The World Needs a Sustainable Energy Economy, not a Hydrogen Economy

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In a sustainable future solar radiation, winds, running water, waves, tides, geothermal heat and biomass will become precious sources of energy. Consequently, sustainable energy must be distributed to the consumer with highest efficiency and used intelligently to provide a maximum of comfort and services. Energy conservation and rational use of energy will become the cornerstones of the Sustainable Energy Economy.

Promoters of renewable energy and advanced energy use and distribution schemes are eager to contribute their share to a sustainable energy future. However, there seems to be no clear picture of the economic mix of clean energy sources, energy distribution and energy demand. The future will certainly not be based on a simple replacement of fossil fuels by hydrogen, but a more complex substitution process involving physical and chemical energy carriers. One might consider the following vision of a Sustainable Energy Economy.

Renewable energy will become available mainly in the form of electricity: DC from photovoltaic arrays, AC from all rotating generators powered by wind, water, waves, tides or steam turbines (geothermal or solar thermal). Also, there is solar heat for hot water and space heating. Chemical energy comes from biomass from plants and organic waste. The renewable energy will be distributed to the consumers with highest efficiency. Whenever possible, conversion processes are avoided. Consequently, AC power will be distributed as AC power, with transmission losses minimized by voltage transformation. DC power may be used as is or for water electrolysis. It may also be converted to AC power and supplied to the grid. AC and DC power transmission technologies are available and working infrastructures already exist. Typically, the efficiency of electric power transmission is better than 90%.

In contrast, the conversion of electric power into hydrogen energy and the distribution of hydrogen to the user are extremely inefficient. About 50% of

the precious renewable electricity is lost. If hydrogen is re-converted to electricity with 50% efficient fuel cells, only 25% of the original electric energy will be available for practical use. This is a very poor alternative to direct energy transport by electrons through wires. The energy needed to take hydrogen through all important steps of a hydrogen economy has been analyzed by Bossel, Eliasson and Taylor ("The Future of the Hydrogen Economy: Bright or Bleak?", www.efcf.com/reports). The results of this study suggest that energy transport by hydrogen is not likely to replace energy transport by electrons.

As only 50% of the original electrical energy is received by consumers, hydrogen energy will be about twice as expensive as grid power. The energy consumer has a choice. Hydrogen heat will cost twice as much as electric heat. As a consequence, hydrogen is unlikely to replace natural gas for space heating, but home owners will prefer electricity.

If hydrogen is re-converted to electricity with 50% efficient fuel cells, the cost of hydrogen-electricity will be about four times higher than electricity from the grid. Residential cogeneration with hydrogen is no good option.

Furthermore, even before a Sustainable Energy Economy is established, the prices for heating oil and natural gas will have reached levels at that make energy conservation by thermal insulation economically attractive. As a consequence, the maximum heating demand of residential buildings will be reduced to a few kW. Central heating systems will be replaced by electric heaters in occupied rooms. The transition from fossil heating fuels to electricity may be accomplished even before hydrogen becomes available to replace natural gas. Electric heat pumps will be installed to provide thermal comfort in larger buildings. Furthermore, saved heating oil will flow to filling stations and power diesel engines. Energy conservation in buildings will thus extend the fossil era in the transportation sector and make an early establishment of a hydrogen infrastructure less likely.

The transition from today's energy economy to a Sustainable Energy Economy will also be characterized by changes within the energy price structure. Today, oil and gas govern the market. Because of the losses in thermal power plants, electricity costs at least three times as much as natural gas. In a Sustainable Energy Economy, electricity will become the price-setter. Because of the inherent losses hydrogen energy will cost at least twice as much as electrical energy. This will result in a complete reversal of the entire energy market. The vision of a simple replacement of natural gas, gasoline or diesel fuel by hydrogen should be abandoned without further discussion.

The energy price reversal will also affect the mobile sector. As electricity from the grid will cost only 50% of hydrogen energy offered by filling stations, electric cars - not hydrogen fuel cell vehicles - will become the preferred option for commuters. Electric cars already exist and are in daily use in some countries for short range driving. The technology can certainly be improved, but the infrastructure exists. Batteries or super capacitors can be charged over night at home or during the day in the parking lot at work. Technical advances are welcome, but the simple electric vehicle technology may be more convincing for ordinary people than hydrogen fuel cell vehicles. The power source-to-wheel efficiency of electric cars is somewhere between 60 and 70%, while only about 17% and 23% can be obtained with fuel cell vehicles energized with liquid or gaseous hydrogen, respectively (see "Efficiency of Hydrogen PEFC, Diesel-SOFC-Hybrid and Battery Electric Vehicles", www.efcf.com/reports).

With all-electric commuting cars and automatic battery chargers in every garage, the bigger family cars will most likely be an electric-hybrid vehicle operated locally on batteries, but on synthetic fuels during longer hauls. It is very unlikely that synthetic hydrogen will be the fuel, because it is much more difficult to distribute and store economically in sufficient quantities and over longer periods than equally synthetic liquid hydrocarbons fuels. As a given volume of methanol or ethanol contains more hydrogen than the same volume of liquid hydrogen, it is likely that hydrogen will be packaged in synthetic energy carriers rather than delivered in its elemental state. Furthermore, most synthetic hydrocarbon fuels can be used in all fuel cells as well as in internal combustion engines. In a Sustainable Energy Economy gasoline and diesel fuels will not simply be replaced by hydrogen, but by a new mobility concept based on electric commuting vehicles and synthetic hydrocarbon fuels for distance driving and trucks. Today's fleet of multi-purpose passenger will be adapted to the new energy supply situation. Hybrid cars are already on the market and set the trend for the mobility future. It is unlikely that hydrogen fuel cell cars will ever play a significant role.

The visionary forecast of some key energetic and economic aspects of a Sustainable Energy Economy seem to indicate that hydrogen will not play a key role in the future as seen by the promoters of a Hydrogen Economy. Instead, the role of hydrogen will be limited to storage of electric energy from intermittent sources, to regional energy solutions or to clean energy applications in mining, submarines, congested urban developments etc. where the equally clean electrical solutions cannot be implemented. Because of the inefficiency of generating, packaging and distributing the

gas, hydrogen will always remain an expensive luxury fuel. Thus, the role of hydrogen within a Sustainable Energy Economy appears to be bleak rather than bright.

But what is the future role of fuel cells? We need fuel cells now for the efficient and clean conversion of natural gas and liquid hydrocarbons. They have the potential to be better than internal combustion engines and gas turbines. With proper reformers all fuel cells qualify for this task. Fuel cells with internal reforming (DMFC, MCFC and SOFC) offer inherent advantages over proton exchange systems. Even in a distant future, these types of fuel cells are needed to convert synthetic hydrocarbons into electric power.

However, we do not need fuel cells as justification for a premature change of our energy system. A Hydrogen Economy will be established if it makes sense, not because there are fuel cells waiting for hydrogen. We will need millions of fuel cells in the highly unlikely event that hydrogen will be established as the main energy carrier. But since a Hydrogen Economy is not likely to ever be established, it does not make sense to develop technologies for a "transition period". This includes the production of hydrogen by reforming of natural gas, the conversion of biomass into hydrogen, or the establishment of local hydrogen infrastructures for demonstration purposes. In particular, the targets of government programs should be carefully assessed, before too much material and intellectual resources are invested in dead-ended technology developments.

About the Author:

Ulf Bossel is founder and organizer of the European Fuel Cell Forum. He holds a Diploma Degree in Mechanical Engineering from the Swiss Federal Institute of Technology (ETH) at Zurich and a Ph.D. from the University of California at Berkeley. For almost 30 years Ulf Bossel has applied engineering and physics to the promotion of renewable energy and energy conservation.