

Climate Change Policy for Transportation While Waiting for H₂

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The vision of a global transportation system powered by hydrogen offers the promise of clean, efficient and sustainable energy for the world's transportation systems, and the possibility of a once-and-for-all solution for transportation's contribution to climate change. But before we decide to place all our bets on the transition from fossil fuels to hydrogen, we should answer three questions.

1. Is hydrogen THE answer to transportation's problems of energy security and greenhouse gas emissions?
2. Is it wise to do little or nothing while we wait for the coming of hydrogen?
3. Will the hydrogen transition just "happen" or must we implement strong policies?

These questions are neither facetious nor trivial. In attempting to answer them, it should become clear that responsible climate and energy policies require much more than a single-minded focus on hydrogen research and development (R&D).

Is hydrogen THE answer for transportation?

It may well be. Using hydrogen as an energy carrier (whether in fuel cells or internal combustion engines) produces very little pollution. Teamed up with electricity, hydrogen could make energy end use virtually pollution free. In addition, hydrogen can be produced from a great many energy sources, including fossil fuels, renewable energy and nuclear energy. Hydrogen could be a flexible and robust energy carrier not tied to depletable fossil resources. However, the cheapest means of producing hydrogen today is from fossil fuels. If hydrogen is produced from fossil fuels, the carbon dioxide generated must be captured and sequestered for there to be significant reductions in greenhouse gas (GHG) emissions versus conventional transportation fuels used with advanced vehicle technologies (e.g., hybrid or diesel powerplants). Carbon sequestration technologies hold a great deal of promise but still face unresolved questions with respect to cost, durability and acceptability.

As a fuel for transportation vehicles, hydrogen faces many technical challenges. Because hydrogen is the smallest and lightest element and a gas under ambient conditions, it is difficult to store in practical quantities for mobile applications. And fuel cells, the key to most envisioned applications for hydrogen, are still an order of magnitude, or more, more expensive than competing conventional technologies. Enormous progress has been made over the past two decades, and it continues to be made rapidly made today. But there is still a long way to go.

What if hydrogen technology does not turn out to be superior to the other alternatives? The possibility must be considered not only because of the challenges facing hydrogen technologies today, but also because the alternatives, especially conventional

technologies, are moving targets. Modern internal combustion engine vehicles can be made clean enough to meet California's near-zero emission PZEV (partial zero emission vehicle) standards at a reasonable price. And gasoline- or diesel-electric hybrid vehicles with the potential to increase fuel economy by 50-100% have been shown to offer equal or better GHG performance compared to hydrogen fuel cell vehicles, if the hydrogen is produced from natural gas (the most economical method today) and the carbon is not sequestered. Conventional technology is not only a moving target, but responds and adapts to challenges.

It also seems likely that that hydrogen will succeed in some transportation applications but not in others. For long distance commercial air travel energy density is critical due to the importance of range. Today, it is difficult to see how hydrogen could compete with liquid hydrocarbon fuels without an unforeseen breakthrough in hydrogen storage or a fundamental change in propulsion technology. Can fuel cells or hydrogen internal combustion engines compete successfully against efficient and economical large diesel engines in heavy trucks, locomotives or ships? Light-duty vehicles, the prime target for mobile fuel cells, are the largest mode of transportation but still account for only 55% of transportation's GHG emissions. And if hydrogen is only partly successful in displacing liquid hydrocarbon fuels in transportation, should we not have an effective mitigation strategy for the remaining uses?

The situation we face is illustrated graphically in a simplified way in Figure 1 (competition from other technologies is not represented, nor is the possibility that hydrogen may succeed in only some transportation applications). The key uncertainties are represented by the nodes on a decision tree. Following the lowest branch, if we cannot sequester carbon and we cannot produce it inexpensively from renewable energy, then we cannot achieve significant GHG benefits. To achieve major reductions in transportation's GHG emissions by 2050, we must have carbon sequestration or inexpensive production of hydrogen from renewable energy, or both. And we must have inexpensive fuel cells and much improved hydrogen storage. In a true decision tree, probabilities would be assigned to each decision point. Of course, the probabilities are unknown, but if we assigned a 50/50 chance to each decision point, the probability that hydrogen would eventually significantly reduce transportation GHG emissions would be less than 1 in 5. Even if we decided that 75/25 was a more accurate description of our chances at each decision point, the odds of hydrogen leading to major reductions in transportation carbon emissions would be only about 50/50.

Hydrogen may well turn out to be THE answer for future transportation fuels. The harder we work at it, the more likely it will be. But the possibility that its currently serious cost and storage problems might not be entirely overcome and that conventional technologies might further narrow its potential environmental advantages cannot be dismissed. And if, despite our best efforts, hydrogen cannot be made competitive, what will we do then?

Is it OK to do nothing in the meantime?

Clearly, if hydrogen failed to become a competitive energy carrier by 2050, the answer to this question would be no. But for the sake of argument, let's assume success. If hydrogen technology ultimately succeeds, this is not a trivial question. Climate analysts have shown that there are many paths to stabilization of atmospheric GHG concentrations at levels that may not do an unacceptable level of damage to the climate (450 ppm? 550 ppm?). Some of these paths allow atmospheric concentrations to temporarily "overshoot" the target concentration levels, but such paths require much greater emissions reductions afterwards. However, if success in achieving the hydrogen economy makes such reductions much easier and cheaper to achieve in the future, overshooting could be a good choice.

On the other hand, the effect of GHGs on climate is essentially cumulative: a ton of carbon kept out of the atmosphere today is a ton that doesn't have to be kept out in the future. Energy infrastructure and energy using equipment are long-lived. Even if hydrogen is ultimately successful, it will take decades before it fully replaces conventional technology. Furthermore, the most economical sources of hydrogen today are the fossil fuels we must ultimately avoid or use only in combination with cost-adding sequestration. When hydrogen is first introduced, it is likely that the most economically competitive way to produce it will be from fossil fuels without the added cost of sequestration. Initial production from fossil fuels without sequestration would further delay the potential GHG benefits of the hydrogen transition. Suppose hydrogen technology is not ready for commercial success in transportation for 15-20 years, that it takes 15-20 years to replace the majority of the energy infrastructure, and that initially hydrogen is produced from natural gas, petroleum or coal without sequestration. Waiting 30-40 years for carbon-free hydrogen would be the right choice only if there are no cost-effective options to pursue in the meantime.

Will the transition just happen, or are policies needed?

Unless there is a compelling business case for hydrogen that depends entirely on private benefits (cheaper, faster, safer, better) rather than societal benefits (energy security, clean air, GHG mitigation), the answer is that strong policies will be needed. Existing analyses indicate that even if the program is successful, hydrogen will be preferable to other advanced technologies as a light-duty vehicle fuel only when its societal benefits are taken into account. If this is the case, then strong policies will be needed to stimulate the transition to hydrogen and permanent policy interventions will be necessary to sustain a hydrogen-based transportation system.

But given what we have said above, it would not be wise to count on hydrogen and hydrogen alone as the only greenhouse gas strategy for transportation. A more robust policy portfolio is needed, one that leads toward a hydrogen economy while providing other options in case they are needed. This policy portfolio should be guided by five simple principles:

- Create technological options through R&D
- Create market signals encouraging GHG mitigation
- Make continuous progress in GHG mitigation
- Promote technologies that enable hydrogen transportation
- Educate and inform the public

The first and most obvious policy needed is support for research and development to create the technological basis for the transition to a hydrogen economy. Direct funding of hydrogen and fuel cell R&D by the government insures that needed research will be done, and also insures that the government stays well informed about the status of hydrogen technology and the challenges facing it. But hydrogen and fuel cell R&D is not enough. Because the technology for the transition to hydrogen may not be ready on schedule, we must also carry out the R&D necessary to hedge our bets. Hedging works best when the success of the alternatives is not related to the success of hydrogen technologies. Advanced internal combustion engines not just for highway vehicles but for aircraft and other transportation vehicles, and low-carbon renewable fuels would seem to be good choices.

Probably the most important way to stimulate the needed R&D is to convey a clear message to the transportation sector that GHGs must and will be reduced, and that low-GHG technologies and energy sources will therefore have extra value in the future. Conveying the importance to society of greenhouse gas mitigation through market signals is critically important. First consideration should be given to carbon cap-and-trade systems because of their theoretical advantages and widespread and growing acceptance as a global strategy. But carbon taxes or carbon emissions standards could also work effectively.

We should make continuous progress in mitigating GHG emissions from transportation. This means chiefly insuring continuous improvement in the energy efficiency of transportation. This can be done by efficiency standards of various forms, or by market based mechanisms such as “feebates”. By making steady progress we avoid wasting the opportunities that cost-effective mitigation options offer today, thereby reducing the burden on future generations, and we also buy time for the technological advances needed for an efficient and effective transition to hydrogen. Implementing meaningful policies today is also a key motivating force for technological change. Making it clear that GHG mitigation must and will be done creates a favorable business climate for investment in hydrogen and other mitigation and sequestration technologies.

While it is important to include market signals in a comprehensive policy framework, it is just as important not to rely on pricing signals alone. Not all energy markets will respond efficiently to price signals. For example, most manufacturers believe that consumers consider only the first 2-4 years worth of fuel savings in their decisions about fuel economy, even though a new U.S. passenger car has a life expectancy of 15 years. Similar market imperfections exist in other sectors, as well. And there are other important complications. Airports, ports and highways are provided by governments not markets, and in other modes competition is often very limited. Governments also

strongly influence the patterns of land development that in turn influence the need for transportation and the choice of modes, and so on. To believe that a single price switch can be thrown and that the problem of transportation's GHG emissions will be solved is naïve.

At the same time we are hedging our bets by advancing technologies unrelated to hydrogen, such as biofuels and efficient internal combustion engines, we should promote the market success of technologies that will help enable hydrogen fuel cell vehicles. Paramount among these is hybrid vehicles. Hybrid vehicles share many components with fuel cell vehicles, such as batteries, electric motors, controllers, inverters, sensors and sophisticated computer control systems. If hybrid vehicles are successful, they will not only directly mitigate GHG emissions by increasing fuel economy up to 50%, but they will enable learning-by-doing and provide economies of scale that will reduce the cost and improve the quality of essential components of hydrogen fuel cell vehicles. Early sales of hybrids can be effectively promoted by direct subsidies to purchasers and tax incentives, but hybrid technology will also benefit from higher fuel economy standards or feebates.

Educating and informing the public is essential. At present, the public does not accept the need for policies that will raise the price of carbon-based fuels. Both government and industry have a responsibility to inform the public about the need for such market signals. Even more importantly, the public should understand the larger context in which all these policies are working to create a transition to a cleaner, more secure and sustainable energy future.

Betting on hydrogen and hydrogen alone to solve the problem of climate change leaves society with an unbalanced policy portfolio. It ignores both the possibility of failure and the likelihood of partial rather than complete success. It overlooks the value of hedging and of buying time by making cost-effective, significant GHG reductions during the decades in which the technology for the hydrogen economy is being developed, the transition to hydrogen is being made, and renewable, nuclear and fossil sources with carbon sequestration are replacing greenhouse gas-emitting conversion processes. While we are working towards and waiting for H₂, there is a great deal more that can and should be done.

“Decision Analysis” of Hydrogen Energy as A Carbon Dioxide Mitigation Strategy for Transportation

