CCST EXPERT BRIEFING SERIES:
Toward a Disaster Resilient California

DECARBONIZING WITH HYDROGEN

Challenges and Opportunities

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Briefing held **MAY 2022**

One Pager

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Photo: Replacing diesel trucks with hydrogen fuel cell trucks (which emit only water at the tailpipe) or other zero emission vehicles would lead to significant air quality improvements at transit centers. The port of Los Angeles invested in a demonstration of hydrogen fuel cell vehicles and fueling stations in 2021. | Kevin Bergen

SUMMARY

- Hydrogen can be used to decarbonize many sectors of California's economy, including those considered "hard-to-abate" like heavy duty transportation and industry.
- The transportation and storage of hydrogen remain significant technological challenges.
- Hydrogen can be produced a number of different ways which can vary in terms of **CARBON INTENSITY** (the amount of carbon emitted for each unit of energy produced) and sustainability.
- Hydrogen fuel cells emit only water, but the combustion of hydrogen in air can produce nitrous oxides—a harmful pollutant.

Hydrogen in a

DECARBONIZED CALIFORNIA

While California has made significant strides in reducing its greenhouse gas emissions, there remain many challenges to achieving carbon neutrality by 2045. Many experts believe that hydrogen could be key to decarbonizing hard-to-abate sectors like cement and steel production, agriculture, and heavy-duty transportation.

A sizable hydrogen economy already exists—today most hydrogen is used in fertilizers and in oil refining processes. Currently, >95% of hydrogen is produced from fossil fuels (mostly natural gas) in a process that emits large amounts of CO2.

However, there are clean alternatives that either capture the CO2 or use renewable resources directly (see "*Colors*" sidebar). For example, cheap renewable energy—like wind and solar—can be harnessed to split water into its oxygen and hydrogen components. Alternatively, waste biomass (like forest wood waste, orchard clippings) can be heated in a controlled environment to extract the hydrogen and other gases stored in the organic compounds—a process known as "**BIOMASS GASIFICATION.**"

The "Colors" of Hydrogen (H2)

Color codes are often used to distinguish different methods of hydrogen production (hydrogen is a colorless gas). Below are the three most commonly referenced.

GREEN

Green hydrogen is produced by electrolysis (i.e., splitting apart water molecules) using energy derived from renewable resources like wind and solar.

GRAY

Gray hydrogen is produced via a process called "steam methane reformation" in which methane found in natural gas is split into carbon monoxide and hydrogen and which leads to carbon emissions. Most hydrogen produced today is "gray" hydrogen.

BLUE

Blue hydrogen is produced via steam methane reformation—the same as gray—but is complemented by carbon capture and storage technology.

While these colors can be useful, some experts believe we should be prioritizing production pathways—not by color—but by carbon intensity ratings.

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About the
CCST Disaster Resilience Initiative:

Ongoing, complex, and intersecting disasters—including climate change, extreme heat, power outages, and the COVID-19 pandemic—are radically disrupting the ways in which Californians live and work. CCST is committed to delivering science and technology advice to improve our resilience to disasters, reduce harm, and improve the lives of all Californians.

SELECT EXPERTS

The following experts can advise on hydrogen:

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Hydrogen **APPLICATIONS**

Heavy Duty Transportation

Heavy-duty and long-haul transportation are not readily electrifiable—the batteries required to power most of these trucks would be too large, too heavy, and would require too much time to charge. Hydrogen fuel cells can power trucks over longer distances than could batteries of equivalent volume, and hydrogen-powered trucks can be refueled almost as quickly as their diesel-powered counterparts.

Replacing diesel-powered trucks with hydrogen fuel cell trucks (or other zero emission vehicles)—which emit only water at the tailpipe—would lead to dramatic improvements in air quality for many communities in California, especially those nearest major ports, like Los Angeles and Long Beach.

Options for decarbonizing maritime, rail, and air transportation with hydrogen are currently being explored.

Long-Duration Energy Storage

As California's energy grid is increasingly powered by a larger percentage of renewable resources, grid reliability becomes a greater concern. One solution would be to capture excess power generated during peak renewable production, use that energy to create hydrogen, and then use that hydrogen for energy when renewable production is unable to meet demand.

Hydrogen is an attractive long-duration energy storage solution because once hydrogen is created, it can efficiently store energy over long time periods (unlike batteries which slowly lose their charge). Integrating long-duration energy storage into the system will allow greater penetration of renewable resources into the grid without sacrificing reliability.

Industry

Many industries are not amenable to electrification as a decarbonization solution. For example, steel and cement manufacturing require extremely high temperatures, usually accomplished by burning natural gas. Current technologies are simply not able to produce the requisite temperatures with electricity in an economically viable way. However, hydrogen can replace natural gas in many of these systems, providing a less carbon-intensive fuel source.

Remaining Technological **CHALLENGES**

Cost

Gray hydrogen is much cheaper to produce than cleaner hydrogen alternatives. Cost-competitive "clean" hydrogen will require the development of cheaper, more efficient means of production.

Storage

Hydrogen gas occupies a lot of volume; compressing hydrogen into smaller volumes for storage and transportation is energetically expensive. Hydrogen used as a long-duration energy storage solution will likely need to be stored in underground geologic features, such as salt caverns (already demonstrated in several US and European projects), depleted natural gas reservoirs, or saline aquifers. More research is needed to determine how effectively features other than salt caverns will store hydrogen or whether California's geology will support these practices.

Transportation

Because California does not currently have an adequate pipeline network in place for its transportation, hydrogen is usually compressed in tanks and trucked to destinations.

Methods of storing and transporting hydrogen, as well as reducing the costs of hydrogen production, are very active areas of research across DOE National Labs and academic institutions in California.

Concerns & **UNCERTAINTIES**

Nitrogen Oxides (NOx)

While hydrogen fuel cells emit no pollutants, the combustion of hydrogen can create nitrogen oxides. Nitrogen oxides are considered poisonous by the EPA and contribute to global warming. Thus, there are concerns about applications of hydrogen that require combustion (e.g., blending hydrogen with natural gas to reduce the carbon footprint of natural gas). However, research about the precise circumstances that result in increased production of nitrogen oxides is inconclusive, and more research is needed. Hydrogen fuel cells may be able to meet many of our needs.

Global Warming Potential of H2

Two recent reports have concluded that hydrogen leaks can lead to increased global warming via interactions with methane in the atmosphere. However, if we replace fossil fuels with hydrogen, many sources of current methane emissions will be eliminated. Thus, there will be less methane with which the hydrogen can react. The total warming effect of this substitution and methane reduction has not yet been evaluated.

Water Requirements for Electrolysis

Concerns have been raised about the sustainability of electrolysis—which currently requires purified water—in a state grappling with water scarcity. Predicted water requirements for commercial-scale hydrogen production are not inconsequential; however, it has been argued that the decommissioning of oil refineries would "free up" much of the water needed to create hydrogen. Meanwhile, research labs in California are exploring the potential for using seawater or wastewater for electrolysis.