Hydrogen and Fuel Cells: It Won't Take Miracles

California Fuel Cell Partnership
DRIVING FOR THE FUTURE

the truth.

1 FCVs are expected to be cost-competitive with other advanced technology vehicles.

2 FCVs using hydrogen are one of the most efficient and cleanest vehicle technologies now and in the future.

3 Hydrogen can be cost-competitive with gasoline and stations can be deployed using a coordinated cost-effective, regional strategy.

4 Several demonstration vehicles have 300-mile and more range using compressed hydrogen storage.

Executive Summary

Critics and skeptics say that hydrogen and fuel cell vehicles are decades from market, and need four "miracles" to be a viable transportation choice. Research, reports and real-world data say just the opposite.

Fuel cells are not too expensive.

According to an MIT study, once in mass production, a fuel cell vehicle with 350-mile all-electric range is projected to cost only $3,600 more than a conventional car. A plug-in hybrid with 30 miles all-electric range will cost $4,300 more than a conventional car and a full battery-electric vehicle with 200-mile range will cost $10,000 more.

Hydrogen from natural gas is not inefficient.

Well-to-wheels studies show that a fuel cell vehicle using hydrogen made from natural gas is more energy efficient and cleaner than gasoline or natural gas in a conventional vehicle. Furthermore, the studies show that FCVs are on par with battery electric vehicles when both fuels are made from traditional sources.

Building the infrastructure is not too difficult.

The California Fuel Cell Partnership's Action Plan provides a nationwide model for deploying hydrogen stations in a cost-effective manner. The National Research Council reported that an investment of $8 billion over 16 years can build stations to supply fuel for 1.8 million vehicles through 2020 and 10 million vehicles through 2025. By comparison, the existing gasoline infrastructure costs $160 billion annually.

Hydrogen storage does not require any breakthroughs.

In real-world driving, several vehicles have met or surpassed the 300-mile range goal using compressed hydrogen.

To meet our country's long-term climate and energy security goals, the best approach is to pursue and invest in every viable option—hydrogen fuel cell vehicles, battery electric vehicles and advanced liquid biofuels in combustion engines—to meet the technical, resource and market challenges of each.

Hydrogen and fuel cells are one of the best options for advanced transportation technology and can come to the early commercial market in just a few years.

Critics say: Fuel cells vehicles are too expensive.

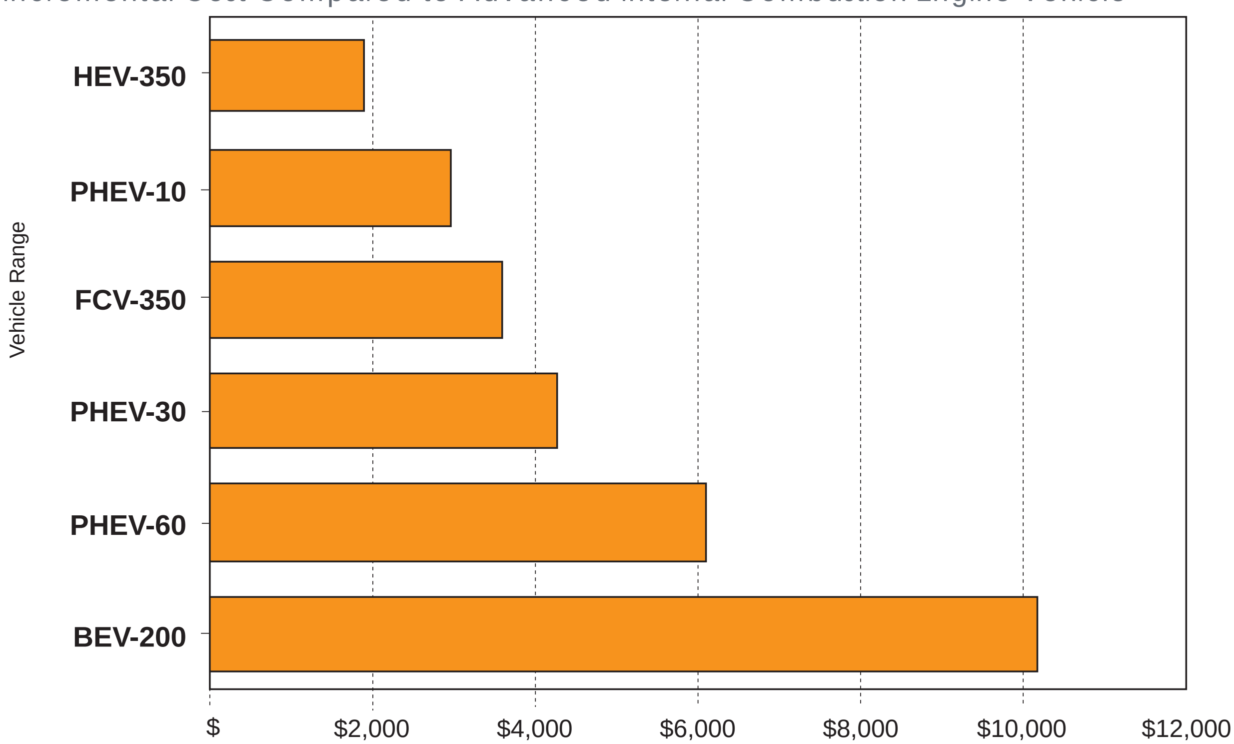
The truth: FCVs are expected to be cost-competitive with other advanced technology vehicles.

Fuel cell systems are approaching the cost of hybrid systems. The Department of Energy sets targets for developing technology to measure progress and inform investment decisions. Fuel cell vehicles have met or surpassed every target since the hydrogen program began.

Fuel cell vehicles are on track to meet cost and performance targets, and have already met range targets.

Fuel cell vehicles are on track to meet cost and performance targets, and have already met range targets. Kromer and Heywood at MIT independently assessed the commercialization prospects of fuel cell and battery electric vehicles.[1] They concluded that a mass produced fuel cell vehicle (FCV) with 350-mile all-electric range is expected to cost $3,600 more than a conventional vehicle and $700 more than a hybrid (HEV). A plug-in hybrid with 30-mile all-electric range is expected to cost $4,300 more than a conventional vehicle and a full battery-electric vehicle (BEV) with 200-mile range is expected to cost $10,000 more.

Incremental Cost Compared to Advanced Internal Combustion Engine Vehicle



1 Kromer & Heywood, "Electric Powertrains: Opportunities & Challenges in the U.S. Light-Duty Vehicle Fleet Report #LFEE 2007-03RP, MIT, May, 2007

The table below compares the current status of fuel cell and plug-in hybrid technology to the 2010 and 2015 DOE targets, and to the inputs used in the MIT study. Note that for fuel cell vehicles, the "Current Status" is close to the MIT inputs, indicting that FCVs are close to realizing the projections.

DOE targets[2] and MIT Inputs for Fuel Cell, Hydrogen and Battery Status

Fuel Cell	Current Status	DOE 2010 Target	DOE 2015 Target	MIT 2030 Input
Fuel cell system cost ($/kW)	$73[a]	$45	$30	$50
Hydrogen storage cost ($/kWh)	$15.5 (30 MPa)[b] $23 (70 MPa)	TBD	TBD	$15
Hydrogen storage density (kWh/L)	0.58 (30 MPa)[b] 0.72 (70 MPa)	0.9	1.3	0.8
FCV range (miles)	Over 250	250	300	350

PHEV Battery	Current Status	DOE 2012 Target	DOE 2014 Target	MIT 2030 Input
Battery cost ($/kWh)	$1,000+[c]	$500	$300	$320
Battery storage density (kWh/kg)	0.043[c]	0.057	0.096	0.135
PHEV range (miles)	10	10	40	30

[a] *DOE Progress Report to Congress, January 2009. (The projected high-volume manufacturing cost of automotive fuel cell systems has decreased from $275/kW in 2002 to $73/kW in 2008.)*

[b] *Dillich, S. Hydrogen Storage, Presented at DOE annual merit review May 19, 2009 (System volumetric capacity 17-18 g/L (35 Mpa) and 19-25 g/L (70 MPa): average of 17.5 g/L and 21.5 g/L, respectively, yields 0.58 kWh/L and 0.72 kWh/L.)*

[c] *Howell, D. Energy Storage Overview. Presented at DOE annual merit review May 19, 2009*

2 *DOE progress report to Congress, Jan. 2009 http://www.hydrogen.energy.gov/pdfs/epact_report_sec811.pdf*

Critics say: It is inefficient to make hydrogen from natural gas

The truth: FCVs using hydrogen are one of the most efficient and cleanest vehicle technologies now and in the future.

Hydrogen is produced in large quantities today, primarily from natural gas. According to a report by the California Energy Commission, making hydrogen from natural gas is about 62% efficient.[3] Making hydrogen from renewables, like solar, wind or hydro power, is about 69% efficient. Making electricity from the "California mix," which is heavy on natural gas and renewables, is only about 50% efficient.

In the transportation world, energy efficiency and emissions are measured "well to wheels," from raw material to use in the vehicle. FCVs using hydrogen from natural gas are 2-3 times more efficient than conventional vehicles using gasoline, diesel or natural gas. In addition, FCVs emit 60% fewer greenhouse gases than conventional vehicles, and 35% fewer GHGs than natural gas vehicles.[4]

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DOE compared well-to-wheel GHG emissions and petroleum energy use in 2020, accounting for increased efficiency and cleaner production pathways, including increased renewable feedstocks and carbon sequestration. FCVs using hydrogen from biomass emit 90% fewer GHGs than today's gasoline vehicles and 60% fewer GHGs than a PHEV running on cellulosic ethanol using the "national mix" of electricity.[5] *(See charts on the following page.)*

The National Research Council analysis recommends a "portfolio approach" to achieve deep reductions in GHG emissions and petroleum consumption through 2050.[6] Reaching our country's goals of reducing petroleum and carbon emissions by mid-century requires improving vehicle efficiency, using advanced low-carbon biofuels, and deploying hydrogen fuel cell vehicles.

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3 CEC "Full Fuel Cycle Assessment Tank To Wheels Emissions and Energy Consumption" January 2007

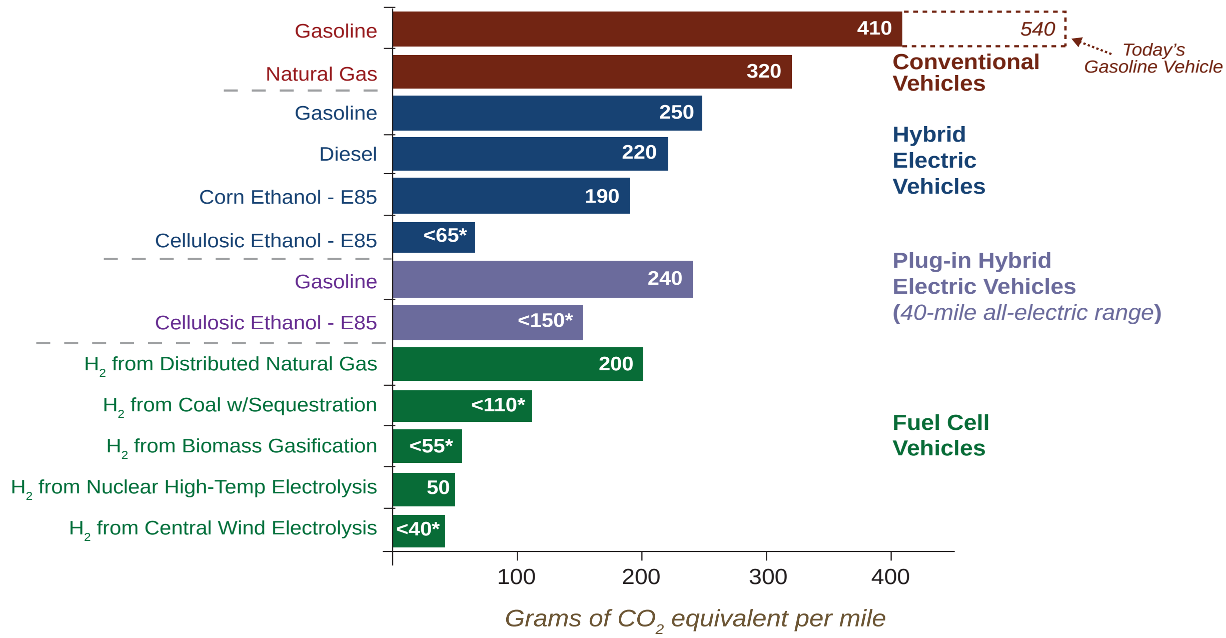
4 California Fuel Cell Partnership "Well to Wheels: A Guide to Understanding Energy Efficiency and Greenhouse Gas Emissions"

5 http://www.hydrogen.energy.gov/pdfs/9002_well-to-wheels_greenhouse_gas_emissions_petroleum_use.pdf; also see: CARB Low Carbon Fuel Standard, http://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor1.pdf

6 Transitions to Alternative Transportation Technologies: A Focus on Hydrogen, NRC 2008

Well-to-Wheels Greenhouse Gas Emissions[5]

(direct emissions, based on a projected state of the technologies in 2020)

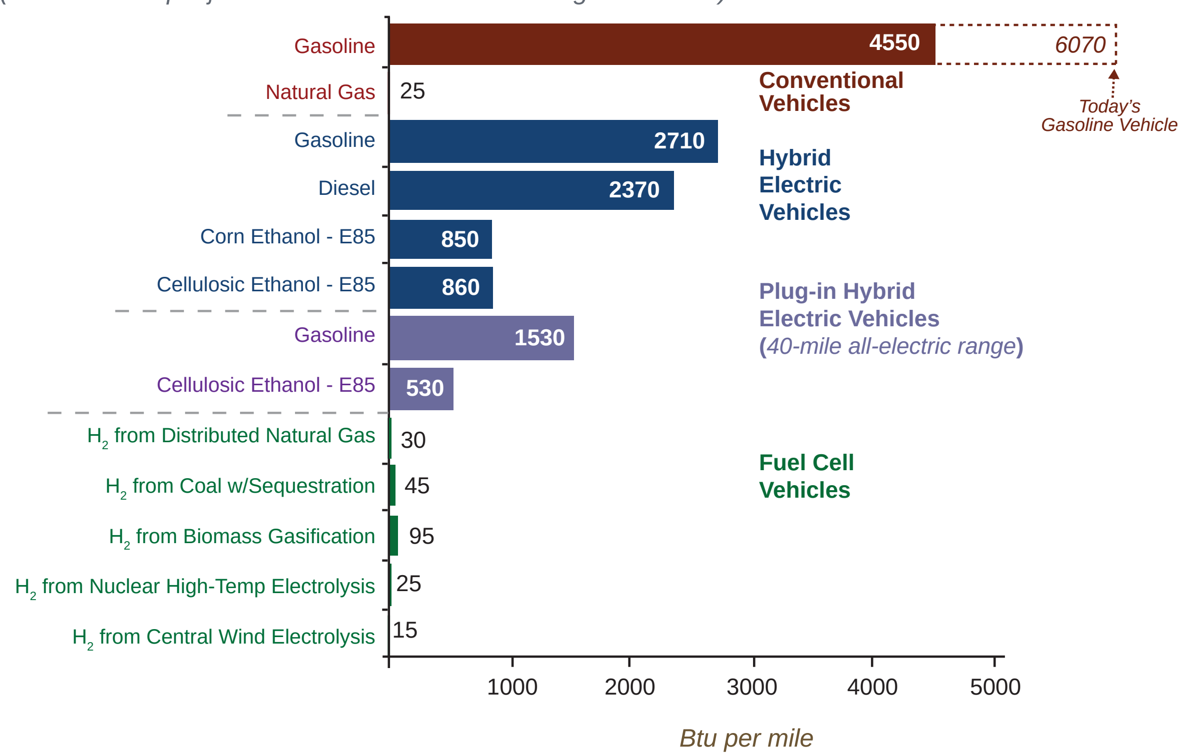


Net emissions from these pathways will be lower if these figures are adjusted to include:

- *The displacement of emissions from grid power-generation that will occur when surplus electricity is co-produced with cellulosic ethanol*
- *The displacement of emissions from grid power-generation that may occur if electricity is co=produced with hydrogen in the biomass and coal pathways, and if surplus wind power is generated in the wind-to-hydrogen pathway*
- *Carbon dioxide sequestration in the biomass-to-hydrogen process*

Well-to-Wheels Petroleum Energy Use[5]

(based on a projected state of the technologies in 2020)



Critics say: Building a hydrogen infrastructure is too difficult and costly

The truth: Hydrogen can be cost-competitive with gasoline and stations can be deployed using a coordinated cost-effective, regional strategy.

To compete with gasoline, any new fuel needs to be cost effective for the customer, available to the customer and profitable for the seller.

Hydrogen can be efficiently made from a variety of feedstocks including natural gas, biomass, and coal with sequestration at levelized costs of $3.00-$6.00/kg,[7] which, when adjusted for the efficiency of FCVs is comparable to $1.50-$3.00/gallon of gasoline in today's vehicles.[8] Because of the diversity of feedstocks and the ability to create fuel at the station, hydrogen will not suffer the same price volatility that gasoline does today.

The smartest and most cost-effective way to make sure that fuel is available to customers is to roll out the vehicles and stations concurrently in specific regions.[9] In assessing a transition to hydrogen fuel cell vehicles, the National Research Council assessed scenarios to supply fuel for 1.8 million vehicles through 2020 and 10 million vehicles through 2025.[10] Approximately $8 billion over 16 years will cover the entire capital cost of the early hydrogen infrastructure to a self-sustaining FCV market.[6] (As a point of comparison, maintaining the existing global gasoline supply system is estimated at $160 billion annually.)[11] CaFCP's Action Plan details a strategy for a coordinated roll-out of 46 stations in California to serve 4,300 fuel cell vehicles by 2014 and begin growing the network to serve more than 50,000 cars through 2017 at a total government and industry cost of $180 million.[12]

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NRC estimates that $2.2 million will build a hydrogen fueling station that could support 1,500 FCVs, or $1,500 per vehicle. By comparison, the Idaho National Laboratory estimates that the average cost of adding a home 120V, 20A circuit to charge one PHEV would be $878 per vehicle, and a 240V circuit needed for a PHEV-30 or PHEV-40 would cost $1,500-$2,100 per vehicle.[13]

7 DOE progress report to Congress, Jan. 2009 http://www.hydrogen.energy.gov/pdfs/epact_report_sec811.pdf

8 Fuel cell vehicles are at least 2-3 times more efficient than a comparable gasoline vehicle.

9 Melendez, M., Milbrandt, A. Geographically Based Hydrogen Consumer Demand and Infrastructure Analysis: Final Report. October 2006. NREL. http://www.nrel.gov/hydrogen/pdfs/40373.pdf

10 Transitions to Alternative Transportation Technologies: A Focus on Hydrogen, NRC 2008, table 6.5

11 http://www.npchardtruthsreport.org/ commissioned by former DOE Secretary Bodman

12 http://www.fuelcellpartnership.org/hydrogen-fuel-cell-vehicle-and-station-deployment-plan

13 Morrow, K., D. Karner, J. Francfort, "Plug-in hybrid electric vehicle charging infrastructure review," Final Report INL/EXT-08-15058, Idaho National Laboratory, November 2008

Critics say: Hydrogen storage needs significant breakthroughs to meet customer expectations for range.

The truth: Several demonstration vehicles have 300-mile and more range using compressed hydrogen storage.

The Department of Energy's Technical Validation Program monitored and evaluated real-world performance of 140 fuel cell vehicles that have safely accumulated more than 85,000 operating hours and 1.9 million miles. Using crash-tested compressed-hydrogen storage on board the vehicles, second-generation FCVs exceeded the 250-mile DOE range target for 2008. For example, the 2008 Honda Clarity using 35 MPa compressed hydrogen storage achieved EPA-adjusted fuel economy at 77 mpg city/67 mpg highway and 280 mile range.[14] The 2009 Toyota FCHV-*adv* using 70 MPa storage has a demonstrated range of 431 miles and 68.3 miles/kg average.[15] The Kia Borrego FCEV, introduced at the 2008 LA Auto Show, has a stated range of 426 miles with 154-hp and 54 mpg combined fuel-economy.[16]

Using crash-tested compressed-hydrogen storage on board the vehicles, second generation FCVs exceeded the 250-mile DOE range target for 2008.

While work continues with storage, today's FCVs have demonstrated range that will meet customer expectations.

Conclusion

Bringing FCVs and hydrogen fuel to market won't require any miracles. A combination of research and real-world operation have repeatedly proven that fuel cell vehicles will meet customer expectations and our nation's environmental goals. Implementing the CaFCP Action Plan is the next logical step. With continued government and industry support for advanced transportation systems and funding for early market deployment, fuel cell vehicles can enter the early commercial market in just a few years.

14 *http://www.fueleconomy.gov/feg/fcv_sbs.shtml*

15 *http://multivu.prnewswire.com/mnr/toyota/39419/*

16 *Kia's LA Auto Show press release http://www.egmcartech.com/2008/11/21/la-2008-live-kia-borrego-fcev-shows-next-generation-fuel-cell-technology/#more-28360*

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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