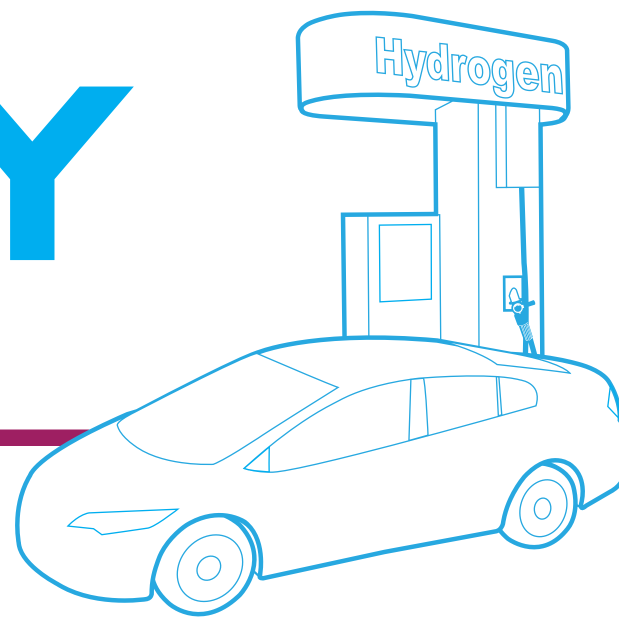
AIR CLIMATE ENERGY WATER SECURITY

California
FUEL CELL PARTNERSHIP
DRIVING FOR THE FUTURE



A guide to understanding the well-to-wheels impact of fuel cell electric vehicles.

THE PROBLEM

AIR: California is home to some of the most polluted air in the United States, with 89% of residents living in counties with unhealthy air during some parts of the year.[1]

ENERGY: About 38% of the energy use in California is associated with transportation.[2]

CLIMATE: The 2012 California greenhouse gas emissions were 459 million metric tonnes of carbon dioxide equivalent. Transportation is the largest source of emissions, accounting for 37 percent.[3]

WATER: Producing fuels requires substantial water input. Biofuel feedstocks need water for growth and conversion to fuel, and petroleum feedstocks require large volumes of water for drilling, extraction, and conversion into petroleum products. In addition, the fuel lifecycle has common sustainability issues, including water quality, limited water resources, and land degradation and ecosystem disruption.[4]

SECURITY: Although the state is the 10th largest U.S. producer of crude oil, California produces only 37% of what we use. In 2007, California spent nearly $60 billion for imported gasoline and diesel.[5]

A SOLUTION

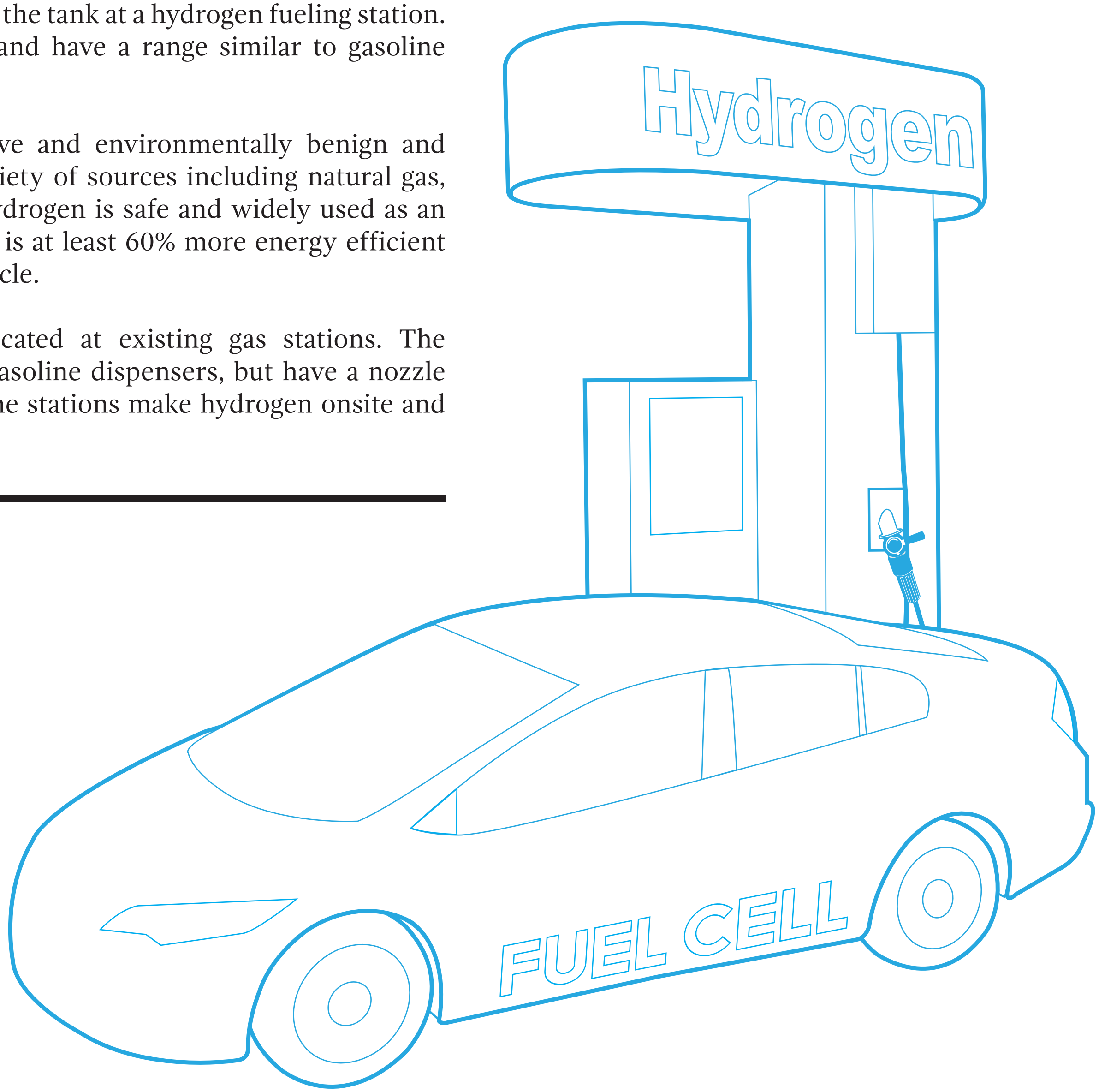
Fuel cell electric vehicles powered by hydrogen are zero-emission vehicles that reduce pollution, greenhouse gases and dependence on petroleum.

FCEVs are part of a portfolio of choices that include battery electric vehicles, low carbon fuels and public transit that will reduce transportation's impact on the environment.

Fuel cell electric vehicles drive using electricity created on-board from hydrogen and oxygen. Hydrogen is stored in the vehicle as a compressed gas. When running low, a driver fills the tank at a hydrogen fueling station. FCEVs take 5 to 7 minutes to fill and have a range similar to gasoline vehicles (250-400 miles).

Hydrogen is nontoxic, noncorrosive and environmentally benign and can be produced locally from a variety of sources including natural gas, biogas and electrolysis of water. Hydrogen is safe and widely used as an industrial gas. In a FCEV, hydrogen is at least 60% more energy efficient than gasoline in a conventional vehicle.

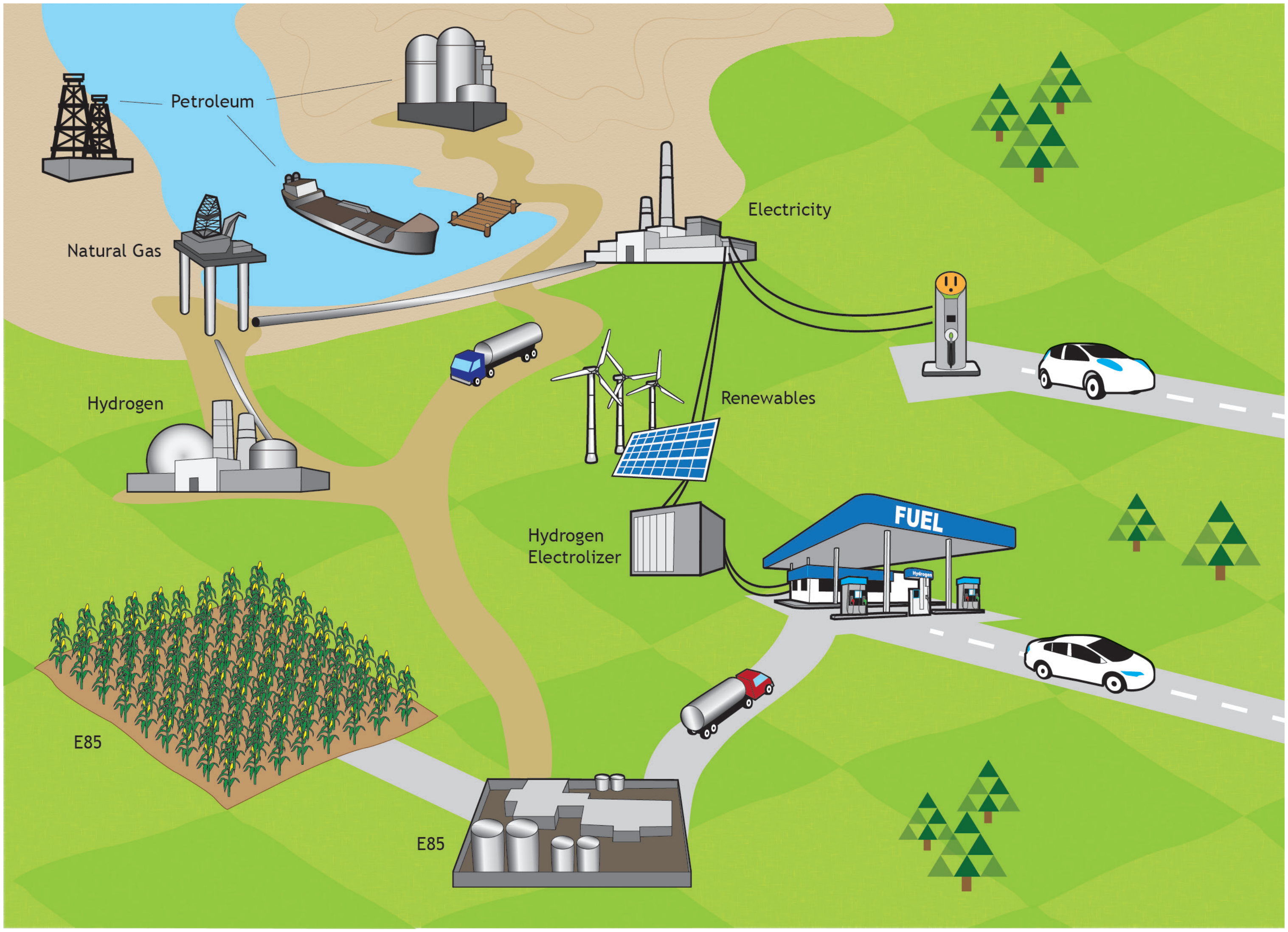
Hydrogen stations are usually located at existing gas stations. The dispensers appear very similar to gasoline dispensers, but have a nozzle designed for a compressed gas. Some stations make hydrogen onsite and others have fuel delivered.



FROM WELL TO WHEELS

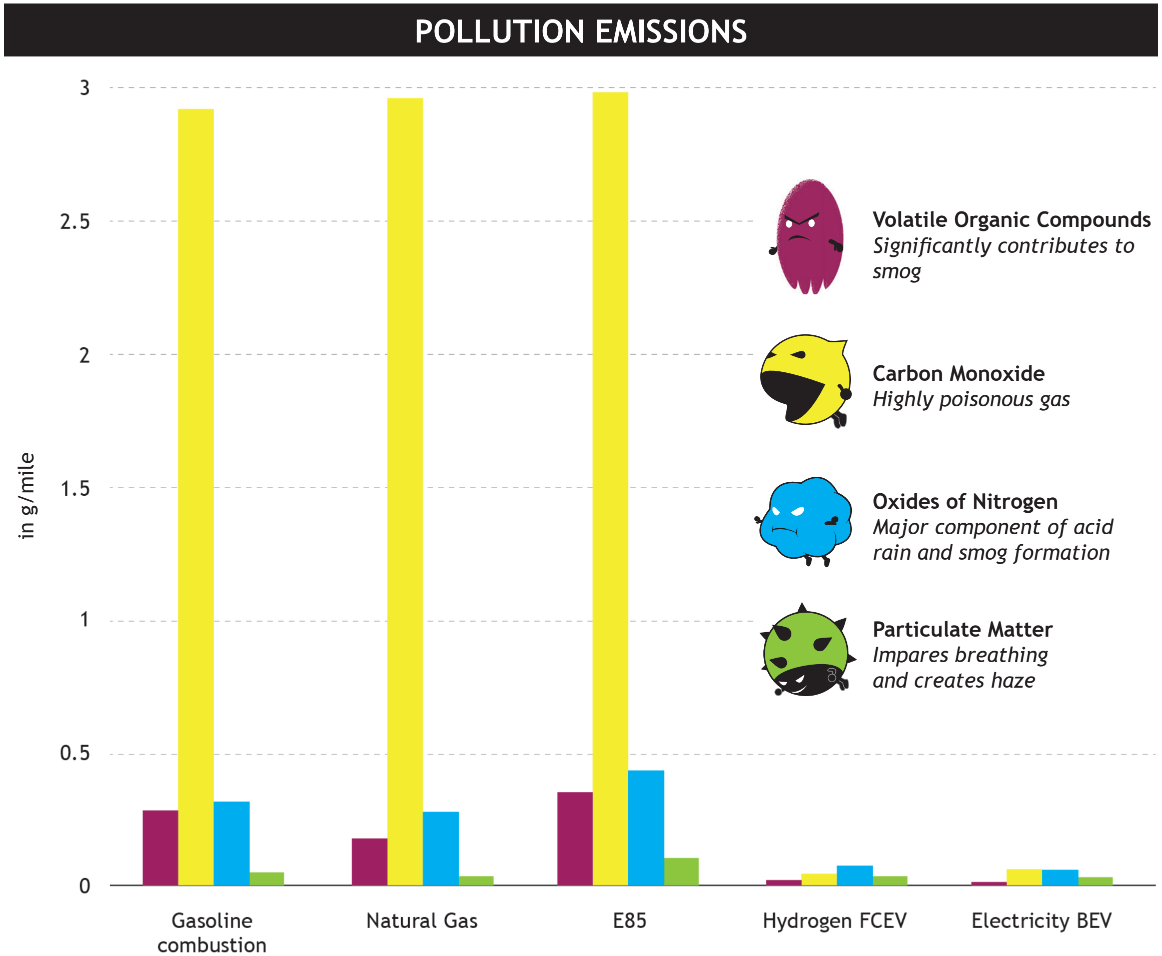
Producing, distributing and using fuel consumes energy and water, and creates emissions. With modeling software, researchers calculate the energy and emissions intensity of fuel in the well-to-tank phase and then in the tank-to-wheel phase. The combined well-to-wheels results present a comprehensive assessment of efficiencies and impacts.

The following pages present results from models created by national labs and universities that show how hydrogen and fuel cell electric vehicles compare to other fuels and vehicles on a well-to-wheels basis.



AIR

Four major air pollutants in California are volatile organic compounds, carbon monoxide, oxides of nitrogen and particulate matter. Studies show direct relationships between health and air quality. In a Cal State Fullerton study, Dr. Jane Hall stated, "Dirty air is like a $28 billion lead balloon on our economy."[6]



GREET V1_2013
Assumes a 2020 model year mid-sized sedan, California mix of electricity in all pathways, and California blend of gasoline.
greet.es.anl.gov

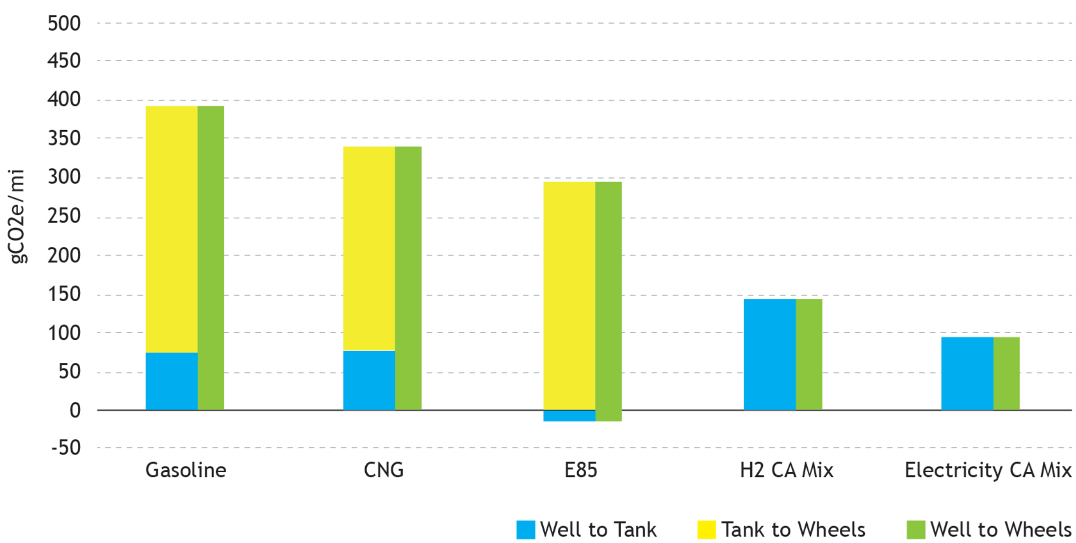
Hydrogen production is a chemical reaction; using heat and catalysts to release hydrogen molecules from natural gas or biogas, or using solar or wind energy to electrolyze water. The fuel cell in an FCEV also uses a chemical reaction to convert hydrogen and oxygen into electricity.

Because most criteria air pollutants are related to combustion, FCEVs have almost zero air pollutants from well to wheels. The small spikes you see in the chart are mostly related to electricity used to compress and dispense the fuel at the station. (Please note that FCEVs and BEVs have zero tailpipe emissions.)

CLIMATE

The build-up of greenhouse gases—CO_2, methane, nitrous oxide and fluorinated gases—is greater than the earth can compensate for and the global temperature is slowly rising. (U.S. EPA) To reduce GHGs, we must reduce the carbon intensity of the entire process by using more renewable power, making fuel at the point of distribution, reducing miles traveled and driving cleaner and more efficient vehicles, like fuel cell electric and battery electric cars.

GHG EMISSIONS



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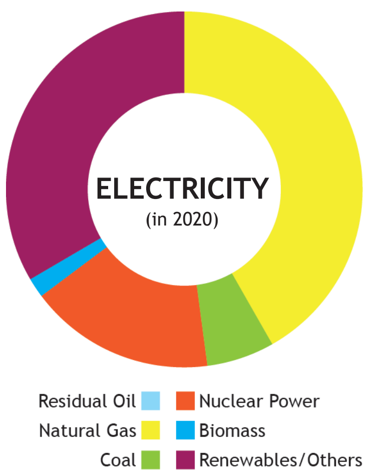
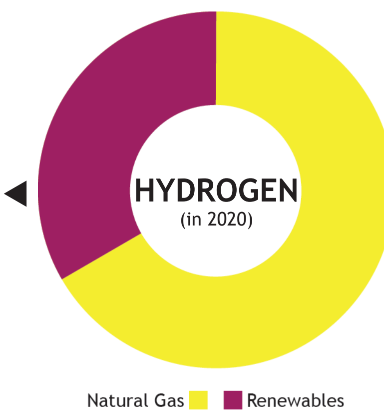


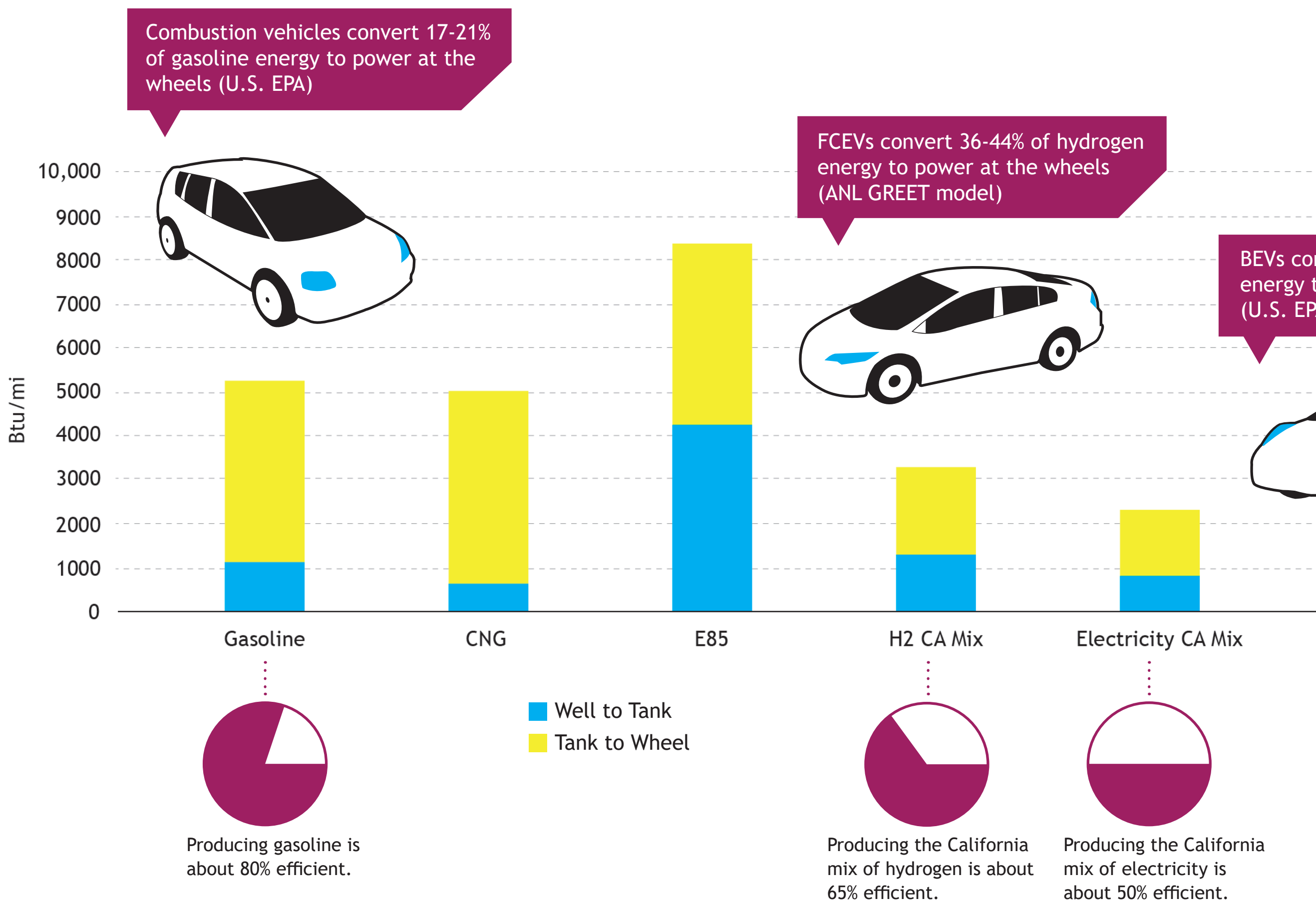
"California mix" refers to the feedstocks used to produce electricity and hydrogen. Compared to other states, California has a cleaner grid because most of our electricity comes from burning natural gas instead of coal and we have a larger share of renewables in the system.

Hydrogen is also produced from natural gas, but through a chemical process instead of combustion, and in California 33% of hydrogen for transportation must come from renewables, such as solar, wind, biogas or biomass.



ENERGY

W2W efficiency is the number of BTUs needed to drive one mile including all the inputs such as diesel to drive a tractor to farm corn, natural gas to heat water for gasoline or hydrogen, and electricity to run dispensing equipment. Fewer BTUs indicate a more efficient well-to-wheels system.



GREET V1_2013

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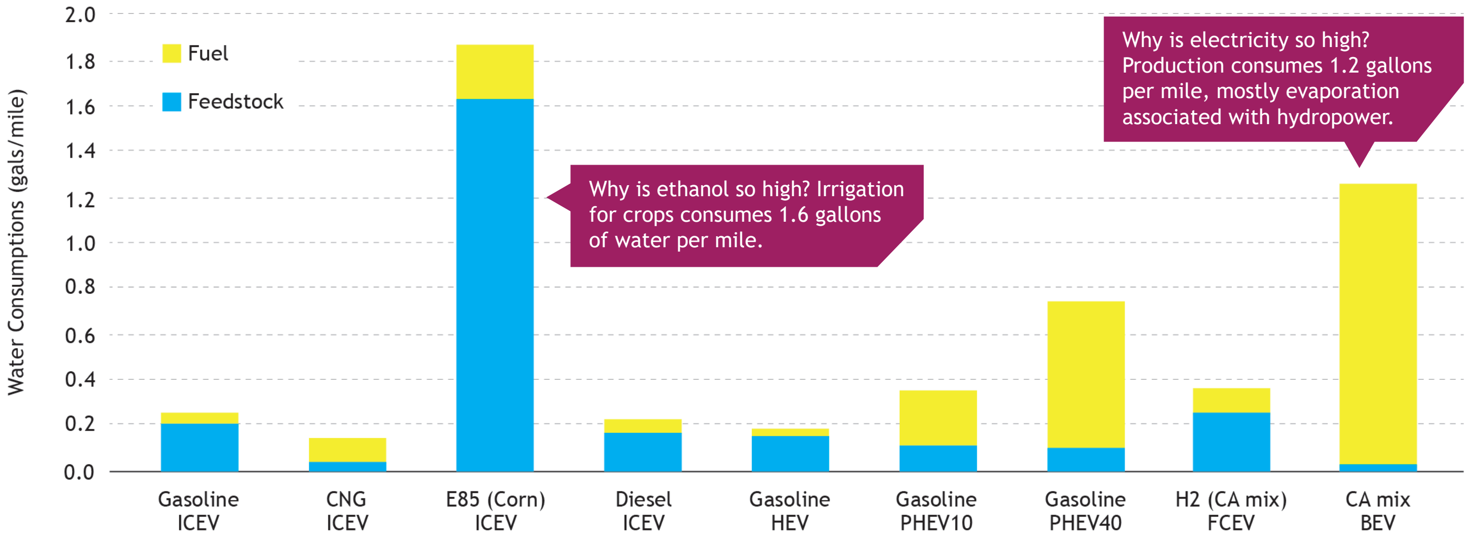
ENERGY EFFICIENCY & FUEL ECONOMY

Energy efficiency is important, but not the whole picture. Fuel economy—"miles per gallon"—is a result of engine (or motor) efficiency, size, weight, road conditions and driving style. A bus and a car could both have a fuel cell that operates at 60% efficiency, but because the bus is heavier and stops and starts often, it will have a lower fuel economy than the car.

WATER

The energy industry is a major consumer of water and the issue of water use in transportation continues to grow. “Consumptive water use” is the amount of water used by a fuel feedstock plus production minus water output that is recycled and reused, although some processes output degraded water.[4] Some fuels are also water pollutants from a single point (tanker spills, broken pipes) or run-off from roads and parking lots into storm drains.[7]

WATER CONSUMPTION

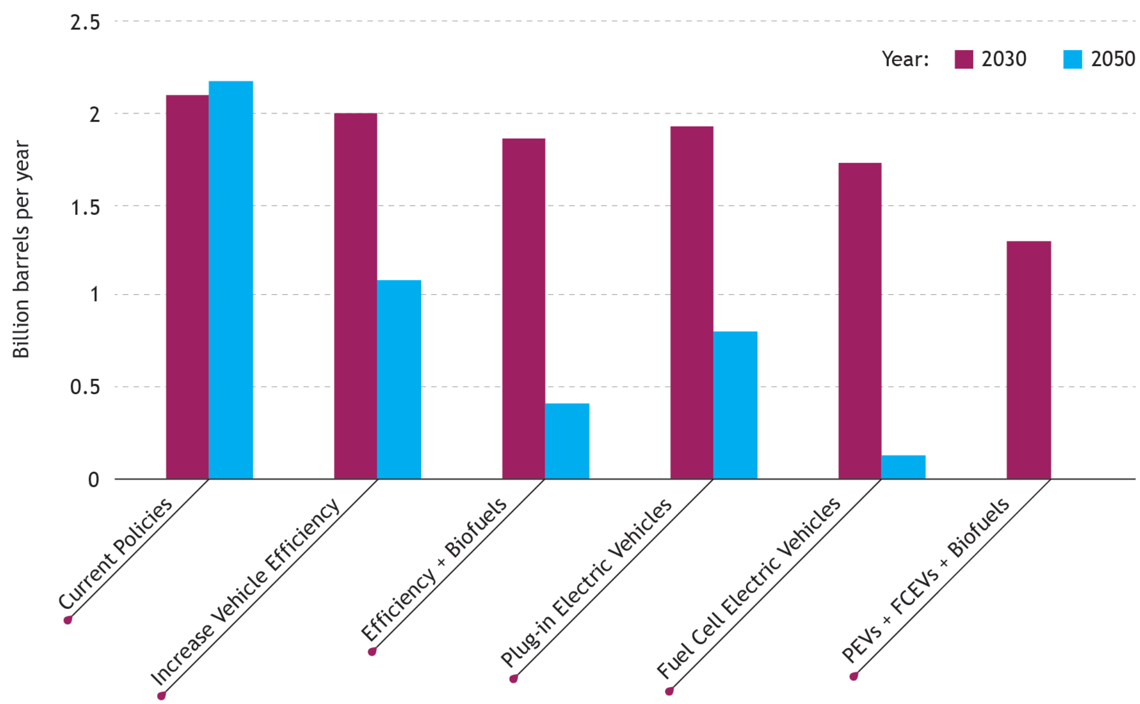


Preliminary results are from a study underway at Argonne National Labs about well-to-tank water consumption of fuel feedstocks and production. Results are based on historic (recent) water consumption data. Data may change in the future, but is unlikely to change in a way that would alter the comparative results. Note that “feedstock” in all pathways includes water consumed by the California mix of electricity. Final data is expected to be published in November 2014 and included in the GREET model.

SECURITY

One definition of energy security is the ability of households and businesses to accommodate disruptions of supply in the energy market. Another definition is the ability to produce the energy we need from domestic resources. No matter the definition, the United States is more secure with a diverse energy mix that can adjust to a disruption in the supply of any one energy source or carrier.[8]

PETROLEUM CONSUMPTION [9]



A National Academies study concluded that a combination of fuel cell electric vehicles, plug-in vehicles and biofuels, along with increased vehicle efficiency, could reduce demand for petroleum by more than 80% from 2005 levels while also reducing GHG emissions and creating a more secure energy future.[9]

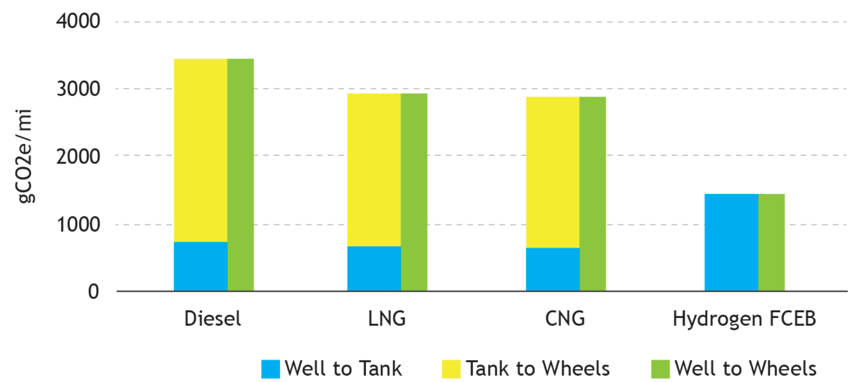
BUSES

Diesel exhaust from heavy-duty vehicles is a greater source of air pollution and greenhouse gas emissions than light-duty gasoline vehicles, especially in urban areas. California transit agencies are replacing diesel buses with CNG and running pilot programs with fuel cell powered buses. CNG buses create about half the PM as a diesel bus. Fuel cell buses have zero tailpipe emissions.

Sources: Well to tank from GREET V1 with an assumption of 2015 fuel mix and tank to wheels from EMBARQ's *Exhaust Emissions of Transit Buses* that used actual emissions of 240 buses (model years 1994-2010) in lab and field tests.

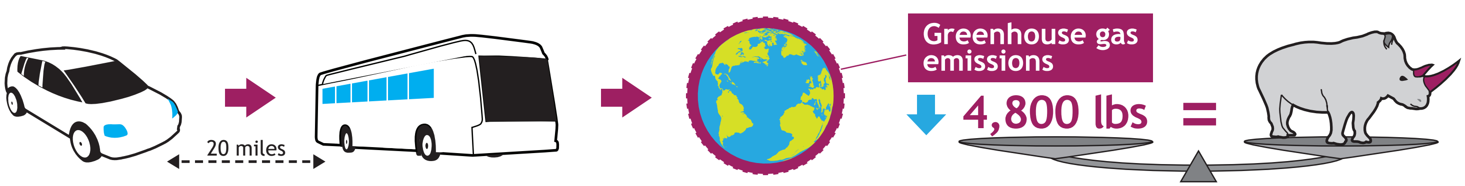
www.embarq.org/sites/default/files/Exhaust-Emissions-Transit-Buses-EMBARQ.pdf

WELL TO WHEELS CO_2 EMISSIONS OF TRANSIT BUSES



$99,792

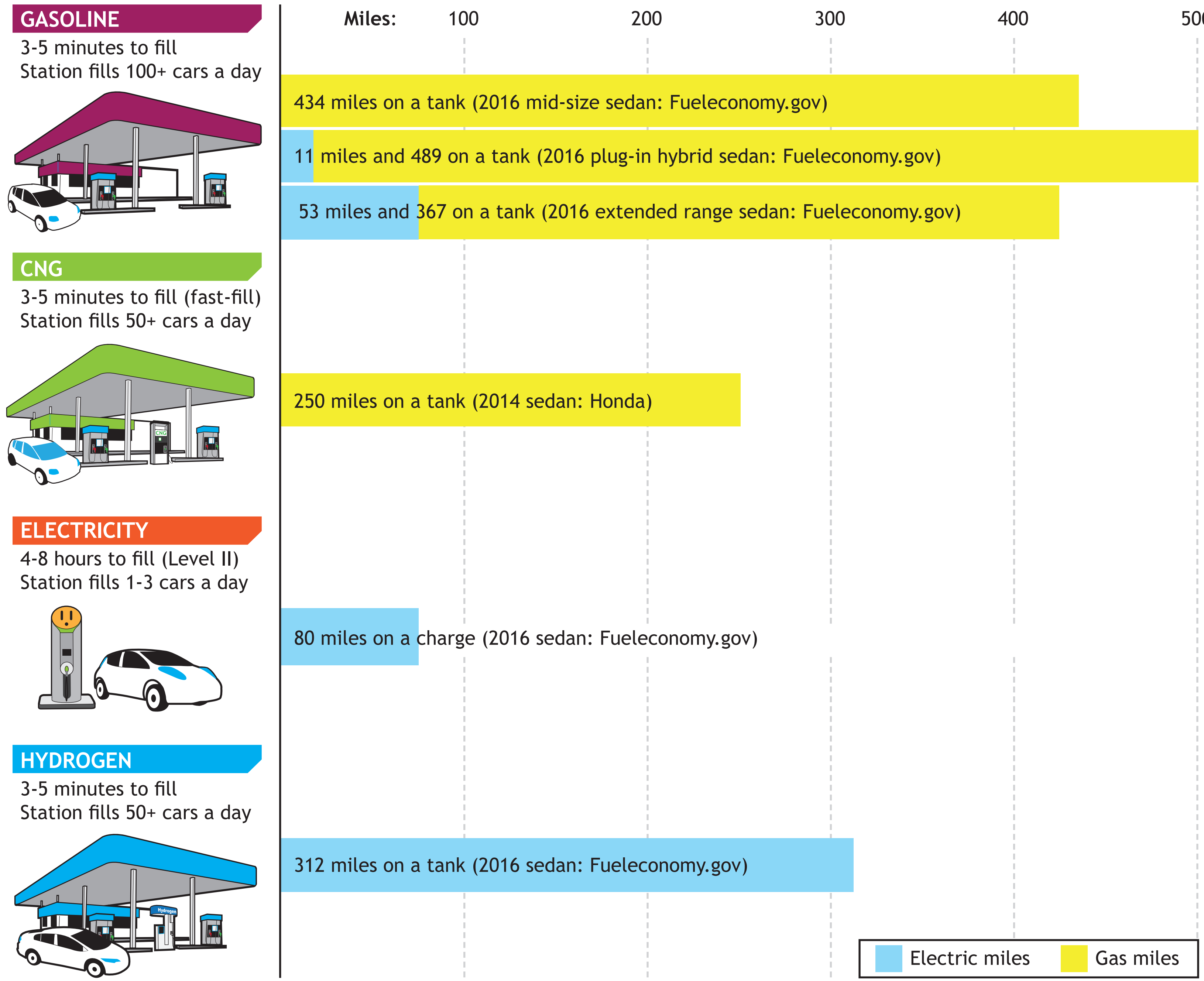
US EPA estimates that 40 fuel cell buses in a community will reduce particulate matter by 1.2 tons per year compared to 2004 model year diesel buses saving an estimated $99,792 in health costs associated with avoided medical care and sick days in Alameda County. And as much as $2.5 million in LA County.



Riding a bus instead of taking a car is a net benefit to the environment. Switching from driving a 20-mile round trip commute in a 2015 model year car to taking public transportation can reduce annual greenhouse gas emissions by 4,800 pounds per year.[10]

RANGE

Gasoline vehicles have improved greatly since Karl Benz built his first automobile in 1885. Alternative fuel vehicles don't yet match the convenience of conventional vehicles, but FCEVs come the closest.



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MotorTrend's summary of projected ownership costs for vehicles: www.motortrend.com

Argonne National Labs GREET models: greet.es.anl.gov

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