grid stability.

Figure 4 | Demonstration of the Role of Electrolyzers in the Electricity Value Chain



Source: Janice Lin et al., "Green Hydrogen Guidebook," Green Hydrogen Coalition, April 2022.

When electrolyzers are powered from the same grid that they subsequently supply energy to through storage solutions or fuel cells, there are opportunities for strategic coordination. Electrolyzers act as both large electric system loads and as assets for grid management because their operation can be dynamically adjusted based on grid conditions. For instance, during periods of low demand and high renewable production, electrolyzers can ramp up to convert excess electricity into hydrogen, effectively storing energy that might otherwise be curtailed. Conversely, during high demand, this stored hydrogen can be converted back to electricity through fuel cells, providing a responsive and flexible energy source that helps balance the grid.

This capability of electrolyzers to both absorb and supply energy underscores the need for sophisticated grid management strategies. Effective coordination involves managing the timing and rate of electrolysis and the subsequent release of energy. This will require real-time communication, advanced control systems, and increased data availability for hydrogen producers. Implementing such a system demands careful planning to ensure that the operation of these technologies aligns with the fluctuating nature of grid conditions, thereby enhancing overall system reliability and efficiency.

ENABLING POLICY ACTIONS

Clean hydrogen has a potential role to play as states aim to reduce emissions in the electric sector. Key use cases may include hydrogen for LDES and fuel cells for microgrid applications. Further, as hydrogen is deployed to meet these use cases, the electrolyzers constructed to produce hydrogen can be leveraged as a flexible load for grid balancing. To enable these applications of hydrogen, states should undertake the following efforts:

1. **Incorporate Hydrogen into Long-Term Planning Efforts**
   Hydrogen should be incorporated into statewide gas and electric decarbonization roadmaps and utility integrated resource plans. This integration ensures that hydrogen's potential to provide energy storage and generation capacity is fully recognized and planned for within state forums, ensuring that future energy mixes are sustainable, reliable, and cost-effective.

2. **Explore Hydrogen as a Resiliency Solution within State Energy Security Plans and Hazard Mitigation Efforts**
   Hydrogen applications can be incorporated into state energy security plans and hazard mitigation efforts to enhance the resilience of energy systems against natural disasters and other disruptions. This is particularly relevant as states explore using hydrogen fuel cells within microgrids.

3. **Enable Grid-Connected Electrolytic Hydrogen to Provide Reliability Services and Create Compensation Frameworks**
   Enabling hydrogen to provide reliability services involves creating compensation frameworks that recognize and reward the value hydrogen systems contribute to grid stability and reliability when electrolyzers are used as grid balancing resources.

These steps will collectively strengthen hydrogen's role in state energy policies, enhancing sustainability and resilience to evolving energy needs.

GREEN
HYDROGEN
COALITION

The Western Green Hydrogen Initiative is a public-private partnership to advance and accelerate deployment of green hydrogen infrastructure in the Western region for the benefit of the region’s economies and environment. It includes representatives from 11 western states and two Canadian provinces—all part of the Western Interconnection—as well as Florida, Ohio, and Louisiana. It is jointly hosted by the Green Hydrogen Coalition, the National Association of State Energy Officials (NASEO), and the Western Interstate Energy Board (WIEB). For more information, please visit wghydrogen.org.