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Toward a Disaster Resilient California

DECARBONIZING TRANSPORTATION with Hydrogen

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CCST CALIFORNIA COUNCIL ON SCIENCE & TECHNOLOGY

Figure: San Bernardino County Transit Authority (SBCTA) is working to develop the nation's first hydrogen-powered passenger train. Sandia National Laboratories has been supporting SBCTA through discussions on safety standards for the train and the necessary supporting infrastructure (e.g., refueling and maintenance facilities). (SBCTA)

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.

SUMMARY

- Hydrogen fuel cells generate electricity in a process that emits only water vapor and heat.
- Hydrogen fuel cells are increasingly viewed as an attractive option for decarbonizing the heavy duty sector given their fast refueling times and high specific energy density (i.e., the energy stored per kg).
- Hydrogen can be as safe or safer than other fuels commonly used today (like natural gas or gasoline). However, as with any flammable fuel, steps must be taken to ensure its proper storage and handling.
- Remaining challenges include the costs of hydrogen fuel and vehicles, limited infrastructure for transporting hydrogen fuel, and an insufficient number of refueling stations.

DECARBONIZING TRANSPORTATION WITH HYDROGEN

The transportation sector alone comprises approximately 50% of California's greenhouse gas emissions. Converting both light duty and heavy duty vehicles to ***Zero Emission Vehicles (ZEVs)*** will be critical to mitigating climate change while simultaneously eliminating major sources of other harmful pollutants like particulate matter and nitrogen oxides.

Hydrogen fuel cells—which combine hydrogen with oxygen pulled from the air and create water vapor and electricity in the process—are one possible tool for decarbonizing vehicles across all weight classes.

California is leading the United States in decarbonizing the transportation sector with hydrogen. More than 10,000 ***Fuel Cell Electric Vehicles (FCEVs)*** were registered in California last year. Over 60 fuel cell electric buses are operating in the state. There are long-haul and drayage truck demonstrations, and California will soon be the first U.S. state with a hydrogen-powered passenger train.

ADVANTAGES OF HYDROGEN

Zero Emissions

Hydrogen fuel cells produce only water vapor at the tailpipe.

Fast Refueling

FCEVs have a refueling process similar to that of their gasoline or diesel powered counterparts, making them an ideal candidate for fleets where long periods of down-time are bad for business.

Energetically Dense

Compressed hydrogen tanks contain significantly more energy than batteries of equivalent size or weight. Thus for long haul or heavy duty trucks that are volume- or weight- constrained, FCEVs have an advantage over current battery electric options.

See reverse for a summary of challenges.

SELECT EXPERTS

The following experts can advise on hydrogen:

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Deploying
HYDROGEN IN TRANSIT

AC Transit Stanford Research

All public transit authorities in California are required to transition to 100% zero emission vehicles by 2040. One such authority, Alameda-Contra Costa Transit District (AC Transit) collaborated with ***Stanford University*** to compare and contrast five different technologies to inform their transition strategy.

The study examined two fuel cell electric bus designs, battery electric buses, diesel hybrid buses, and conventional diesel buses. As a result of this study, AC Transit updated their zero emission bus rollout plan to reflect a fleet comprised of 70% hydrogen fuel cell electric buses and 30% battery electric buses.

Hydrogen & Long Haul Trucking

Heavy duty vehicles have greater durability and performance requirements for fuel cells than light duty vehicles. The ***Million Mile Fuel Cell Truck Initiative (M2FCT)***—a Department of Energy-funded effort co-led by ***Los Alamos and Berkeley National Laboratories***—is working to leverage lessons learned from light duty applications to make fuel cell trucks competitive options for long-haul trucking.

Photo: AC Transit updated their zero emission bus rollout plan to reflect a fleet comprised of 70% hydrogen fuel cell electric buses and 30% battery electric buses, following a Stanford collaboration comparing technologies. (Calif. Fuel Cell Partnership).

Is Hydrogen Safe?

Hydrogen can be as safe or safer than other fuels commonly used today. Hydrogen is a non-toxic gas and, if leaked, will dissipate rapidly into the atmosphere, rather than accumulating in the area or seeping into the ground.

However, hydrogen differs from conventional gases in some important ways.

For example, hydrogen flames can be difficult to see in daylight—special flame detectors are required. As with any flammable gas, appropriate precautions must be taken to ensure its safe transport and use. Researchers at ***Sandia National Laboratories*** and other institutions are helping to develop guidance for hydrogen safety, codes, and standards.

Remaining Challenges

There is currently limited infrastructure for transporting hydrogen fuel. Inefficient transport significantly increases hydrogen fuel costs. In addition, there are only 56 operational hydrogen fueling stations in California. A report released by the California Air Resources Board estimates that the market can reach self-sufficiency by 2030 with an additional $300 million in state funding (beyond what's provided by AB 8) for developing hydrogen refueling infrastructure.

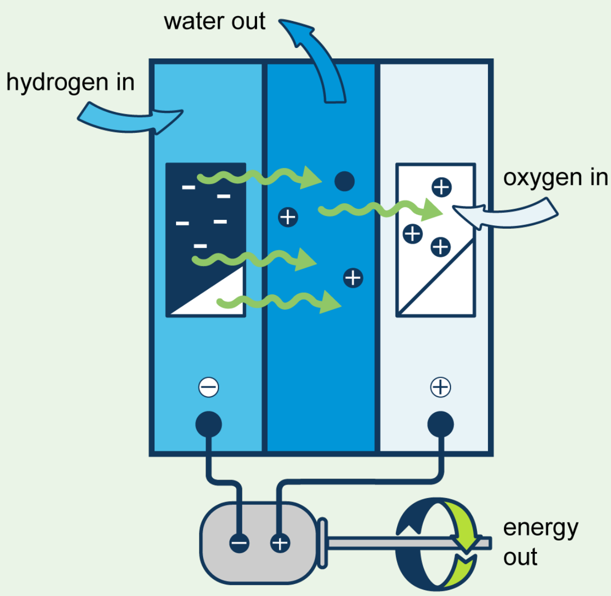

Figure: A hydrogen fuel cell. Diagram adapted from the National Energy Education Development Project.

INSIDE A Hydrogen Fuel Cell

At a basic level, hydrogen fuel cells have structures similar to batteries: there's an anode (-), cathode (+), and an electrolyte (in the middle).

Hydrogen is introduced to the fuel cell at the anode where a chemical reaction separates the hydrogen molecules into protons and electrons. The protons pass through the electrolyte towards the cathode.

Meanwhile, the electrons, unable to pass through the electrolyte, are forced through an external circuit generating electricity. The electrons then recombine on the other side of the fuel cell with the protons and with oxygen—which comes from the air—creating water.

Researchers at the National Fuel Cell Research Center at UC Irvine and other institutions are working to improve the cost and durability of fuel cells.