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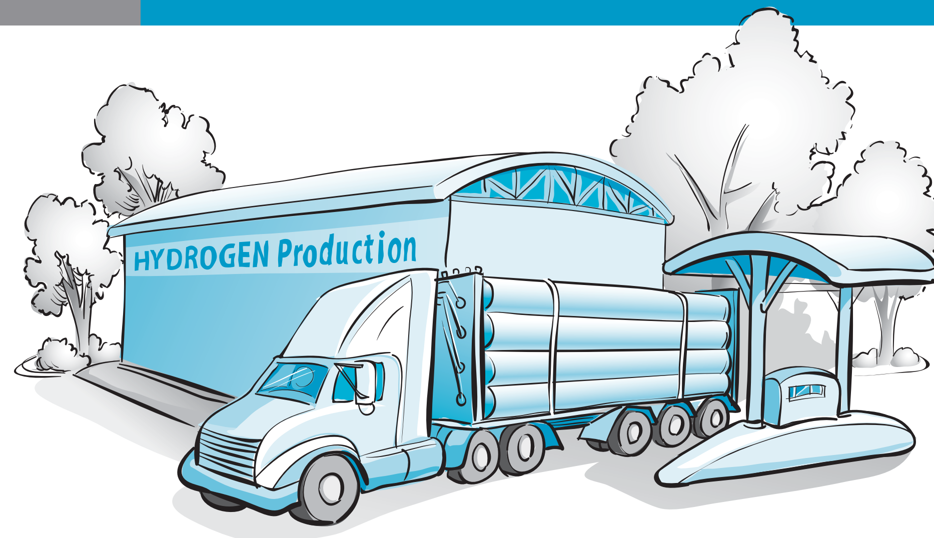
California Fuel Cell Partnership
DRIVING FOR THE FUTURE

The members of the California Fuel Cell Partnership believe fuel cell vehicles powered by hydrogen have the potential to change the future of transportation.

For a complete list of members, please visit us at

www.cafcp.org

H_2 Hydrogen as a Transportation Fuel



The California Fuel Cell Partnership is a unique collaborative of auto manufacturers, energy companies, fuel cell technology companies and government agencies.

To reach California's goals for cleaner air and reduced greenhouse gases we need full-function cars, pickups, vans and SUVs that people want to drive and transit buses they want to ride. These vehicles must be comparable or better than the vehicles we are driving today, and be better for the environment.

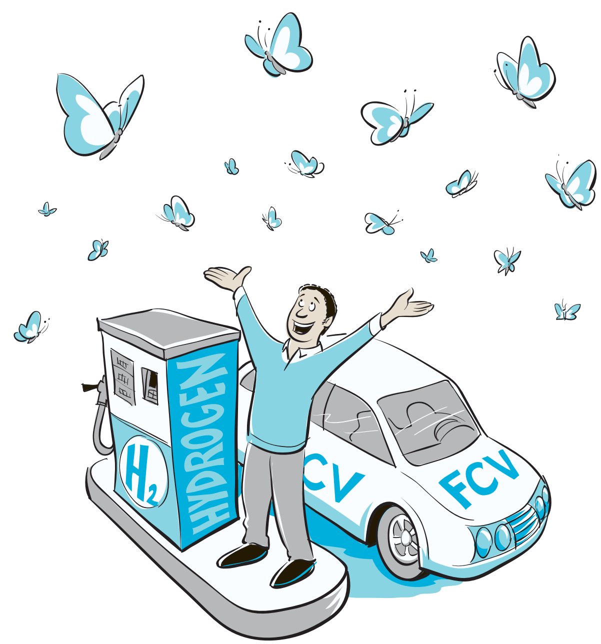
We believe hydrogen-powered fuel cell vehicles are the best option for fulfilling this promise.

BENEFITS OF FCVS AND HYDROGEN

Fuel cell vehicles have the power and performance of an electric vehicle with the range and refueling time of a gasoline vehicle. They are the best of both worlds. FCVs have zero tailpipe emissions—only a bit of water vapor—and require less routine maintenance than conventional vehicles. FCVs will provide the range, durability, reliability, safety and comfort that people expect from their vehicle. They are vehicles that fit people's lifestyles and happen to be very clean and green.

Hydrogen is a natural part of our world and can be produced from local resources. Well to wheels, hydrogen in a fuel cell vehicle produces fewer greenhouse gases, reduces pollution and uses less energy than gasoline in a conventional or hybrid vehicle. When making hydrogen from renewable resources, the total GHGs is almost zero. Hydrogen is economically competitive today and safe to use in a vehicle.

Learn more about FCVs and hydrogen fuel at www.cafcp.org



VEHICLE ROLLOUT

Most of the automakers plan to commercialize fuel cell vehicles around 2015 with thousands of vehicles in target markets worldwide, including California. Today, hundreds of FCVs are in the hands of drivers in California, and hundreds more in other regions of the US, Europe, Japan and Korea. In addition to the passenger vehicles, fuel cell transit buses, heavy-duty trucks and lift trucks for material handling are in use today. Manufacturers are also working on fuel cell motorcycles and scooters, and at least one company is looking at hydrogen for construction equipment.

The California Fuel Cell Partnership's action plan describes fuel cell passenger vehicle, transit bus and station rollout in California. By 2015, the first wave of thousands of FCVs will be sold and leased at dealerships in and around Santa Monica, Torrance, Irvine, Newport Beach, Sacramento and the San Francisco Bay Area. Hydrogen dispensers must be operating at conveniently located stations slightly ahead of vehicle deployment.

Currently, eight new locations are in construction. Six are new stations that will offer only hydrogen at one or two dispensers, without the conveniences that a traditional service station offers. Two of the projects are adding a hydrogen dispenser to an existing retail fuel station. Other projects are in the funding stages; most are adding hydrogen to existing retail fuel stations.

HYDROGEN

Hydrogen is the most abundant element in the universe. It is non-toxic, environmentally benign and odorless. On Earth, hydrogen does not naturally exist by itself and is never found by itself; it must be separated from other substances such as water, plant material, fossil fuel or biogas.

The U.S. hydrogen industry currently produces 9 million tons of hydrogen per year (enough to power 20-30 million cars or 5-8 million homes). More than half of the manufactured hydrogen is used in refining gasoline. Hydrogen is also used to produce fertilizer, process food, manufacture consumer products, make computer chips and treat metals. NASA has used hydrogen as fuel for every spacecraft since the 1950s.

In the nearly 60 years that hydrogen has been used in the U.S., government and industry have developed an infrastructure to produce, store, transport and use hydrogen safely. Many properties of hydrogen, make it safer to use than other fuels, including gasoline and natural gas. Safety systems are designed for hydrogen's properties, which include it being a lighter-than-air gas and the smallest molecule. As with all fuels, hydrogen can be safely handled when people follow the guidelines and understand its behavior.

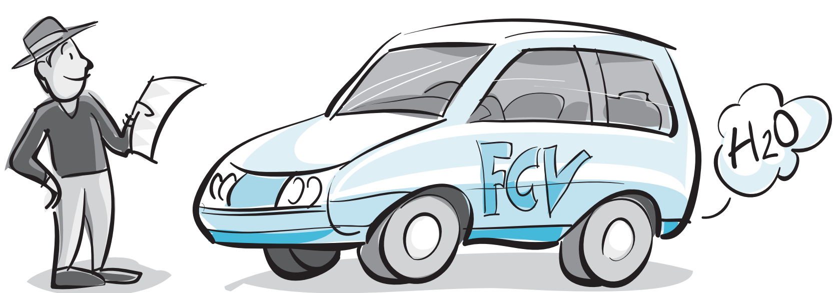
Source: The National Hydrogen Association

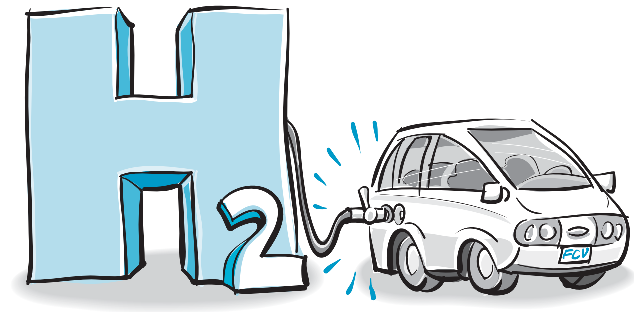
HYDROGEN AS A VEHICLE FUEL

Most of the major auto companies currently have fuel cell vehicles (FCVs) on the road. A fuel cell uses hydrogen and oxygen to create electricity, which provides propulsion in an electric motor and runs the power electronics. The only tailpipe emissions are water vapor and heat. FCVs are very energy efficient, traveling about twice as far on the same amount of energy as an internal combustion engine. FCVs can get 300-400 miles on a tank of fuel.

To refuel, the driver goes to a hydrogen station and fills the tank with compressed, gaseous hydrogen. Most vehicles hold 4-6 kilograms of hydrogen, which has the energy equivalent of 4-6 gallons of gasoline. It takes about 10 minutes to fill the tank.

The metrology standards for hydrogen are being set now and hydrogen should be available as a retail transportation fuel by the end of 2011. The Department of Energy's target cost for hydrogen is $2-3/gge—comparable to a gallon of gasoline.





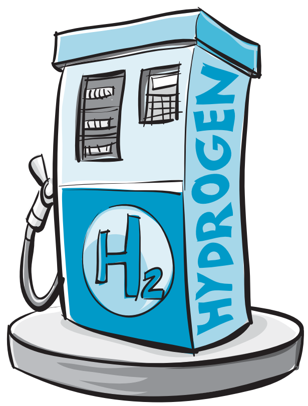
HYDROGEN COSTS

Currently, adding hydrogen to an existing retail station or building a new station is expensive—$750,000 and up. Until the technology matures and costs decrease, federal and state subsidies, tax credits and co-funding options are available for capital and O&M costs. However, a fuel that depends on subsidies cannot survive the market. Businesses and researchers are looking at business models that show when station operators can profit from hydrogen without government subsidies.

Hydrogen is produced domestically using local feedstocks. The price of hydrogen has been remarkably stable over decades. The Department of Energy's target is that the cost of hydrogen will be competitive with gasoline on a per-mile basis. Fuel cell vehicles use about half the amount of fuel as a comparable conventional vehicle. If gasoline is $4 a gallon, then hydrogen is cost competitive at $8 a kilogram. Fuel cell vehicles use only hydrogen. Unlike flex-fuel vehicles, FCV drivers will not choose one fuel over another based on price.

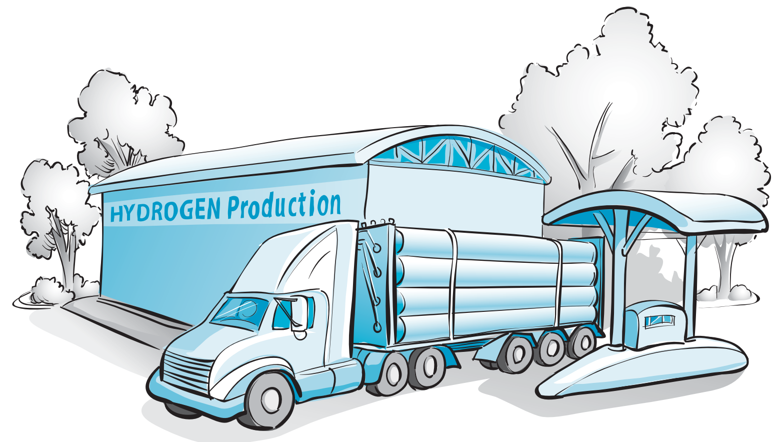
DISPENSING HYDROGEN

A hydrogen dispenser looks similar to a gasoline dispenser. Most dispensers have two hoses, one for H35 and one for H70. Just like the old leaded/unleaded gasoline nozzles, hydrogen nozzles are not interchangeable. A driver cannot connect the H70 nozzle to a vehicle with a H35 tank.



Putting hydrogen into a fuel tank is similar to dispensing CNG or filling a propane tank, and sounds like filling a tire with air. The driver connects the nozzle to the vehicle's receptacle to form a hydrogen tight seal. If the seal isn't complete, the fuel won't flow. Once the connection is firm, fuel flows from the storage cylinders into a cooling unit in the dispenser and into the vehicle's tank. If the vehicle uses H70, the hydrogen first passes through a boost compressor. When the tank is full, the dispenser stops. Filling a tank with hydrogen takes about the same amount of time as filling a gasoline tank.

Dispensing hydrogen is clean and safe. The dispensing equipment is a closed loop system with redundant safety systems. As with gasoline dispensers, hydrogen dispensers have breakaway hoses and e-stops. FCVs are also designed to not turn on if the fuel door is standing open. Because FCVs are electric vehicles, they do not have liquids such as transmission fluid and engine oil. Nothing drips or spills from the vehicle or the dispenser to create safety or environmental hazards.



PRODUCING AND DISTRIBUTING HYDROGEN

Industrial gas companies produce and deliver tons of hydrogen worldwide every day. Most hydrogen is produced by steam methane reforming. It is a cost-effective and energy efficient process, but also produces CO_2. Using biogas—methane from landfills, waste water treatment plants and agricultural waste—reduces CO_2 to nearly zero. Currently, this technology is new and expensive, but it holds great promise for the future.

Smaller quantities of hydrogen are produced by electrolysis with the option of using renewable energy from wind or solar to produce hydrogen with zero greenhouse gas emissions. Hydrogen from electrolysis is usually produced at the point of use.

Some hydrogen is also produced biologically using high-temperature fuel cells to separate hydrogen from biogas to produce heat, electricity and hydrogen. Researchers are making very small quantities of hydrogen from algae, microbes and direct electrolysis of water. These laboratory projects could become the future of fuel production.

Producing and distributing large volumes of hydrogen isn't new. The infrastructure exists today, with alternative production methods on the horizon. What is new is distributing hydrogen to service stations and dispensing it as vehicle fuel.

STATION CONFIGURATION

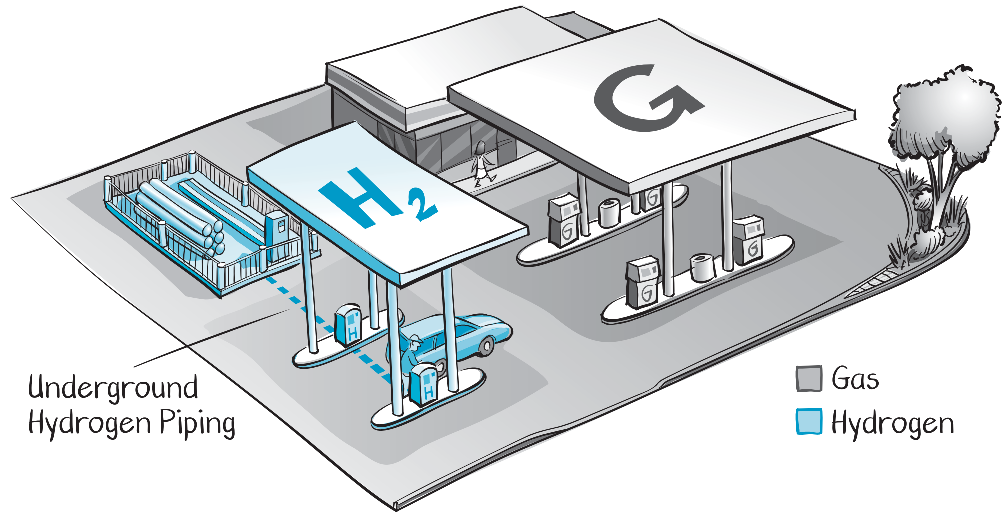
Hydrogen stations are not cookie cutter configurations. Some stations have hydrogen delivered as a liquid or gas, and others make hydrogen on site. Each type of station needs equipment for storing, compressing and dispensing hydrogen.

Liquid hydrogen is stored at -423°F. The storage tank is like a giant thermos and does not require electricity. A distributor's tanker truck fills the station's storage tank. As needed throughout the day, a valve on the liquid tank opens and the hydrogen flows into a small heat exchanger. The now-gaseous hydrogen flows into a compressor where it is compacted to 35 megapascals (called "H35") and then pushed into long steel storage cylinders, or "tubes." The tubes are connected to the dispensers by pipes that can be above- or under ground. Most stations have a boost compressor that further compresses the hydrogen to 70 MPa (H70) during dispensing. (35 MPa=5,000 psi)

If hydrogen is used at a predictable pace, boil-off from the liquid storage tank is minimal. A vent stack from the storage tank allows hydrogen gas to vent if it does boil off. Hydrogen is non-toxic and non-polluting, so the vent stack does not require air pollution controls. Compressed gaseous hydrogen in the tubes can be stored indefinitely with no inventory or energy content loss.

At a station that has fuel delivered as a gas, the equipment is slightly different. The hydrogen is compressed and packed into tubes at the point of production. The distributor delivers a trailer loaded with tubes to the station. The delivery driver connects a feed on the first tube to the pipes that are connected to the boost compressor and dispensers. A gaseous station requires less equipment, but it cannot store as much fuel as a liquid station and the tube trailer must be integrated into the site design.

The third option is to make hydrogen at the station. Some stations have small reformers that use natural gas or biogas onsite. The reformer is usually inside a building that is on or next to the station's property. The compressor and storage tubes are nearby. An on-site reformer provides fuel production at the point of sale, but requires substantial space and capital investment. A small reformer could be at the terminal or distributor's property to fill tube trailers for customer stations.



Another choice for on-site fuel production is to use an electrolyzer and solar panels to make hydrogen from water and electricity. Electrolyzers look like commercial refrigerators and are attached to a water line. Usually, solar panels on the property are connected to the grid, feeding electricity to the utility during peak daylight hours. At night, when the demand and rates are lower, the electrolyzer "buys back" electricity to make hydrogen.

Currently available electrolyzers can make about 100 kg/day. Electrolyzers provide zero-emission hydrogen and the flexibility of making fuel on site. Although they are smaller than a reformer, an electrolyzer still needs space on the forecourt or nearby.

Nationwide, about 60 hydrogen stations are in operation in the U.S., all built within the last 10 years. The technology for making, storing and dispensing hydrogen has rapidly changed in a decade, and will continue to make progress. The technology has stabilized to a point where the first codes and standards have been published, and others are in process.