Renewable Hydrogen Roadmap

Executive Summary

LEADERSHIP

EXECUTIVE DIRECTOR
BRIAN GOLDSTEIN

DEPUTY DIRECTOR
JUSTO ROBLES

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Primarily using the lens of the transportation market in California, this roadmap identifies the opportunities and challenges for renewable hydrogen to provide zero-emission or even carbon-negative transportation fuel as well as critical energy storage for renewables. It considers the many aspects of the current hydrogen ecosystem and identifies the steps and policy decisions that are necessary to stimulate growth in the renewable hydrogen marketplace and clean energy economy.

As clean energy technologies achieve economies of scale and become universally accessible, constraints on sustainable energy production and storage are beginning to emerge. California experiences periods of high energy demand when renewables aren't available, as well as periods of substantial overproduction of renewable electricity. The latter scenario is already forcing the state to curtail renewables at unprecedented rates. These circumstances highlight the need for energy storage mediums that enable grid flexibility and allow consumers to utilize renewables on demand.

Hydrogen has the unique potential to connect the clean energy systems of the future by allowing storage of renewable energy that can be used to fuel transportation, generate heat for industrial processes and send electricity to the grid. California already leads the world in adopting hydrogen as an alternative fuel source for transportation and bipartisan leaders are committed to building 200 hydrogen fueling stations as part of the state's implementation of the "California Hydrogen Highway". California policymakers are collaborating with automakers to bring zero-emission Fuel Cell Electric Vehicles (FCEVs) to market and they have already adopted mandates requiring that 33.3% of the hydrogen used to fuel those vehicles at publicly funded stations must be produced from renewable sources.

Increasing the production of renewable hydrogen is necessary in order for California to achieve its current and emerging clean energy goals. SB 350, passed into law in 2015, already mandates 50% renewable energy by 2030 and Governor Brown has set a state goal of 5 million zero-emission vehicles (ZEVs) during the same time frame. In addition, the California Legislature is currently considering SB 100, which would establish an overall state target of 100% clean energy for California by 2045, while accelerating the interim benchmarks of 50% by 2026 and 60% by 2030. Due to the intermittent nature of wind and solar, the state simply cannot reach 100% renewable without energy storage. Similarly, due to the range, size and recharging limitations of battery electric vehicles, FCEVs are a necessary component of the state's ZEV goal.

Renewable hydrogen presents a near best-case scenario for clean energy storage and zero-emission transportation. Today in California and across the world, hydrogen is already produced at scale for industrial processes like oil refining and ammonia production. Industrial hydrogen is commonly produced through the reformation of natural gas but there are many ways to produce hydrogen renewably. This roadmap explores those that are currently most cost-effective and scalable – including production technologies and feedstocks.

The following series of eight high-priority recommendations for policymakers and stakeholders will help California catalyze the renewable hydrogen marketplace and achieve its ambitious economic and environmental goals:

1. **Begin the Journey to 100% Renewable Hydrogen Now**
2. **Fund Scalable Projects for 100% Renewable Hydrogen Production**
3. **Improve Low Carbon Fuel Standard (LCFS) Incentives**
4. **Promote Tools to Lower the Cost of Electricity for Renewable Hydrogen Producers**
5. **Address Hydrogen Distribution and Storage Challenges**
6. **Expand the US EPA's Renewable Fuel Standard (RFS) Program**
7. **Incentivize Consumers and Stakeholders**
8. **Broaden the Hydrogen Community Through Education & Outreach**

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EIN's Mission

Energy Independence Now (EIN) is the only nonprofit organization dedicated to advancing fuel cell electric vehicles (FCEVs) and the hydrogen-fueling infrastructure required to catalyze a rapid transition to a clean energy and transportation economy. EIN engages in comprehensive research, strategic policy advocacy and public outreach to promote the widespread adoption of FCEVs and renewable hydrogen (RH_2) as a key part of a zero-emission transport future.

EIN's RH_2 Project Partners

LEONARDO DICAPRIO FOUNDATION

CALIFORNIA HYDROGEN BUSINESS COUNCIL

Introduction to Hydrogen and Definition of Renewable Hydrogen (RH_2)

Hydrogen is the lightest, smallest and most abundant element in the universe. It naturally carries a very high amount of energy relative to its weight. Hydrogen is a necessary component for large-scale industrial processes such as oil refining and ammonia production but its use as a transportation fuel, industrial heating feedstock and storage medium for renewable electricity is growing.

Naturally-occurring, pure hydrogen readily combines with other elements to form molecules such as water (H_2O) or methane (CH_4). Hydrogen must therefore be isolated or "produced" by breaking the chemical bonds in the molecules that form these substances. While most hydrogen is currently produced from natural gas, it can also be produced without the carbon byproduct of fossil fuels.

It is this central theme of decarbonized or carbon-free hydrogen production that this paper will explore, primarily through the lens of California's zero-emission transportation goals and its Renewables Portfolio Standard. In that capacity, **renewable hydrogen can be defined as any hydrogen produced using renewable energy or electricity derived from renewable sources as defined and accepted by California policy.**[1]

Eligible renewable hydrogen energy sources in California currently include facilities using "biomass, solar thermal, photovoltaic, wind, geothermal, fuel cells using renewable fuels, small hydroelectric generation of 30 megawatts or less, digester gas, municipal solid waste conversion, landfill gas, ocean wave, ocean thermal, or tidal current, and any additions or enhancements to the facility using that technology."[2]

1. Provided by the California Hydrogen Business Council
2. California Public Resources Code, Div. 15 Energy Conservation and Development, §25741