NREL Advances in Analysis/Assessment at the National Renewable Energy Laboratory

Analytic Studies Brief

# Study Characterizes Benefits of Fuel Cell Vehicles

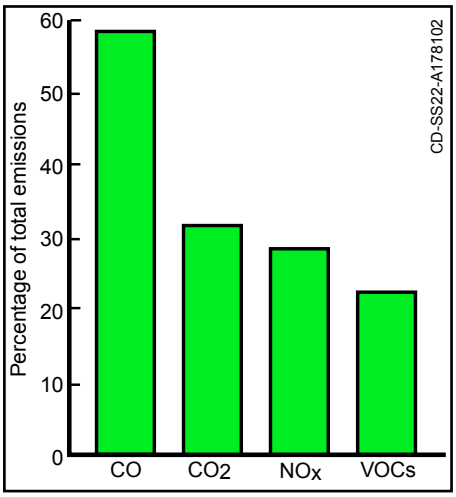
## Fuel Cell Vehicles Offer Potential for Major Emissions Reductions and Fuel Savings

The transportation sector has a major impact on energy consumption, economics, and the environment in the United States. Of particular importance are the implications of dependence on imported oil and the environmental impacts of air emissions from vehicles. Fuel cell vehicles (FCVs) have the potential to mitigate these concerns because of their low emissions, high efficiency, and ability to operate on nonpetroleum fuels.

Analysts at the National Renewable Energy Laboratory (NREL) examined the ability of FCVs to reduce air emissions and oil consumption. They found that FCVs could reduce air pollution and dependence on foreign oil while providing fuel savings for consumers. Documented in *Fuel Savings and Emissions Reductions from Light Duty Fuel Cell Vehicles* (NREL/TP-463-6157), the NREL study examined the potential benefits of large-scale FCV deployment in the light duty vehicle market (cars and light trucks).

### Fuel Cells

Used in space applications for three decades, fuel cells are now being developed for a variety of other purposes, including stationary power generation and transportation. Fuel cells generate electricity from the electrochemical reaction of hydrogen and oxygen, and the only resulting emissions are water and some heat. In automobiles, fuel cells would power an electric motor, replacing the internal combustion engine and conventional drivetrain. Because the theoretical efficiency of a fuel cell far exceeds that of a combustion engine, FCVs are expected to achieve large improvements in fuel economy over conventional vehicles.

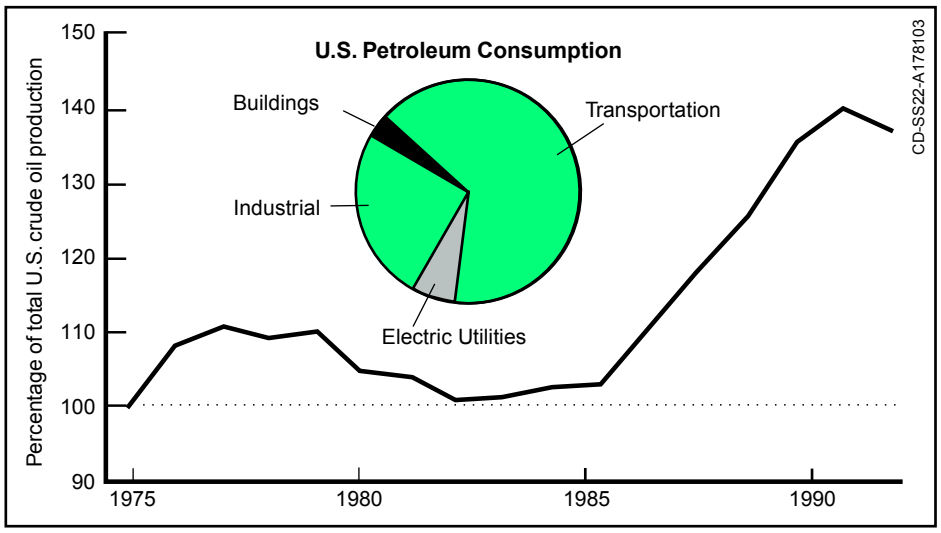



Highway vehicles account for a large portion of all emissions of key air pollutants in the United States. This chart shows the percentage of total U.S. emissions by highway vehicles.

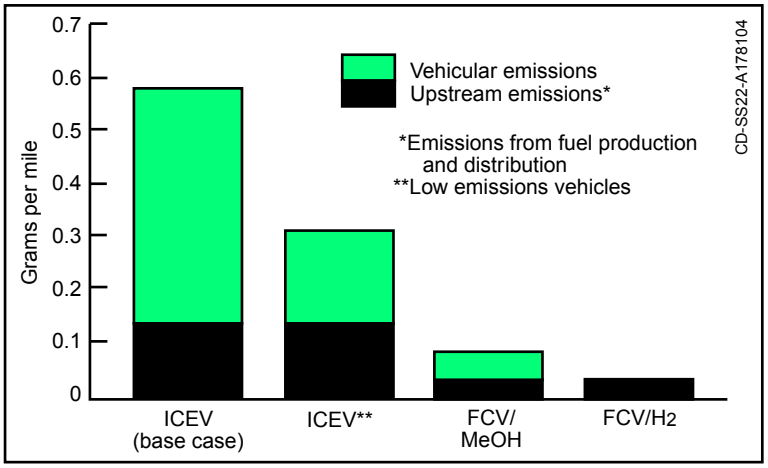
Future automobiles powered by fuel cells are projected to have fuel economies of more than 85 miles per gallon (gasoline-equivalent); fuel economies of light trucks with fuel cell engines are expected to exceed 60 miles per gallon.

### The Analysis

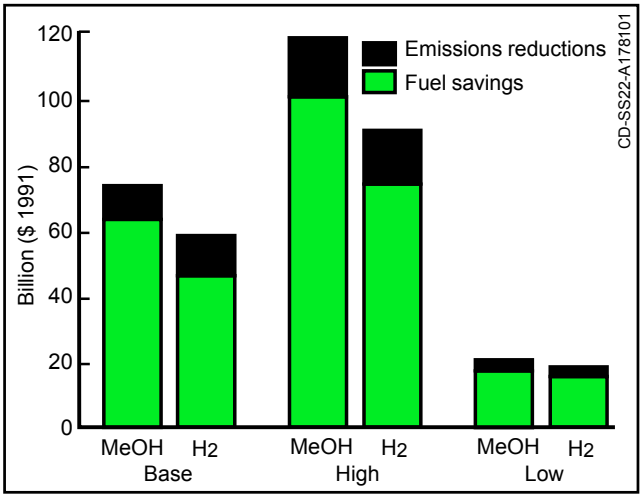
The NREL analysis projected base case, low-level, and high-level deployment of FCVs in the light duty vehicle market; market penetrations for these three scenarios reach between 12% and 50% of new vehicle sales by 2030. The analysis assumed that light duty FCV technologies would be commercially available by 2010. In addition, it assumed that fuel supplies, including the necessary infrastructure, would be increasingly accessible over time and be available nationwide by 2020.




Transportation accounts for almost two-thirds of U.S. petroleum consumption and about 140% of domestic crude oil production.




Fuel cell vehicles will emit much less pollution from tailpipes and throughout the total energy cycle than internal combustion engine vehicles. This chart shows projected hydrocarbon emissions from light duty vehicle use in 2020.




This graph shows the present value of the benefits (based on avoided cost of compliance with the Clean Air Act Amendments of 1990), accrued through 2030, that would be derived from FCV deployment for each scenario in the analysis.

The analysis characterized three technology/fuel combinations: internal combustion engine vehicles (ICEVs) using reformulated gasoline, which served as the benchmark technology; FCVs using a reformer to convert methanol (MeOH) to hydrogen ($H_2$) on board the vehicle; and FCVs with on-board hydrogen storage. Analysts assumed that the FCVs would use the proton exchange membrane fuel cell technolgy, which promises high power density and potentially low costs.

The methanol and hydrogen fuels for FCVs were assumed to be derived from natural gas, and estimates of the cost of these fuels relative to gasoline prices were the basis of the fuel-savings analysis. Because these fuels are projected to be more expensive than gasoline throughout the analysis period, fuel savings from FCV use results entirely from increased vehicle efficiency.

The environmental component of the NREL analysis focused on emissions that affect local air quality—volatile organic compounds (VOCs), nitrogen oxides ($NO_X$), and carbon monoxide (CO)—as well as carbon dioxide ($CO_2$) because of its important role in global climate change. Although traditional environmental studies of the transportation sector have dealt exclusively with tailpipe emissions, this study estimated emissions over the total fuel cycle—from resource extraction through fuel conversion and end use in the vehicle. The analysis confirmed that tailpipe emissions are a primary component of transportation-related emissions; however, it also showed that air emissions associated with producing and distributing fuel are not insignificant.

## Study Results

Results of the study indicate substantial fuel savings and emissions reductions from the deployment of light duty FCVs on a national scale. The cumulative (1994–2030) present value in 1991 dollars of these benefits (discounted at 4%) is estimated to reach between $60 billion and $75 billion in the base case penetration scenario. As expected, larger market shares would result in proportionally greater savings, and benefits would increase sharply over time in all cases.

Although the study assumes that fuels for the FCV will be produced exclusively from natural gas feedstocks, preliminary results indicate that renewable-energy-based pathways to methanol or hydrogen (such as biomass gasification or photoconversion) may offer even larger benefits to the nation.

## For More Information

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