Support for hydrogen cars has reached new heights, especially for fuel-cell vehicles that use hydrogen directly. The largest effort is President Bush's FreedomCAR and Fuel Initiative, which amounts to $1.7 billion over 5 years (*1*). Critics suggest the plan is a tactical move to avoid policies such as strict fuel efficiency standards that could be readily implemented today (*2*). Here, we take a longer-term strategic view of energy policy and argue against early adoption of hydrogen cars.

The introduction of any new transportation fuel is a rare, difficult, and uncertain venture—it demands a linked introduction of a new fuel distribution system and new vehicles, because neither is useful without the other (*3*). Although technically feasible, a hydrogen refueling infrastructure would be expensive: initial cost would likely exceed $5000 per vehicle even if one assumes large economies of scale (*4*). The cars themselves will also likely be expensive. If hydrogen cars are ever to match the performance of current vehicles at a reasonable cost—particularly fueling convenience, range, and size—technological breakthroughs in hydrogen storage and energy conversion will be required.

Like electricity, hydrogen is an energy carrier that must be produced from a primary energy source. Today, hydrogen is produced from natural gas on a large scale and at low cost: hydrogen production consumes

production, CCS could change the game because it is comparatively easy to capture CO_2 from synfuel production. Indeed, CO_2 from the major U.S. coal-to-gas facility is currently being captured and stored. Bio-fuel production with CCS would have net negative CO_2 emissions, which could lower the cost of mitigation (*1*).

Such petroleum substitutes are cost-competitive with hydrogen, and because they can be stored, transported, and distributed through the existing infrastructure and used in existing vehicles, they can be introduced more quickly with much less technological risk than could hydrogen.

Hydrogen's Role as a Transportation Fuel

Global CO_2 emissions must decline by about an order of magnitude in order to stabilize atmospheric concentrations, so major emission reductions will eventually be required from cars. Cost-effective climate policy, however, starts with low-cost emissions reductions and proceeds at a measured pace. Analysis of op-

Hydrogen Cars and Water Vapor

D. W. KEITH AND A. E. FARRELL'S POLICY FORUM

"Rethinking hydrogen cars" (18 July, p. 315) draws attention to the need for broad technology assessment of a popular policy alternative. In the pursuit of this new technology, the focus on the problem to be solved can lead to insufficient attention being paid to new environmental problems that might follow from its adoption. These new problems become tomorrow's unanticipated consequences, and the cycle begins again. This cycle could be dampened, however, with a thorough assessment of the new technology before it has completed development.

This cycle is currently under way with hydrogen fuel cells. As fuel cell cars are suggested as a solution to global climate change caused by rising levels of greenhouse gas emissions, they are frequently misidentified as "zero-emissions vehicles." Fuel cell vehicles emit water vapor. A global fleet could have the potential to emit amounts large enough to affect local or regional distribution of water vapor.

Variation in water vapor affects local, regional, and global climates (*1*). Data on such effects are

Response

WE ARE DEEPLY SKEPTICAL OF TOTTEN'S

exaggerates the benefits of switching to hydrogen fuel.

DAVID W. KEITH[1] AND ALEXANDER E. FARRELL[2]

[illegible]

short-term measures are important, which is why the Bush Administration advocated hybrid vehicle tax credits, raised Corporate Average Fuel Economy (CAFE) standards for the first time since the 1996 model year (the greatest increase in fuel economy standards in the past 20 years), and supports a renewable fuels standard to increase ethanol production and use. But these are interim strategies that can only briefly moderate, and cannot completely eliminate, our increasing demand for foreign oil. Over the long term, alternatives to petroleum fuels are needed, and hydrogen is the only energy carrier that offers the prospect of a domestically based zero-emissions transportation fuel.

The Department of Energy is not rushing to deploy hydrogen cars, as Keith and Farrell seem to suggest and as some in Congress are urging us to do. Instead, we are engaged in a long-term research and development effort focused on key enabling technologies. Only after these technologies

Schultz *a* . estimate of H_2 needed for 50% reduction in fossil fuel use (*3*, *4*); the source of this discrepancy is unclear to us.

Garman also takes exception with our suggestion that economy-wide leakage of up to 10 to 20% should be considered. However, but very unlikely [for] safety and economic reasons." Prather's recent calculations also make use of the 3 to 10% estimate (*4*). Combination of Schultz *a* .'s preferred leakage rate (3%) with the H

$_2$ production needed to replace one-third of projected global fossil fuel use in 2020 results in expected emissions of about 140 megatons per year—similar to the current amount in the entire atmosphere, or $1.8^{+1.5}_{-0.5}$ times current annual production from all sources ( ). There are insufficient data to project how such a rise in hydrogen sources would translate into increased steady-state atmospheric concentrations, because the current rate of soil uptake and its dependence on atmospheric concentration are poorly known. Nevertheless, it seems reasonable to consider that factors of several increases in sources could lead to factors of several increases in concentration.

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Response

GARMAN'S CLAIM THAT WE OFFER NO measures to address air pollution or greenhouse gas emissions is simply not true. To restate, policies to address current high emitters, to improve average vehicle efficiency, and to reduce emissions of CO_2 and pollutants in the electric power sector will be highly cost-effective and should be aggressively pursued in the near term, while long-term goals can be addressed by research on biofuels and synthetic petroleum, in addition to hydrogen.

The Bush Administration's minor (7%) increases in fuel economy for the least efficient half of light-duty vehicles and small changes in tax credits are indeed short-term measures. The new light-truck fuel economy standard will only slow, not