

California

FUEL CELL
PARTNERSHIP

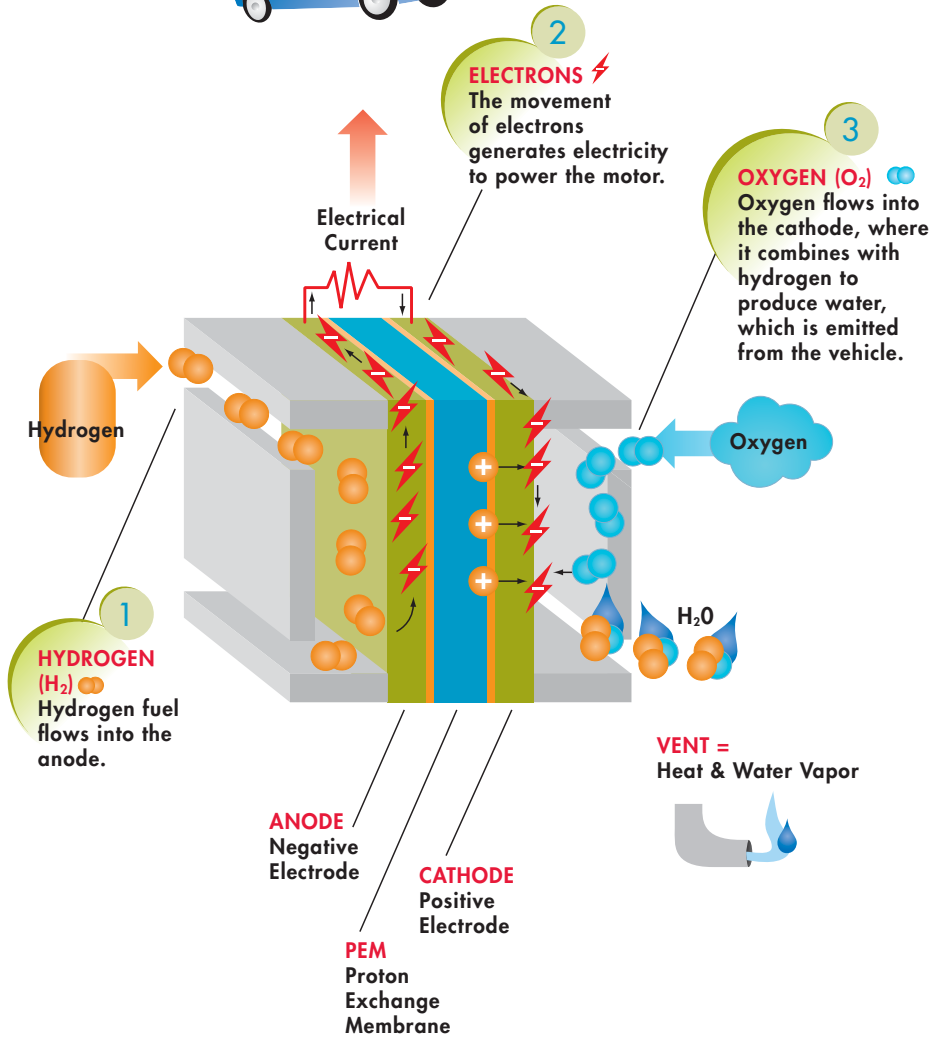


DRIVING FOR THE FUTURE

HOW IT WORKS

www.fuelcellpartnership.org

FUEL CELL ENERGY POWERS THE CAR!



Fuel cells also provide power to forklifts, airport tugs and even NASA's space shuttles. Large fuel cells can create electricity for houses and buildings. Tiny fuel cells can run laptop computers or digital cameras.

Automakers and bus builders use proton exchange membrane, or PEM, fuel cells to power the vehicles. A PEM fuel cell combines hydrogen fuel with oxygen from the air to generate electricity. In its simplest form, a PEM fuel cell is two electrodes—the anode and the cathode—separated by a catalyst-coated membrane. Fuel cells produce electricity as long as fuel is supplied.

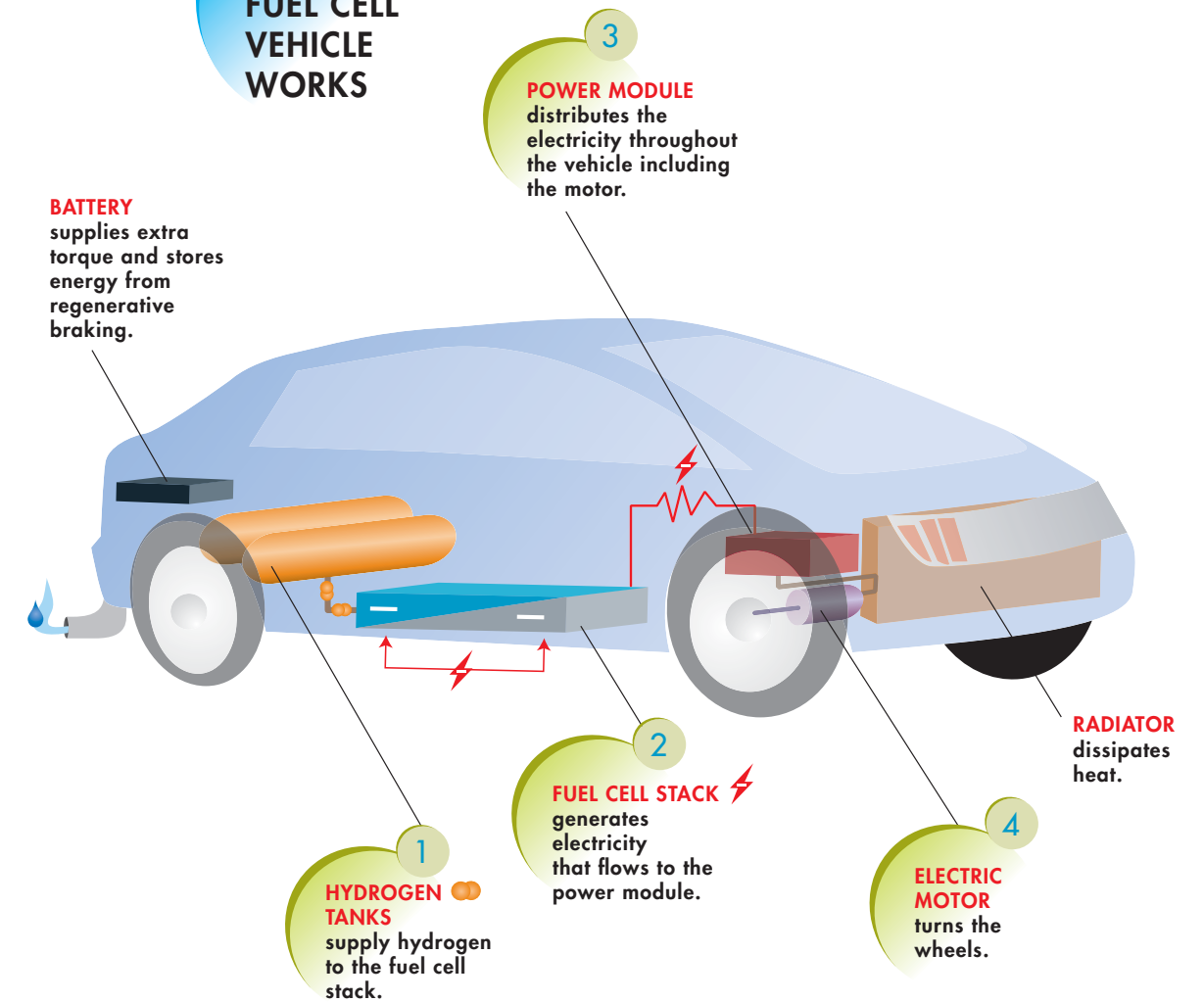
A fuel cell stack is made up of many PEM fuel cells that are stacked together, like slices in a loaf of bread. The stack generates electricity that powers the vehicle.

Fuel cell vehicles are electric vehicles that are refilled, not recharged like a battery.

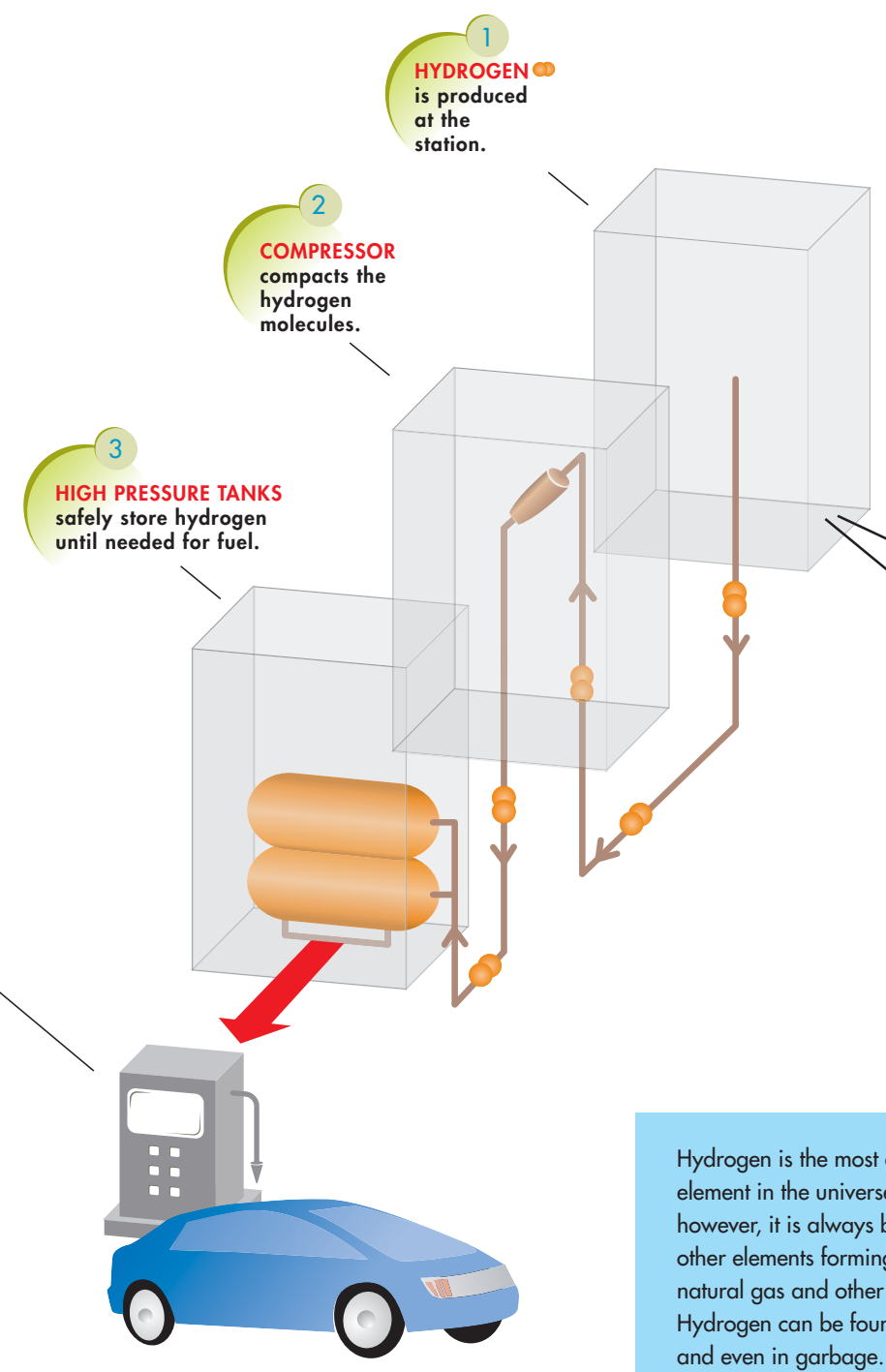
The electricity from the fuel cell stack flows into a power module, which distributes the electricity to the electric motor that turns the wheels of the car. The power module also distributes electricity to the air conditioning, sound system and other on-board devices.

A high-voltage battery, similar to those in gasoline hybrids, provides extra torque when accelerating or climbing a hill, and helps improve fuel economy.

HOW A FUEL CELL VEHICLE WORKS



STATIONS CAN PRODUCE FUEL ON-SITE



1 **HYDROGEN** is produced at the station.

2 **COMPRESSOR** compacts the hydrogen molecules.

3 **HIGH PRESSURE TANKS** safely store hydrogen until needed for fuel.

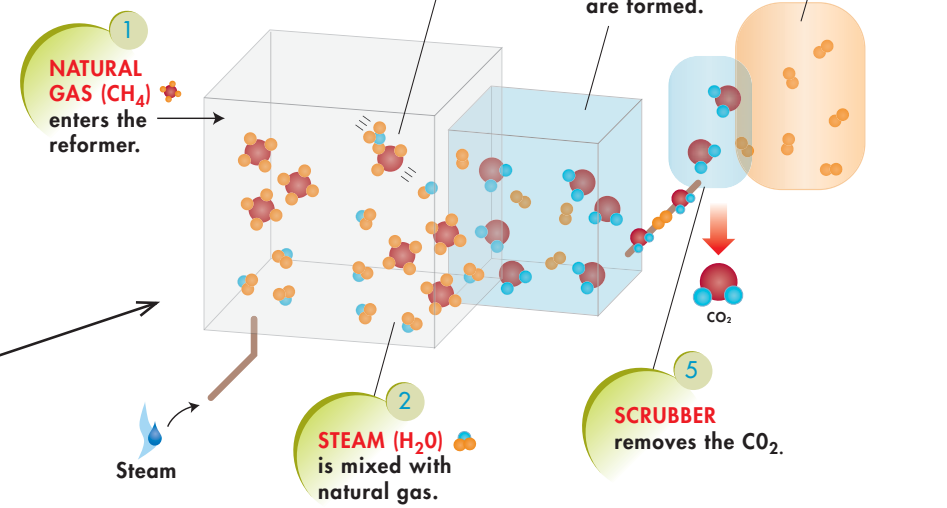
4 **DISPENSER** regulates hydrogen flow to vehicle tanks.

Hydrogen is the most abundant element in the universe. In nature, however, it is always bonded to other elements forming water, natural gas and other fossil fuels. Hydrogen can be found in plants and even in garbage. To produce hydrogen, we unlock the chemical bonds in the molecules.

In California and around the world, some fuel stations produce hydrogen on-site. These stations produce fuel with either a reformer or an electrolyzer, resulting in gaseous hydrogen. A compressor/pump pulls the hydrogen through a pipe, compresses it to 350 bar and then pushes it into long cylinders for storage. The hydrogen remains compressed at 350 bar in the tanks until a vehicle needs it for refueling. Some stations have a second compressor before the dispenser to compress the fuel to 700 bar.

Currently, most hydrogen is produced by steam reforming natural gas. Steam reforming combines natural gas with super-heated steam and a catalyst. The heat causes the molecules to collide, releasing the hydrogen from both the hydrocarbon and water molecules. Immediately, the loose oxygen and carbon combine into carbon dioxide, leaving the hydrogen molecules free. Hydrogen can also be produced by reforming biogas, methanol, gasoline or ethanol through a similar process.

STEAM REFORMING PRODUCES HYDROGEN



1 **NATURAL GAS (CH₄)** enters the reformer.

2 **STEAM (H₂O)** is mixed with natural gas.

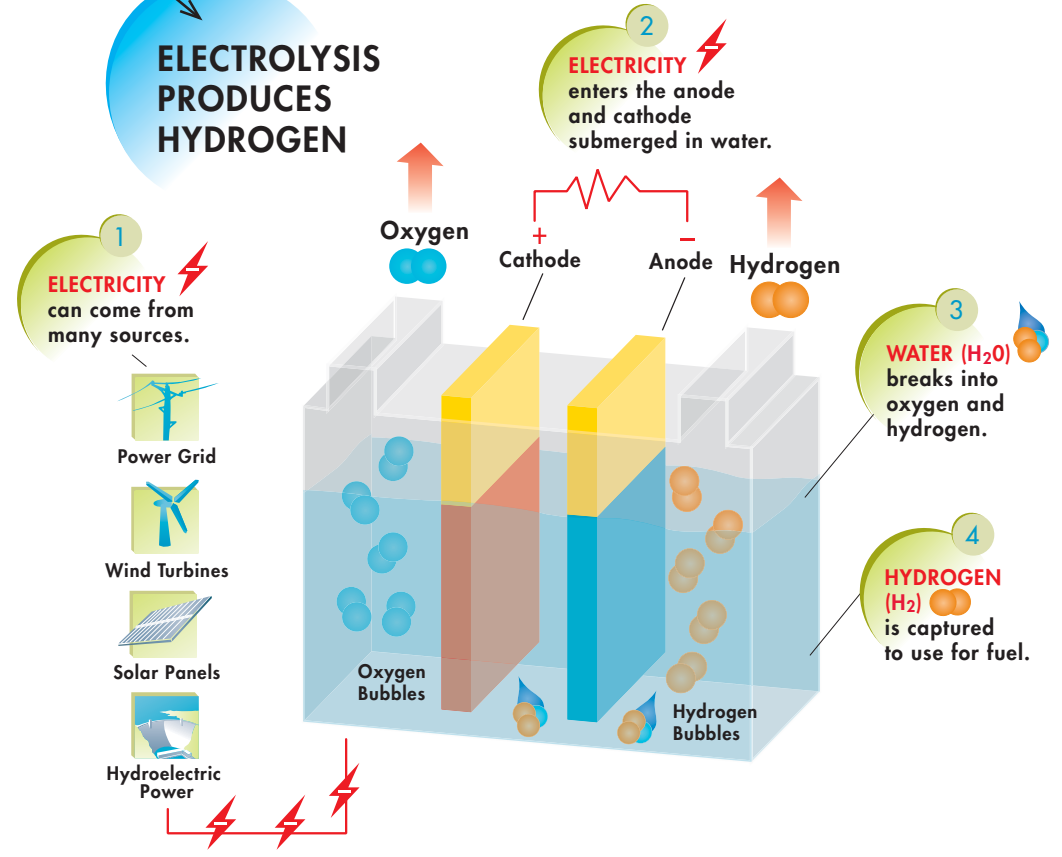
3 **HEAT** breaks apart the molecules.

4 **HYDROGEN AND CARBON DIOXIDE** are formed.

5 **SCRUBBER** removes the CO₂.

6 **END RESULT** is hydrogen that can be used for many purposes, including fuel.

ELECTROLYSIS PRODUCES HYDROGEN



1 **ELECTRICITY** can come from many sources.

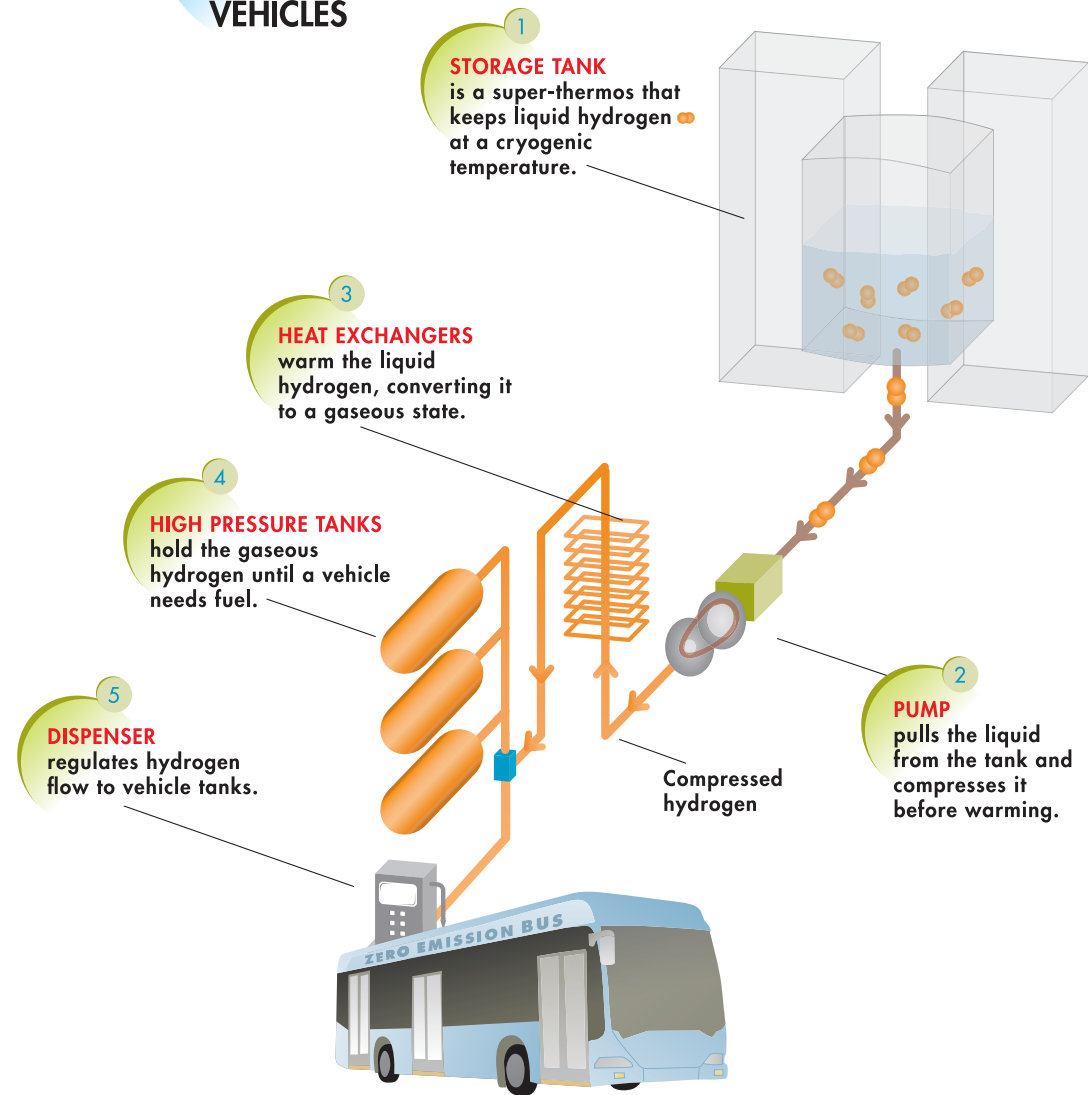
2 **ELECTRICITY** enters the anode and cathode submerged in water.

3 **WATER (H₂O)** breaks into oxygen and hydrogen.

4 **HYDROGEN (H₂)** is captured to use for fuel.

Electrolysis passes a current through water, splitting the water molecules into hydrogen and oxygen. The electrolyzer contains a thin membrane coated with a catalyst to speed the reaction. The hydrogen is stored for fuel and the oxygen is released into the atmosphere. When hydrogen is produced by renewable energy and used in a fuel cell vehicle, it is nearly pollution-free and has almost no impact on the environment. Researchers are exploring even more renewable sources of hydrogen, including biomass and algae.

HYDROGEN STATIONS REFUEL THE VEHICLES



Hydrogen stations can store hydrogen as a gas or liquid, and produce hydrogen on-site or have hydrogen delivered by a tanker or via a pipeline. The station in this illustration stores the hydrogen as a liquid at a cryogenic temperature of -423°F (-253°C).

A reciprocating pump pulls the liquid hydrogen from the storage tank. As the hydrogen gets warmer, it converts to a gas—just like boiling converts water to steam. The gas is compressed and stored.

To fuel, the vehicle driver connects a dispenser nozzle to a receptacle on the vehicle. The dispenser pushes the hydrogen into the vehicle's tank, maintaining the compression. Filling the tank takes just a few minutes!

The California Fuel Cell Partnership is a collaboration of auto manufacturers, energy providers, government agencies, technology companies and transit agencies that work together to promote the commercialization of hydrogen fuel cell vehicles.

Today, CaFCP members operate fuel cell vehicles and hydrogen stations in California, and in other regions of the U.S. and countries around the world. More cars and buses are on California's roads than any other region of the world. California also has the most hydrogen stations.

PUBLIC TOUR

On the fourth Friday of every month, the California Fuel Cell Partnership welcomes guests to tour the facility and hydrogen station, and ride in a fuel cell vehicle.

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THE BENEFITS

Fuel cell vehicles powered by hydrogen are a long-term solution to air quality, energy dependence and climate change issues.

- Fuel cell vehicles have great acceleration, are fuel efficient and virtually silent.
- Fuel cell vehicles only emit heat and water.
- Fuel cell vehicles have the range, performance and reliability people expect in their vehicles.
- Every country and region of the world can produce hydrogen from a variety of sources using multiple methods.
- Hydrogen can be made from renewable sources of energy with almost no environmental impact.
- Stations can produce hydrogen fuel on-site using several different methods.

THE NEXT STEPS

Many automakers have identified 2015 as the beginning of the commercial market for fuel cell vehicles. To prepare for thousands, and then tens of thousands of FCVs in California, we must:

- Build retail-ready hydrogen stations in the communities where FCVs will first be sold and leased. Customers need convenient access to fuel where they live and work.
- Synchronize and augment regulations and policies to launch California on a path to meet our 2050 climate goals and help coordinate fuel availability to vehicle deployment.
- Complete the initial codes and standards so that hydrogen can be sold as a retail transportation fuel.
- Support business models developed by the private sector to show how hydrogen can eventually compete with gasoline and yield profits for business.
- Support early market communities to meet their environmental and energy goals, reducing local emissions as well as their carbon footprint.

Read CaFCP's *Hydrogen Fuel Cell Vehicle and Station Deployment Plan: Progress and Next Steps* at www.cafcp.org.



DRIVING FOR THE FUTURE

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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