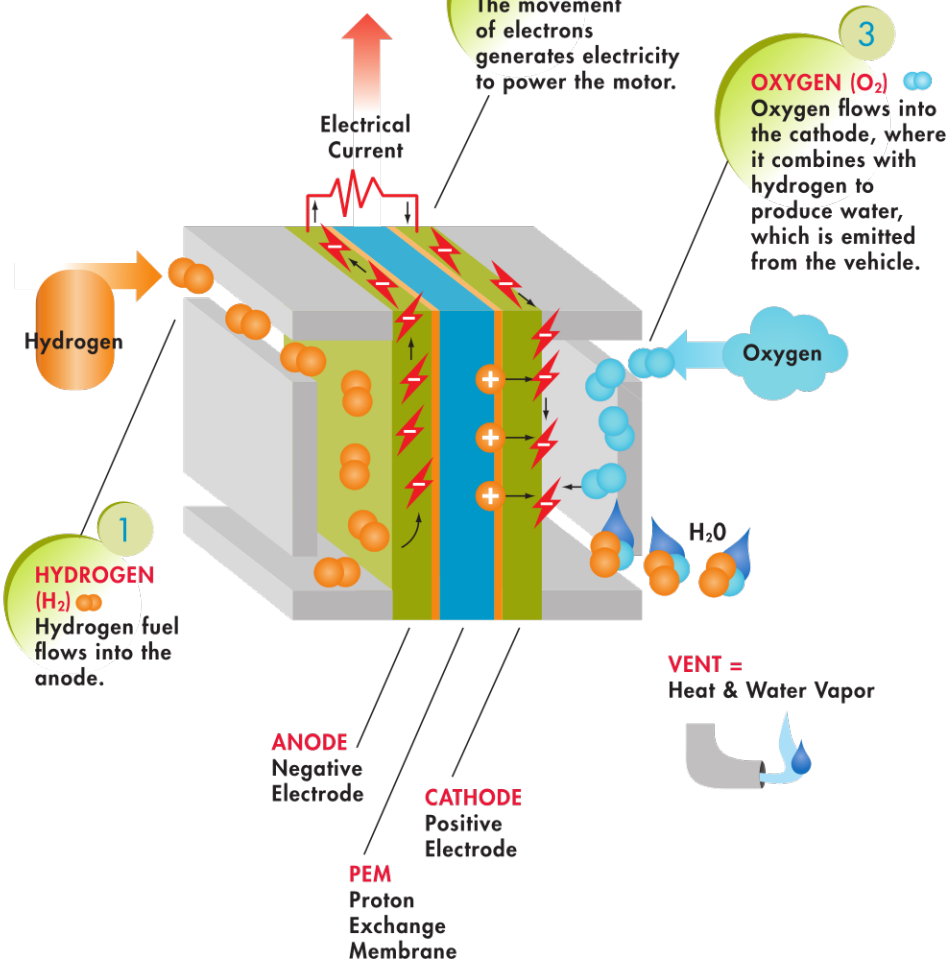
California
FUEL CELL
PARTNERSHIP

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.

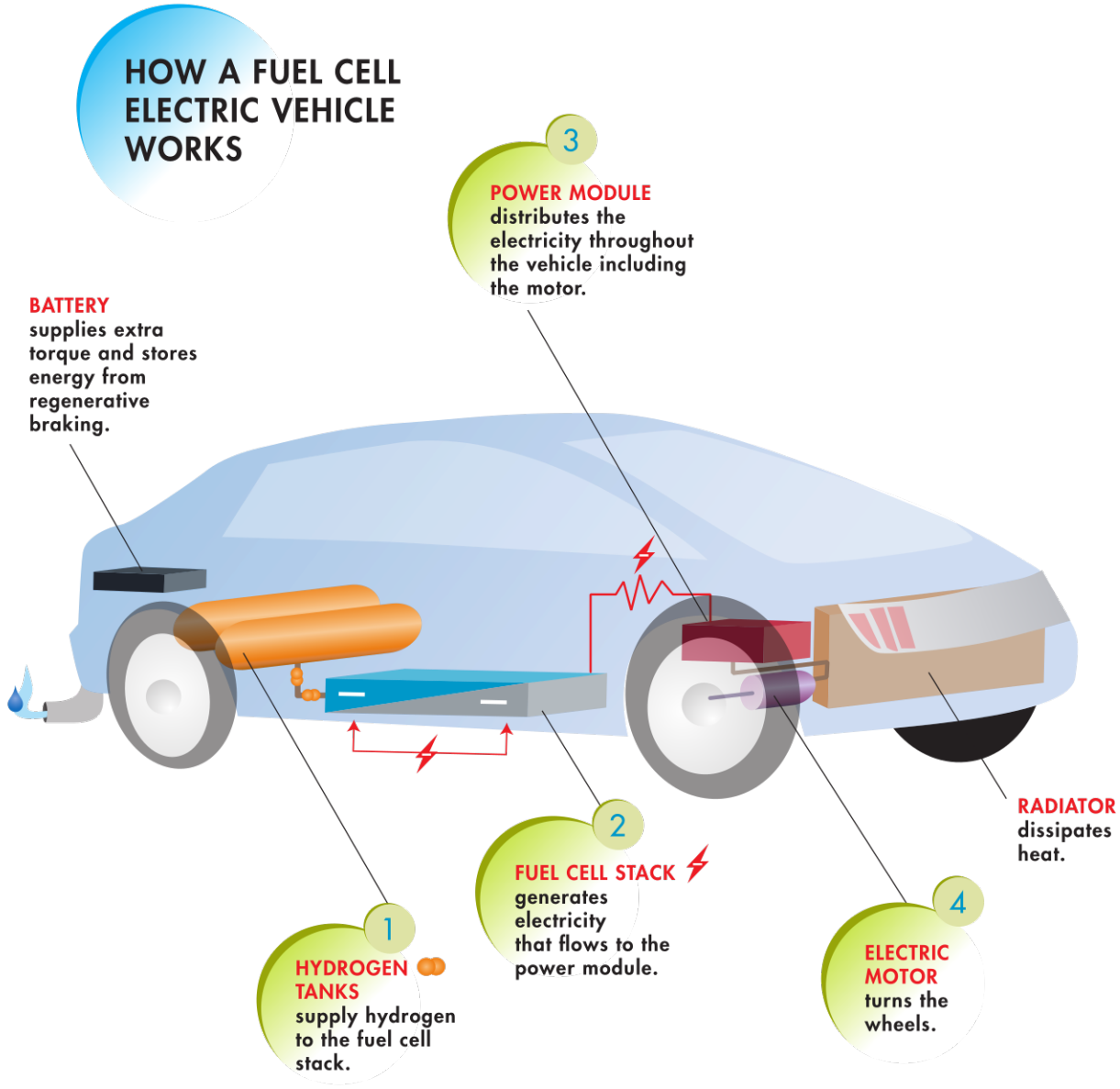
Automakers and bus builders use proton exchange membrane, or PEM, fuel cells to power the vehicles. A PEM fuel cell combines hydrogen fuel with oxygen from the air to generate electricity. In its simplest form, a PEM fuel cell is two electrodes—the anode and the cathode—separated by a catalyst-coated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

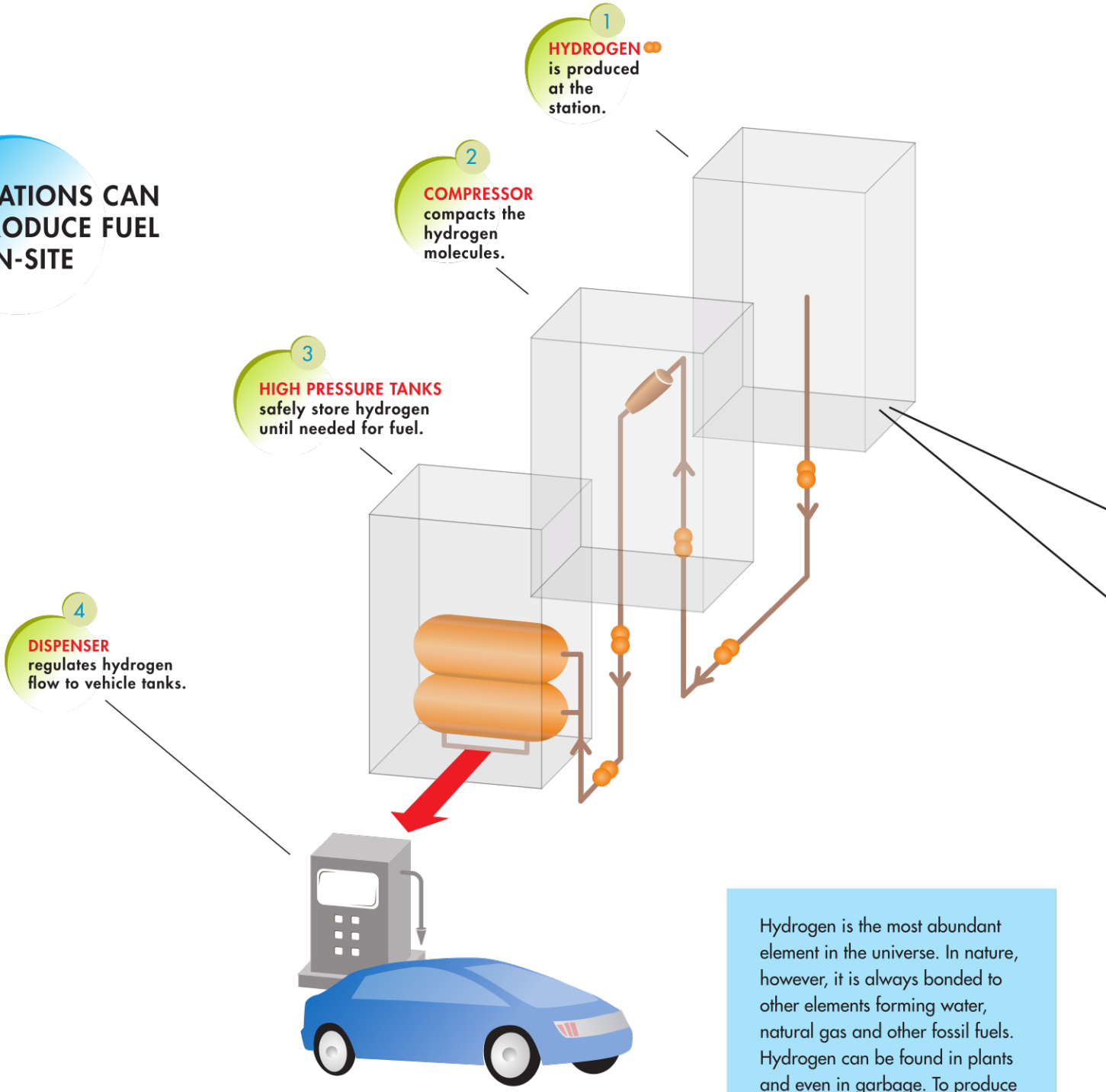
Fuel cell electric vehicles are electric vehicles that are refilled, not recharged like a battery.

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.



STATIONS CAN PRODUCE FUEL ON-SITE



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.

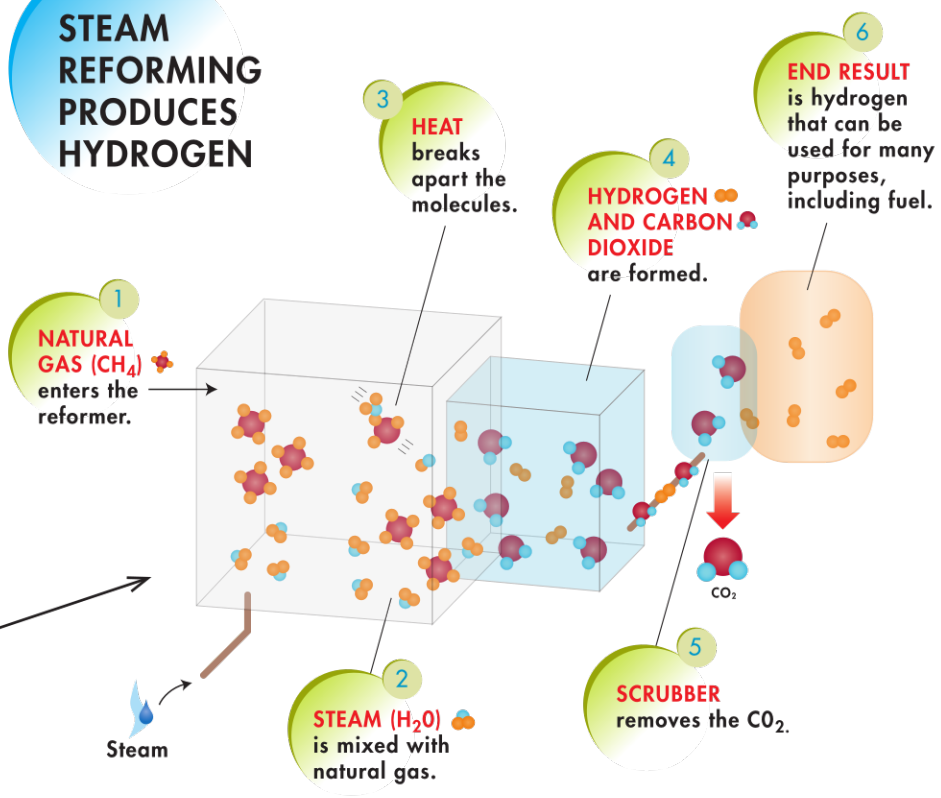
In California and around the world, some fuel stations produce hydrogen on-site. These stations produce fuel with either a reformer or an electrolyzer, resulting in gaseous hydrogen.

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. Many stations have a booster compressor before the dispenser to compress the fuel to 700 bar.

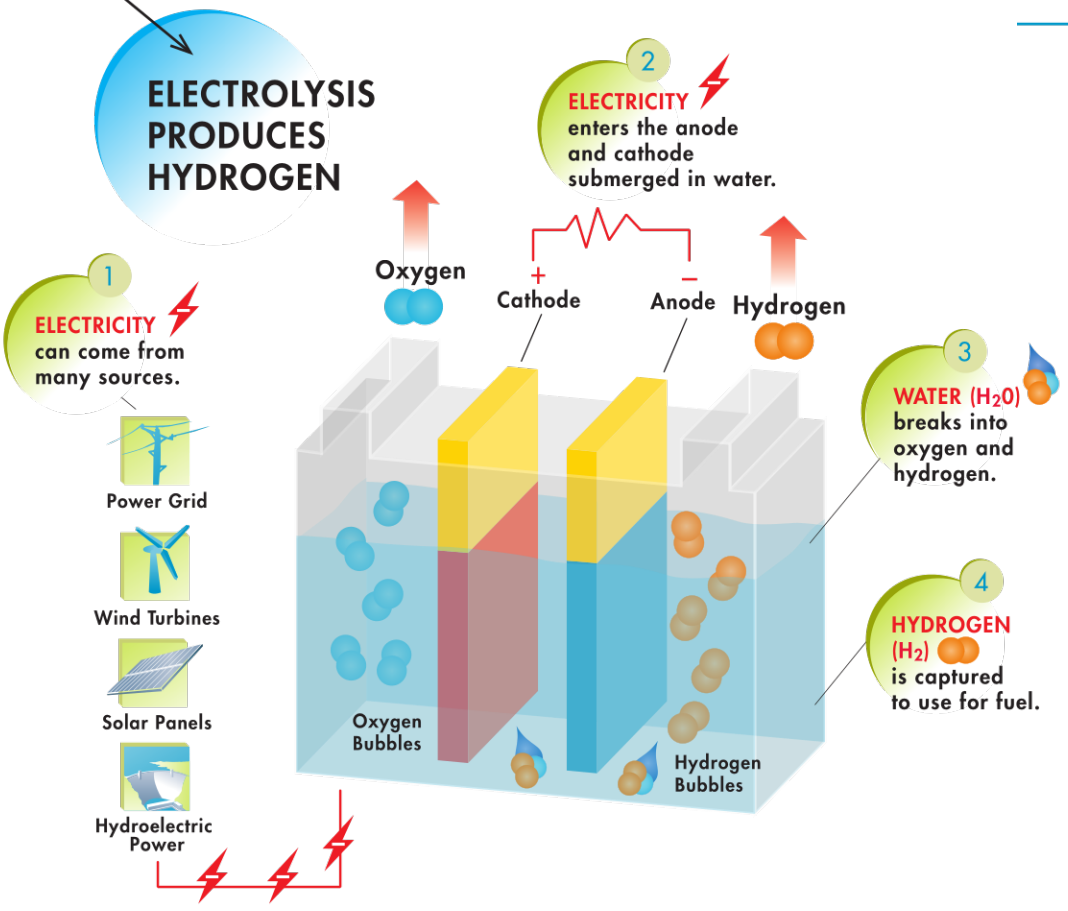
Currently, most hydrogen is produced by steam reforming natural gas. Steam reforming combines natural gas with super-heated steam and a catalyst. The heat causes the molecules to collide, releasing the hydrogen from both the hydrocarbon and water molecules. Immediately, the loose oxygen and carbon combine 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



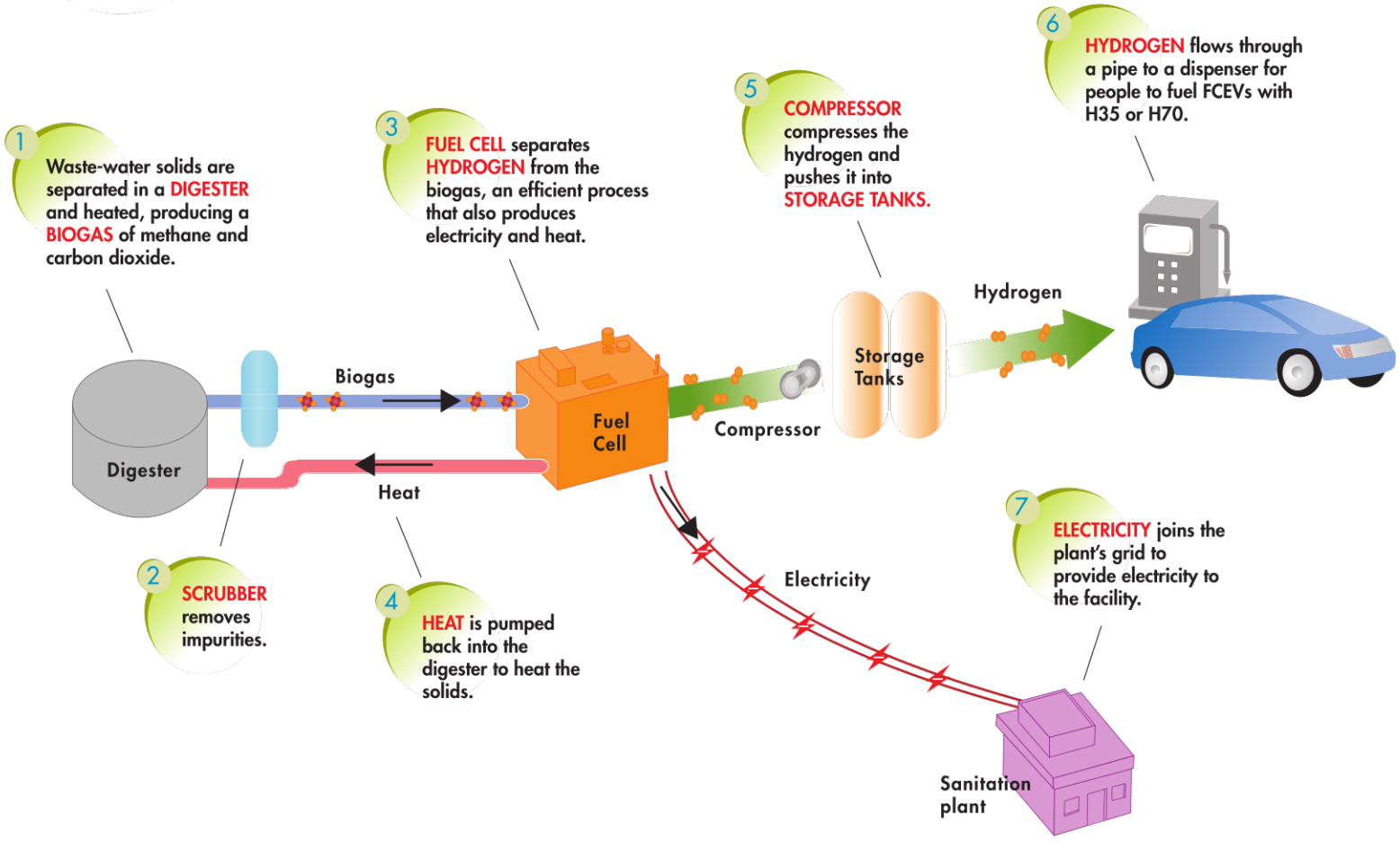
ELECTROLYSIS PRODUCES HYDROGEN



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 electric 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.

BIOGAS MAKES HYDROGEN



Wastewater solids enter an anaerobic digester at the wastewater treatment plant. Microbes convert the waste into a biogas (CH_4) similar in composition to natural gas, but with more impurities. A scrubber removes many of the impurities, including carbon and sulfur. Cleaned biogas enters a stationary fuel cell where heat and water vapor separate CH_4 into hydrogen and CO_2. Separating the gas creates heat and water vapor, which is used in the reaction in the fuel cell. Excess heat goes back into the digester. The fuel cell also consistently and reliably produces electricity that is sent to the facility's grid.

Hydrogen enters one more cleaning process (not in the diagram) and is then compressed and stored at just above 350 bar to support H35 fills. Hydrogen flows through a small underground pipeline to a public station. Additional storage tanks at the station hold compressed hydrogen for immediate use. A booster compressor pumps up the pressure to 700 bar for the vehicles that fuel at H70. As the storage tanks at the station run low, additional compressed hydrogen from the energy station fills the tanks.

From well to wheels, a biogas system creates net zero greenhouse gases, virtually zero criteria pollutant emissions and makes commercial use of hazardous waste.

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 electric 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.

THE BENEFITS

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

- FCEVs have great acceleration, are fuel efficient and virtually silent.
- FCEVs only emit heat and water.
- FCEVs have the range, performance and reliability comparable to conventional 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.

A California Road Map

"A California Road Map: Bringing Hydrogen Fuel Cell Vehicles to the Golden State," describes the infrastructure needed to successfully launch the commercial FCEV market. A network of 68 stations operating statewide in California will enable the launch of FCEVs. This small network will provide consumers with confidence that they can fill up near their homes, close to their jobs or at key locations and destinations throughout the state. At the same time, hydrogen stations must have an adequate fuel supply on a daily basis and during peak hours to supply the growing number of vehicles. Providing customers with sufficient locations will initially result in more available hydrogen supply than needed, but location and minimum station coverage are essential to the customer adoption that will launch the early commercial market. At 100 stations statewide, supply and demand will be consistent enough to sustain market growth.

http://cafcp.org/carsandbuses/caroadmap

A Bus Road Map

"A Road Map for Fuel Cell Electric Buses in California: A zero-emission solution for public transit" looks at the progress of FCEBs in California and across the globe, and offers recommendations to state and federal policy makers about actions they can take to put FCEBs on the path to full commercial readiness. It calls for two Centers of Excellence that incorporate:

- Two single production runs of 40 buses each to provide capital cost at or below $1 million from the vehicle suppliers
- 40 FCEBs at each location that meet transit agency requirements and are operated in normal revenue service
- A 12-year operating period
- Fuel use that is sufficient to achieve a fuel cost-per-mile comparable to diesel and natural gas buses
- Regional training and education for transit staff and community stakeholders

http://cafcp.org/carsandbuses/busroadmap

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

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