

## What is required to make hydrogen a real energy carrier option ?

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### Abstract

The driver for the introduction of hydrogen as mobile energy-carrier is regulatory measures to avoid the CO<sub>2</sub> emissions which are related to the current fossil carbon based situation. H<sub>2</sub> is a large volume chemical product with an annual production of about  $45 \cdot 10^6$  tons, most of which however is also derived from fossil sources.  $45 \cdot 10^6$  tons H<sub>2</sub> correspond to  $\sim 5,5 \cdot 10^{12}$  MJ heating value. The German transport sector consumes  $2,6 \cdot 10^{12}$  MJ/a<sup>1</sup>, which is already 50% of the worldwide produced H<sub>2</sub>. There are estimates that in Europe a potential  $\sim 2$  million tons “excess H<sub>2</sub>” exists as inadvertently occurring byproduct of chemical processes<sup>2</sup>. The endothermic dehydrogenation of Ethylbenzene to Styrene for example releases 19,2 kg H<sub>2</sub> per ton of Styrene, the world capacity for Styrene in 2008 being 26 million tons, this process alone would be good for up to 0.5 million tons of H<sub>2</sub>. Proposals to start the “hydrogen economy” with this type of “excess H<sub>2</sub>” however don’t realize that today either it is directly consumed to fuel the typically endothermic processes which are the source of this hydrogen or it is chemically used after cleanup in the H<sub>2</sub> pipeline system of integrated chemical sites. Therefore, a hydrogen based energy scenario has to rely on new sources. The only viable carbon-free hydrogen source is water, which has to be split into its constituting elements. This highly endothermic reaction requires  $1,2 \cdot 10^5$  MJ/ton H<sub>2</sub>. Energy input can either be by means of electrical or by thermal high temperature energy, in the long run possibly also by photocatalysis. Electrolysis is an established technology, however not for water- but for chlor-alkali-electrolysis, to produce chlorine, sodium hydroxide and hydrogen as a byproduct. On-purpose water electrolysis for the production of H<sub>2</sub> has a negligible share of only 1 % of the worldwide hydrogen production. The reason is high electricity cost and the low efficiency of only  $\sim 65\%$ .

If hypothetically the above mentioned energy for the German transport sector would be supplied by means of H<sub>2</sub> from water electrolysis (assuming 65% electrolysis efficiency), an electricity input of  $4 \cdot 10^{12}$  MJ would be needed. Currently, Germany has 25 GW<sup>3</sup> of installed wind turbine capacity with a weather-based  $\sim 16\%$  year-round on-stream factor. These plants thus could deliver  $1,3 \cdot 10^{11}$  MJ which is less than 5% of the currently used energy for transportation. Still another issue is to make this hydrogen available on board of the vehicle, and the balancing of fluctuating wind/solar power. This sheds some light on the dimension of the needed capital investment and the required research efforts, namely:

- Develop processes for efficient H<sub>2</sub> storage in chemical transportation fuel compounds
- Increase the efficiency of water electrolysis
- Develop technologies which can cope in an economic way with fluctuating power input

Chemical and chemical engineering know how will be indispensable to solve these issues.

<sup>1</sup> Energieflußbild Deutschland 2008, AG Energiebilanzen e.V. ([www.ag-energiebilanzen.de](http://www.ag-energiebilanzen.de))

<sup>2</sup> European Hydrogen Infrastructure Atlas, July 2007, [www.roads2hy.com](http://www.roads2hy.com); eds Steinberger-Wilckens; Trümper – PLANET GbR

<sup>3</sup> Source: Deutsches Windenergie Institut ([www.dewi.de](http://www.dewi.de))