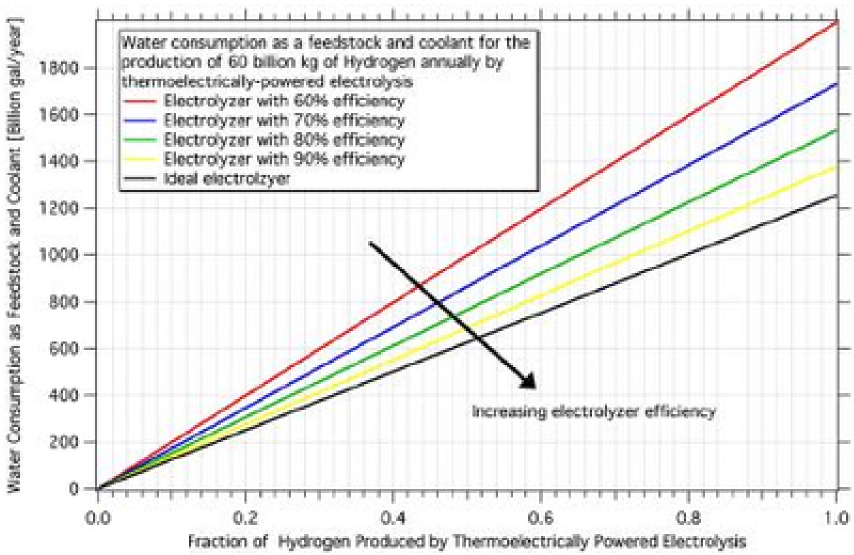
First Analysis of the Water Requirements of a Hydrogen Economy

October 18 2007, By Lisa Zyga



This graph shows the annual water consumption as a feedstock and coolant for generating 60 billion kg of hydrogen, which is influenced by both the fraction of hydrogen that is produced by thermoelectrically powered electrolysis and electrolyzer efficiencies. Image credit: Michael E. Webber.

One of the touted benefits of the futuristic US hydrogen economy is that the hydrogen supply—in the form of water—is virtually limitless. This assumption is taken for granted so much that no major study has fully considered just how much water a sustainable hydrogen economy would need.

Michael Webber, Associate Director at the Center for International

Energy and Environmental Policy at the University of Texas at Austin, has recently filled that gap by providing the first analysis of the total water requirements with recent data for a “transitional” hydrogen economy. While the hydrogen economy is expected to be in full swing around 2050 (according to a 2004 report by the National Research Council [NRC]), a transitional hydrogen economy would occur in about 30 years, in 2037.

At that time, the NRC predicts an annual production of 60 billion kg of hydrogen. Webber’s analysis estimates that this amount of hydrogen would use about 19-69 trillion gallons of water annually as a feedstock for electrolytic production and as a coolant for thermoelectric power. That’s 52-189 billion gallons per day, a 27-97% increase from the 195 billion gallons per day (72 trillion gallons annually) used today by the thermoelectric power sector to generate about 90% of the electricity in the US. During the past several decades, water withdrawal has remained stable, suggesting that this increase in water intensity could have unprecedented consequences on the natural resource and public policy.

“The greatest significance of this work is that, by shifting our fuels production onto the grid, we can have a very dramatic impact on water resources unless policy changes are implemented that require system-wide shifts to power plant cooling methods that are less water-intensive or to power sources that don’t require cooling,” Webber told *PhysOrg.com*. “This analysis is not meant to say that hydrogen should not be pursued, just that if hydrogen production is pursued through thermoelectrically-powered electrolysis, the impacts on water are potentially quite severe.”

Webber’s estimate accounts for both the direct and indirect uses of water in a hydrogen economy. The direct use is water as a feedstock for hydrogen, where water undergoes a splitting process that separates hydrogen from oxygen. Production can be accomplished in several ways, such as steam methane reforming, nuclear thermochemical splitting, gasification of coal or biomass, and others. But one of the dominant production methods in the transitional stage, as predicted in a 2004 planning report from the Department of Energy (DOE), will likely be electrolysis.

Based on the atomic properties of water, 1 kg of hydrogen gas requires about 2.4 gallons of water as feedstock. In one year, 60 billion kilograms of hydrogen would require 143 billion gallons of fresh, distilled water. This number is similar to the amount of water required for refining an equivalent amount of petroleum (about 1-2.5 gallons of water per gallon of gasoline).

The biggest increase in water usage would come from indirect water requirements, specifically as a cooling fluid for the electricity needed to supply the energy that electrolysis requires. Since electrolysis is likely to use existing infrastructure, it would pull from the grid and therefore depend on thermoelectric processes.

At 100% efficiency, electrolysis would require close to 40 kWh per kilogram of hydrogen—a number derived from the higher heating value of hydrogen, a physical property. However, today's systems have an efficiency of about 60-70%, with the DOE's future target at 75%.

Depending on the fraction of hydrogen produced by electrolysis (Webber presents estimates for values from 35 to 85%), the amount of electricity required based on electrolysis efficiency of 75% would be between 1134 and 2754 billion kWh—and up to 3351 billion kWh for a lower electrolysis efficiency of 60%. For comparison, the current annual electricity generation in the US in 2005 was 4063 billion kWh.

In 2000, thermoelectric power generation required an average of 20.6 gallons of water per kWh, leading Webber to estimate that hydrogen production through electrolysis, at 75% efficiency, would require about 1100 gallons of cooling water per kilogram of hydrogen. That's 66 trillion gallons per year just for cooling.

By 2050, the NRC report predicts that hydrogen demand could exceed 100 billion kg—nearly twice the 60 billion kg that Webber's estimates are based on. By then, researchers may find better ways of producing hydrogen, with assistance from the DOE's large-scale investments, which will exceed $900 million in 2008.

"That most of the water use is for cooling leaves hope that we can change the way power plants operate, which would significantly ease up the potential burden on water resources, or that we can find other means of power production at a large scale to satisfy the demands of electrolysis," said Webber.

If electrolysis becomes a widespread method of hydrogen production, Webber suggests that researchers may want to look for an electricity-generating method other than thermoelectric processes to power electrolysis. With this perspective, he suggests hydrogen pathways such as wind or solar sources, as well as water-free cooling methods such as air cooling.

"Each of the energy choices we can make, in terms of fuels and technologies, has its own tradeoffs associated with it," Webber said. "Hydrogen, just like ethanol, wind, solar, or other alternative choices, has many merits, but also has some important impacts to keep in mind, as this paper tries to suggest. I would encourage the continuation of research into hydrogen production as part of a comprehensive basket of approaches that are considered for managing the transition into the green energy era. But, because of some of the unexpected impacts—for example on water resources—it seems premature to determine that hydrogen is the answer we should pursue at the exclusion of other options.”

More information can be found at the Webber Energy Group, an organization which seeks to bridge the divide between policymakers and engineers & scientists for issues related to energy and the environment.

Citation: Webber, Michael E. “The water intensity of the transitional hydrogen economy.” *Environmental Research Letters*, 2 (2007) 034007 (7pp).