Welcome to the RFF Weekly Policy Commentary, which is meant to provide an easy way to learn about important policy issues related to environmental, natural resource, energy, urban, and public health problems.

This week, Joan Ogden and Ed Rubin discuss the potential for hydrogen fuel cell cars to reduce U.S. dependence on gasoline over the longer term. They describe the technological obstacles that must be overcome before fuel cell vehicles might become competitive, as well as future policy actions that would be needed to jolt the market penetration of these vehicles. They also discuss whether it makes sense to invest in fuel cell vehicles as part of a portfolio approach to developing alternatives to traditional gasoline vehicles.

The Outlook for Hydrogen Cars
By Joan Ogden and Edward S. Rubin

The U.S. automotive fleet will be dramatically transformed over the next several decades, the result of national energy and environmental policies being debated right now. Reductions in oil imports to enhance energy security and reduce trade balances will demand greater use of alternative fuels instead of gasoline. So too will anticipated requirements to reduce carbon dioxide emissions linked to global climate change. Improving the fuel economy of current cars is an important first step, but achieving deep cuts in oil use and greenhouse gas emissions will require a suite of commercially viable alternatives, including more efficient vehicles (such as gasoline-battery hybrids, plug-in hybrids, and those powered by fuel cells), plus
“decarbonized” fuels such as renewable biofuels, electricity, and hydrogen produced from low-carbon sources.

While recent media coverage and political debates on alternative fuels have been dominated by a “fuel du jour” syndrome—waves of short-lived enthusiasm first for batteries, then fuel cells, ethanol, and plug-in hybrids—the consensus emerging among transportation energy analysts is that a portfolio strategy encompassing a variety of options is needed to nurture both near-term and longer-term technologies to address these problems. One of the most promising and challenging long-term options in this portfolio is hydrogen.

Two recent studies by the National Academies assessed hydrogen as a potential replacement for gasoline in light duty vehicles. The 2004 report showed that hydrogen had the potential to dramatically reduce oil use and greenhouse gas emissions from light duty transport by 2050, but only if an array of technical and transition barriers could be overcome. The 2008 report (in which we participated) examined a possible transition to hydrogen in detail, offering critical assessments of the timing and resources needed to bring fuel cell vehicles (FCVs) into widespread use.

Fuel cells are at the heart of the hydrogen strategy. They are electrochemical devices, akin to batteries, that combine hydrogen and oxygen (from air) to generate electricity to fully power a vehicle. The only tailpipe emission is water vapor from the reaction of hydrogen and oxygen. While fuel cell technology has improved substantially in recent years, current devices have not yet achieved the performance and cost goals required for large-scale commercial production. The chief technical challenges are to make fuel cells as durable and cost-effective as today’s internal combustion engine, to reduce the use of costly materials such as platinum-based catalysts, and to develop a compact, low-cost hydrogen storage system capable of providing a driving range of 300 miles or more, which is what most consumers demand.

Several auto companies, including General Motors, Honda, Daimler, and Toyota are currently introducing pre-commercial FCVs and hydrogen fueling stations in limited markets, notably in California and Germany. If technical progress continues at its current pace, FCVs could be ready for mass production by 2015. Initial costs would be high, but should fall quickly as manufacturing volumes increase and vehicles continue to improve. Hydrogen for these vehicles can be produced from a variety of energy sources, including fossil fuels, renewables, and nuclear energy. In the near term, the most economical approach is to manufacture hydrogen from natural gas at individual refueling stations. The projected cost is about $1.50 per gallon of gasoline equivalent on a mile per gallon basis, but fuel cost would vary with natural gas prices. As the use of hydrogen grows, it can be produced more economically at large centralized plants and distributed to refueling stations via pipelines or trucks, much like gasoline supplies.

Most hydrogen today is produced from fossil fuels, which releases significant amounts of carbon dioxide (CO₂)—the major greenhouse gas (GHG) linked to climate change. For large central plants that might produce hydrogen from coal, it is technically feasible to capture the CO₂ and permanently sequester it in deep geological formations. Such systems are currently in use at four large industrial operations in Europe, North Africa, and Canada, but their widespread use for climate change mitigation is still at least a decade away, pending further developments in
technology and climate policy. In the meanwhile, FCVs using hydrogen made from natural gas would still reduce overall (“well-to-wheels”) GHG emissions by half compared to current gasoline vehicles, largely through gains in overall efficiency. Production of hydrogen from biomass also is advancing and could be competitive by the mid to late 2020s. In the longer term, carbon-free renewables such as wind and solar energy might be harnessed for hydrogen production via electrolysis of water.

Development of the hydrogen refueling infrastructure is another critical step for hydrogen cars. Current strategies, developed in close coordination with vehicle manufacturers, focus on targeted introduction of FCVs and hydrogen infrastructure in a number of “lighthouse cities” such as Los Angeles, New York, and Houston.

As a practical matter, the 2008 NRC report estimated that the maximum number of hydrogen-fueled vehicles on U.S. roads by 2020 would be no more than about 2 million, out of an estimated vehicle population of 280 million. This assumed that mass production of FCVs gets underway around 2015, all technology goals are met, and fuel cell vehicles rapidly gain market share, reaching 10 percent of new car sales by 2020. Under such favorable conditions—requiring government support during the transition period—hydrogen cars could become commercially competitive by about 2023. The number of vehicles could then grow rapidly, to 60 million in 2035 and 220 million in 2050—some 60 percent of the future fleet.

In this “maximum practical” scenario, after about 2035, hydrogen cars exhibited greater potential to reduce oil use and greenhouse gas emissions than near-term technologies like advanced internal combustion engines and hybrids, or expanded use of biofuels. The NRC study emphasized, however, that this was not a forecast. Rapid deployment of hydrogen cars is uncertain at this stage because is impossible to know how fast technological obstacles will be overcome, how fast competing technologies will develop, and to what extent consumers will be willing to switch to a new type of vehicle with an initially more limited network of refueling stations.

Any significant market penetration of hydrogen vehicles in the next decade or so will require substantial, sustained, and coordinated public support, according to the NRC report. First, there must be continued support for research and development (R&D), amounting to some $16 billion through 2023. About a third of this would be government funding of basic and applied research, with the remaining funds from the private sector, similar to current public-private spending for hydrogen and fuel cell R&D, which totals about $1 billion per year.

Second—and far more challenging—is the need for government support of fuel cell vehicle production during the transition period when hydrogen cars cost more than gasoline counterparts. Historical experience shows that mass production of new vehicles is essential for lowering unit production costs, but manufacturers will not mass produce a new vehicle unless they ultimately expect to profit. This would require an estimated $40 billion in government support for incremental vehicle costs (for example, through vehicle purchase subsidies) until FCVs become competitive around 2023.

An additional $10 billion in support is needed to share the cost of initial investments in hydrogen infrastructure in the lighthouse cities, mainly at existing gasoline stations. Longer-term
investments in infrastructure would be more sizeable, but would be borne by the private sector as FCVs gain acceptance.

Overall, then, the total government investment needed to accelerate a transition to hydrogen cars is roughly $55 billion over the next 15 years. This averages $3.7 billion per year, similar to current government subsidies for other transportation fuels such as ethanol. Note, however, that this support for hydrogen R&D, incremental vehicle costs, and early infrastructure does not guarantee success—remaining technical and consumer acceptance hurdles must still be overcome.

Finally, to realize the long-term environmental benefits of hydrogen, along with its potential to reduce oil use, government policies to limit CO2 and other greenhouse gas emissions also are essential. These might include a carbon tax, a cap-and-trade program, or performance and portfolio standards, such as those adopted by California. The point is to ensure that hydrogen is produced with little or no greenhouse gas emissions.

Given the uncertainties facing all automotive technologies, neither hydrogen nor any other transport option can be declared the “winner.” The recent NRC analysis showed that a portfolio approach including sustained fuel economy improvements for gasoline vehicles and hybrids, a rapid phase-in of renewable biofuels, plus an aggressive introduction of hydrogen fuel cell vehicles could cut carbon emissions by 90 percent in 2050 compared to “business as usual,” with virtually no gasoline use. According to the study, hydrogen was the dominant contributor to achieving these national goals over the longer term. While the future remains uncertain, clearly a wise national strategy should include vigorous support for hydrogen cars as part of a national portfolio of promising transport options.

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Views expressed are those of the author. RFF does not take institutional positions on legislative or policy questions.

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Additional Resources


**Joan Ogden** is a professor of environmental science and policy at the University of California, Davis and director of the Sustainable Transportation Energy Pathways Program at the campus’s Institute of Transportation Studies. Her primary research interest is technical and economic assessment of new energy technologies, especially in the areas of alternative fuels, fuel cells, renewable energy, and energy conservation.

**Edward S. Rubin** is the Alumni Professor of Environmental Engineering and Science in the Engineering and Public Policy Department at Carnegie Mellon University. His research deals with technical, economic, and policy issues related to energy and the environment, with a major focus on design and analysis of environmental control options for electric power systems.