CALIFORNIA HYDROGEN HIGHWAY NETWORK

Hydrogen Production Methods and Environmental Impacts
Fact Sheet

Hydrogen has the potential to unlock a new energy future for California—a future based on secure, local, and renewable energy sources that reduces harmful air pollutants, and is accessible and affordable to all Californians. This transition won't happen overnight but over time it can help create a sustainable transportation future for California.

Hydrogen is the most abundant element in the universe, however, it is most often found in combination with other elements such as water or fossil fuels like natural gas. Separating hydrogen from these molecules can present a number of challenges. Like any fuel, hydrogen takes energy to produce, creating the potential to increase pollution or rely on fossil fuels and other unsustainable resources. When hydrogen is produced from a variety of feed stocks including renewable sources of energy such as wind and solar power the emission impact can be zero it is used in a fuel cell vehicle. This is the long-term vision of the California Hydrogen Highway Network (CaH2Net)

Environmental Goals
To ensure that the vision of a clean, sustainable transportation future is made a reality, CaH2Net stations funded by the State must meet or exceed the environmental goals outlined in the California Hydrogen Blueprint Plan. These goals are: a 30% reduction in greenhouse gas emissions; the use of at least 20% new renewable energy resources to produce the hydrogen; and no increase in toxic or smog-forming emissions relative to comparable gasoline vehicles.

There are a number of ways that hydrogen can be produced including electrolysis of water, steam reformation of natural gas, biomass gasification and coal gasification to name a few. Today, the two most common ways to produce hydrogen are steam reformation of natural gas and electrolysis of water.

To make a fair comparison of the full environmental impacts of hydrogen, the entire system of production from "source-to-wheel" must be examined. This means that the analysis takes into account all of the steps it takes to get the fuel from the source to driving the wheels of the vehicle, including the extraction and processing of the fuel, transport of the fuel to the point of use, any additional processing that is needed, fueling the vehicle and vehicle operation.

Electrolysis of Water
Electrolysis of water is a common method of producing hydrogen, and it involves using electricity and a catalyst to break water apart into hydrogen and oxygen. Additional energy is then required to compress the hydrogen into a high-pressure gas or cool the hydrogen into a liquid that can be stored and dispensed into a vehicle.

How the electricity is generated is key to electrolysis equation because it can be produced using fossil resources (i.e., natural gas and coal) or renewable resources like solar, wind, geothermal, hydroelectric, and, biomass. When using renewable resources the emissions can be zero. However, when hydrogen is produced using the current mix of sources on the California grid, particulate matter (PM) emissions and the greenhouse gas (GHG) emissions can be greater than those associated with gasoline on a well to wheel basis. California recognizes that using renewable resources for electricity production will help improve air quality, which is one reason why the State is requiring utilities to increase the amount of renewable resources used for grid-electricity production to 20% by 2010 (The California Renewable Portfolio Standard (RPS). The goals of the CaH2Net are to use renewable resources to produce hydrogen that exceed the State's 20% RPS requirement. This is because, for electrolysis to be a viable and sustainable method of producing hydrogen, it must employ more clean renewable electricity than what the grid alone currently provides.

Steam Reformation of Natural Gas
Currently, most hydrogen is produced by steam reformation of natural gas – mainly because it is one of the cheapest methods of production. In this process, natural gas is combined with high temperature steam to extract the hydrogen along with carbon monoxide, and carbon dioxide. The unwanted carbon monoxide and carbon dioxide is removed from the mixture and the final result is pure hydrogen.

Although on-site steam reformation of natural gas is not the ultimate goal, it does provide a number of near term benefits such as a 50 percent "source-to-wheel" reduction in greenhouse gas emissions and a 40-90% reduction in emissions of smog forming and toxic emissions compared to today's gasoline-powered cars.[1] It also lays a foundation for increasing the use of renewable feed stocks because hydrogen stations that are constructed initially using natural gas could be modified to accept fuels derived from renewable and other sources of energy as they become available. Additionally, the experience gained and improvements made at stations using natural gas reformation could be applied to new reformation stations sited where renewable fuels such as biomass, municipal solid waste, and landfill gas can be used as the fuel source.

Environmental Impacts of a Hydrogen Fuel Cell Vehicle Compared to a Gasoline Vehicle

Production Method	Smog-forming and toxics emissions	Greenhouse gas emissions	Particulate Matter
On-Site Steam Reformation of Natural Gas	40 – 90% Lower	50% Lower	Lower
Electrolysis of water using the California grid	Lower	Higher	Higher
Electrolysis of water using renewable resources	Lower – zero	Lower – zero	Lower – zero

Conclusions
Actions are being taken to bridge the gap between the current dominance of gasoline and the introduction of hydrogen as a transportation fuel. Hydrogen is one of many options, including biodiesel, natural gas, ethanol, and electricity, being explored and supported to provide a diverse mix of transportation fuels. In the near-term hydrogen will be produced using a variety of methods, some cleaner than others. However, as the network grows, California will work hard to ensure that hydrogen is produced in the most environmentally sound manner possible. In order to realize this long term vision, steps must be taken during this demonstration and testing phase to learn about all of the different hydrogen production options.

For More Information
To learn more about how hydrogen is produced, please see the Societal Benefits Topic Team Report located on the California Hydrogen Highway web site located at (www.HydrogenHighway.ca.gov).

[1] M. Wang, Y. Wu, and A. Elgowainy, 2005, *Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) 1.7*, Center for Transportation Research, Argon National Laboratory. Model simulation comparing 2005 model year light duty vehicles to FCVs.