The Wedge from Substituting Wind H2 Fuel Cell for Gasoline in Hybrid Car

A wedge can be achieved through eliminating tailpipe carbon emissions

- H2 is produced by wind power instead of fossil fuel power
- Wind power output is 10,000 TWh/y that needs 4000 GW capacity, which can be achieved by 4 million 1 MW_p windmills

Comments

As we already saw in Section 2 of the Supporting On-Line Material (Energy Efficiency and Conservation), a wedge is available from more efficient light-duty vehicles. Specifically, we considered cars on the road in 2054, driven 10,000 miles per year, and achieving either 60 mpg or 30 mpg. As in Section 2 of the Supporting On-Line Material, we attribute 3 kgC of carbon emissions to each gallon of conventional fuel, thereby including a 25% overhead on a fuel carbon intensity of 2.4 kgC/gallon. Then, these cars emit, annually, either half a ton of carbon (at 60 mpg) or a full ton of carbon (at 30 mpg). A strategy that puts on the road in 2054 two billion 60 mpg cars, instead of two billion 30 mpg cars, is a wedge. Clearly, a second wedge can be obtained if these two billion 60-mpg cars run on hydrogen, as long as the carbon emissions associated with the hydrogen production are negligible.

Let us first assume that the substitution of energy as hydrogen for energy as gasoline is one-for-one. Invoking the useful fact that the energy content (lower heating value) of 1 U.S. gallon of gasoline and 1 kg of hydrogen are both almost exactly the same (120 MJ), the one-for-one assumption, therefore, means one ton of hydrogen fuel backs out three tons of carbon emissions at the tailpipe. The hydrogen vehicle gets 60 miles per gallon of gasoline equivalent and is driven 10,000 miles per year, so it requires 170 kg of hydrogen fuel per year and backs out 500 kg of carbon per year in conventional fuels. Two billion cars require 330 million tons of hydrogen per year and back out 330 billion gallons of gasoline or diesel fuel (containing 1 GtC) per year.

Treating the energy stored in hydrogen and stored in gasoline as equivalent leaves out many critical issues. Hydrogen scores less well than gasoline from the perspective of safety and storage. Hydrogen scores better than gasoline, if the full promise of fuel cells can be realized. The NRC Report postulates that fuel cells deliver a 67% premium in energy efficiency for hydrogen, relative to hybrid vehicles running on hydrocarbons (S38, Chapter 4); 100 mpg-equivalent fuel cell cars would displace 60 mpg gasoline or diesel cars, for example[1]. Then, each kilogram of hydrogen fuel backs out five kilograms of carbon in conventional fuel, and each 100-mpg-equivalent hydrogen car requires 100 kgH_2 per year and prevents 500 kgC/y of tailpipe emissions. Where two billion 60-mpg-equivalent cars required 330 million tons of hydrogen per year, two billion cars with a fuel economy of 100-mpg-equivalent require 200 million tons of hydrogen per year.

For the remainder of this section, we will assume the hydrogen fuel cell cars achieve

[1] The fuel economies of the NRC hybrid and fuel cell vehicles in 2050 are somewhat less: 50 and 83 mpg, respectively (S38, Chapter 4).

100 mpg-equivalent, and we will identify several wedges, each associated with a different way of producing, annually, 200 MtH_2 of carbon-free hydrogen, or an appropriately larger amount of low-carbon hydrogen.

We discuss three ways in which renewable energy can produce wedges by decarbonizing fuel. Hydropower, wind power, and photovoltaic electricity can produce hydrogen via electrolysis. Direct sunlight can provide heat that backs out fossil fuels used for space and water heating in buildings. And, plant matter (biomass) can be converted into fuels.

Electrolytic hydrogen from renewables

Electrolyzers producing hydrogen do not know the difference between renewable electricity, nuclear electricity, and other sources of electricity. Thus, the result above, that 1 kg of hydrogen can be produce from 52.5 kWh of electricity, based on the NRC electrolyzer, holds for renewable energy as well. A wedge from our car substitution strategy requires 10,000 TWh/y of renewable electricity. This may be compared to the 2002 global rate of production of electricity from hydropower, 2650 TWh/y, four times less and almost exactly the same as the rate of production of electricity from nuclear energy (S33, p. 411).

While nuclear electricity comes only at large unit scale and must be grid-connected, renewable electricity comes at all scales. It can produce distributed power, and it can produce grid-independent power. A wedge from 10,000 TWh/y of renewable electricity making hydrogen that eliminates tailpipe carbon emissions could be produced by four million 1 MW_p windmills or four hundred million 10 kW_p photovoltaic arrays, operating at 30 percent capacity factor.

References

S33 International Energy Agency, 2002. *World Energy Outlook 2002*. Paris, France: OECD/IEA. By subscription: http://library.iea.org/dbtw-wpd/Textbase/nppdf/stud/02/weo2002_1.pdf**.**

S38 National Research Council, 2004. *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*. Washington, D.C., National Academy Press. http://www.nap.edu/books/0309091632/html/