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Hydrogen as Strong Partner of Renewable Energy Systems

The Importance of Hydrogen as Secondary Energy Carrier for Renewable Primary Energies

Wasserstoff als Energiespeicher und Brennstoffzellen als Energiewandler sind ausgezeichnete Partner erneuerbarer Primärenergien. Dies ist das Ergebnis einer Studie, die im Jahr 2008 von der Ludwig-Bölkow-Systemtechnik GmbH, Ottobrunn, im Auftrag des Deutschen Wasserstoff- und Brennstoffzellen-Verbands (DWV) sowie der European Hydrogen Association (EHA) durchgeführt wurde. Im Folgenden sind die Ergebnisse zusammengefasst dargestellt. Es ist die Kurzfassung eines Vortrags, der im Juni 2008 auf der World Hydrogen Energy Conference in Brisbane/Australien gehalten wurde. Langfassungen in deutscher Sprache sind beim DWV erhältlich.

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Hydrogen as a universal energy carrier can be produced as secondary energy from a wide variety of primary energy sources. Considering the whole energy chain from production to end-use, hydrogen, used in fuel cells to power transport and stationary applications, can provide significant benefits in terms of greenhouse gas emissions and local pollutants through increased efficiency and/or lower rate of emission per end-use energy unit.

As the EU Strategic Energy Technology Plan is pointing out in its Technology Map »The possible competition for primary energy sources for hydrogen production and other sectors of activities indicates a need for synergies and coordination between policies and industrial sector strategies«. From today's observations, there also will be a mix of different solutions suited to individual mobility needs. This will include shifts in the modal split.

The aggregate supply of fossil and nuclear energy is expected to peak by around 2015. After the peaking of the oil supply (today), the global supply of natural gas, coal and nuclear fuel is expected to reach a combined maximum by around 2020 – at the latest. This will have significant impacts on the total energy supply. With peak oil we are entering into a transition phase towards a post-fossil energy era (*figure 1*).

The limitation in availability of fossil energy resources as well as the threat of climate change to biosphere have led to the formulation of political goals with regard to security of energy supply and especially reduction of greenhouse gas emissions. All the underlying issues can be addressed in an efficient and sustainable way by energy conservation, by the increased use of renewable energy sources and by the use of hydrogen and fuel cells.

First markets – the role of by-product hydrogen

Today, large quantities of excess hydrogen are already available in

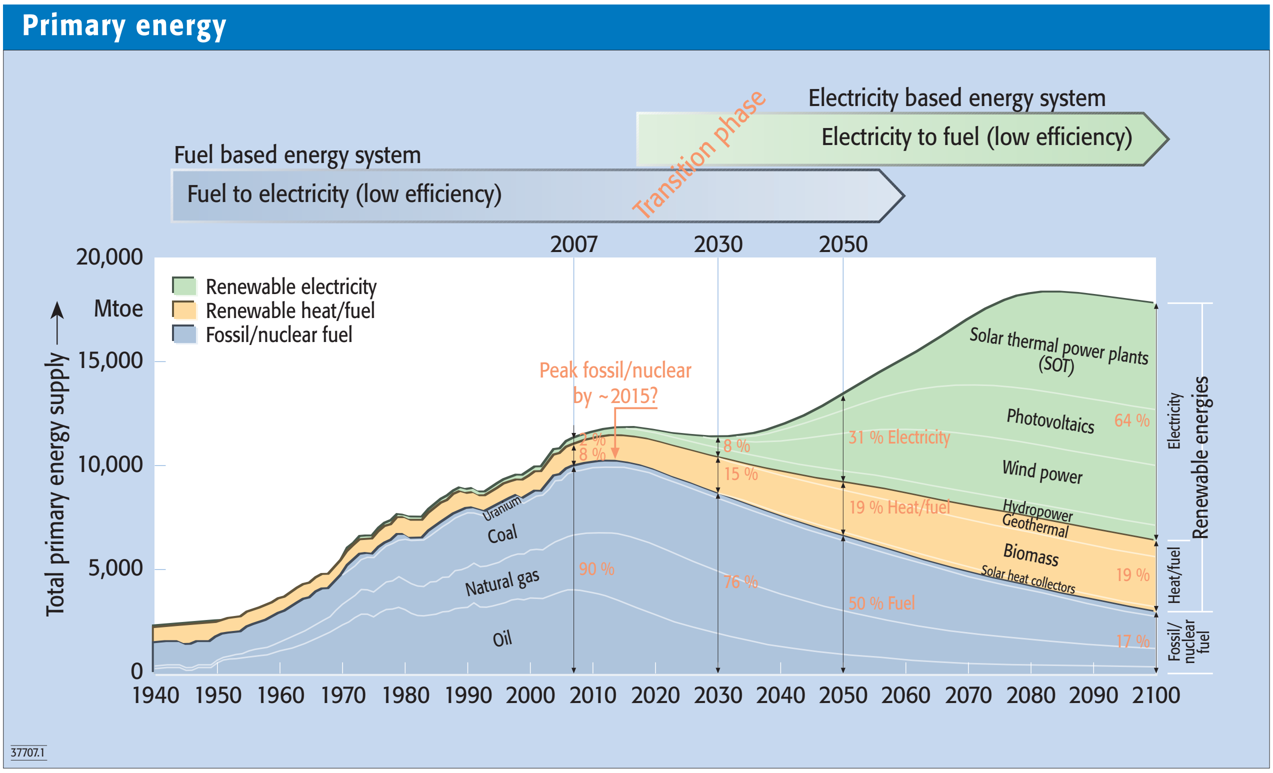

Figure 1. Future primary energy supply

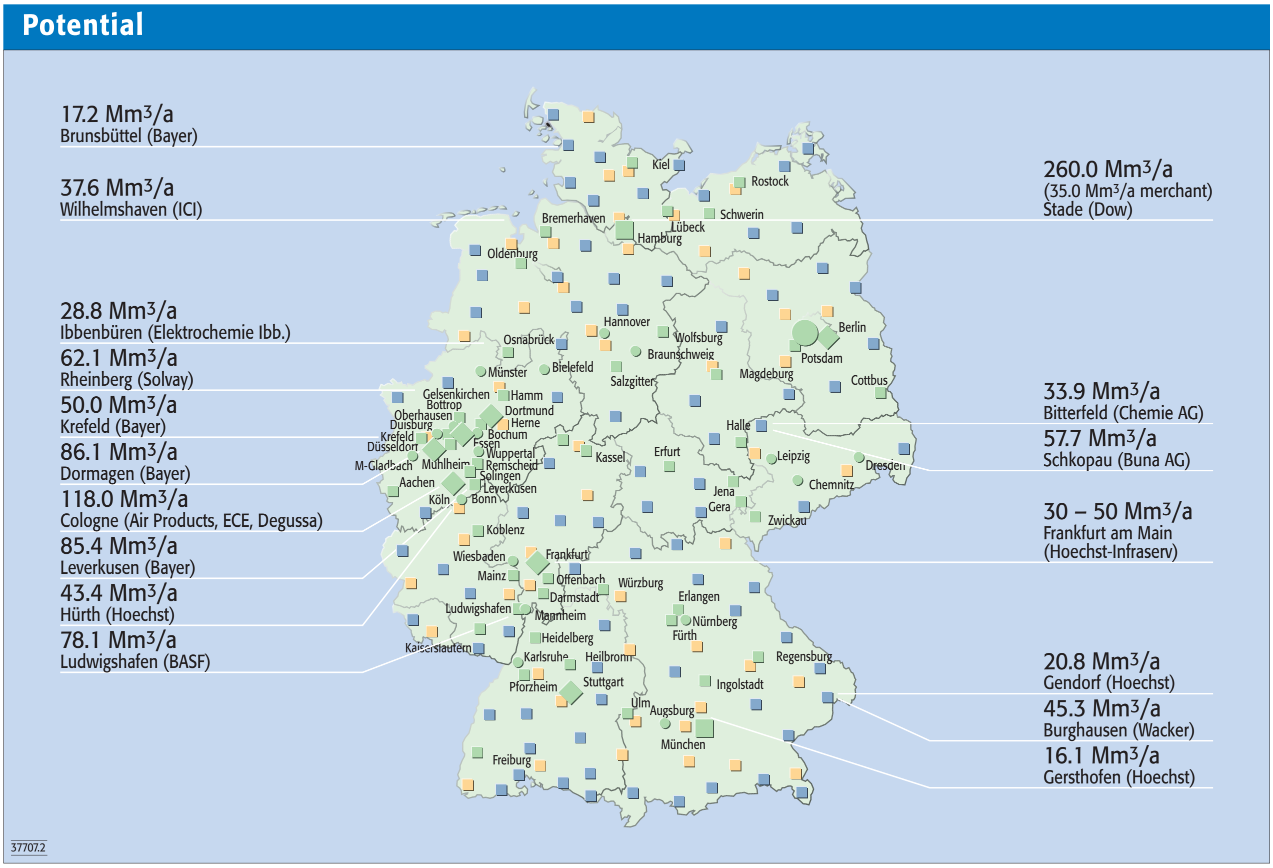

Figure 2. Potential for chemical by-product hydrogen in Germany in 1998
blue countryside filling station yellow highway filling station green filling stations in metropolitan areas

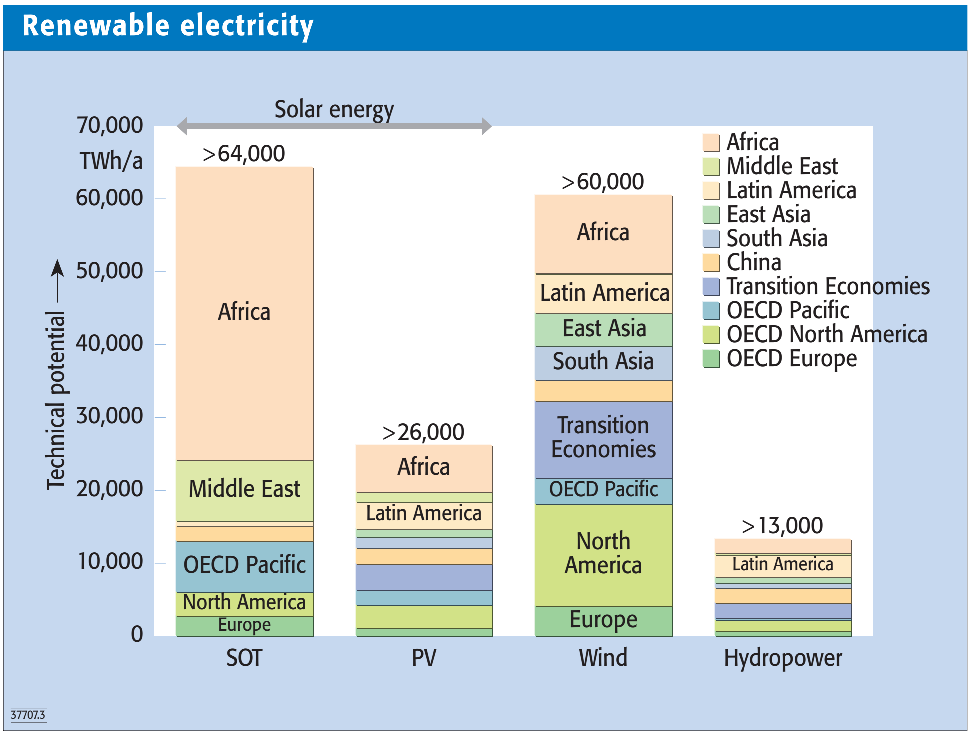

Figure 3. Potential of renewable electricity

some regions in Europe. In most cases hydrogen is produced as by-product in chemical processes. Hydrogen from these sources offers an interesting option for first applications in transport and stationary uses.

In case hydrogen can be used near the production site, it can constitute an early but also economic source for first large-scale vehicle demonstrations and commercialisations. Also the use in efficient stationary fuel cell CHP units is feasible and economic.

As these sources are not available everywhere, they will have to be complemented by other hydrogen supply sources as time progresses. Nevertheless, these by-product sources can assist in providing low cost hydrogen efficiently, as they save the energetic losses and associated CO_2 emissions of at least 20 % incurred by natural gas reforming or other conversion processes.

In order to give an estimate, if it is assumed that 800 million Nm³ of by-product hydrogen can be made available as vehicular fuel in Germany, some 600,000 efficient fuel

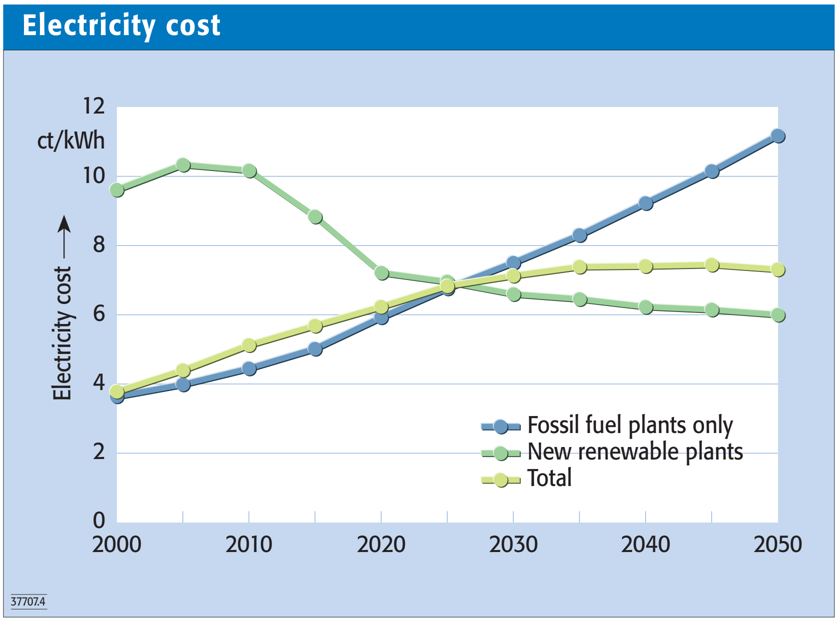

Figure 4. Average electricity cost scenario – medium voltage level – for renewable and fossil plants; without CCS, in 2002 Source: Nitsch 2007

cell passenger cars could be operated [assuming an energy consumption of 0.3 kWh/vehicle-km and an annual operating range of 12,500 km/a].

In Germany, at various locations there is a surplus of hydrogen which today can only be burnt for thermal uses (*figure 2*). This hydrogen, if substituted 1:1 by natural gas for its thermal uses, could be made available for other energetic uses with higher value, like e.g. vehicle fuel. In most cases purification and additional compression is required. In Germany the potential amounts to between 800 million and 1 billion Nm^3/a or 2.5 – 3 TWh (9 – 10.8 PJ).

Technical potential of renewable electricity – worldwide

Renewable electricity could become the most important energy of the world. *Figure 3* summarises the technical potential for the production of renewable electricity from photovoltaics (PV), solar thermal power plants, wind and hydropower by world regions. Today's global electricity use lies in the order of 18,000 TWh/a.

Biomass energy potentials
The potential of biomass for transport fuel production is limited and in direct competition with food production and other usages. The worldwide potential of solid biomass is estimated at about 95 EJ/ a.

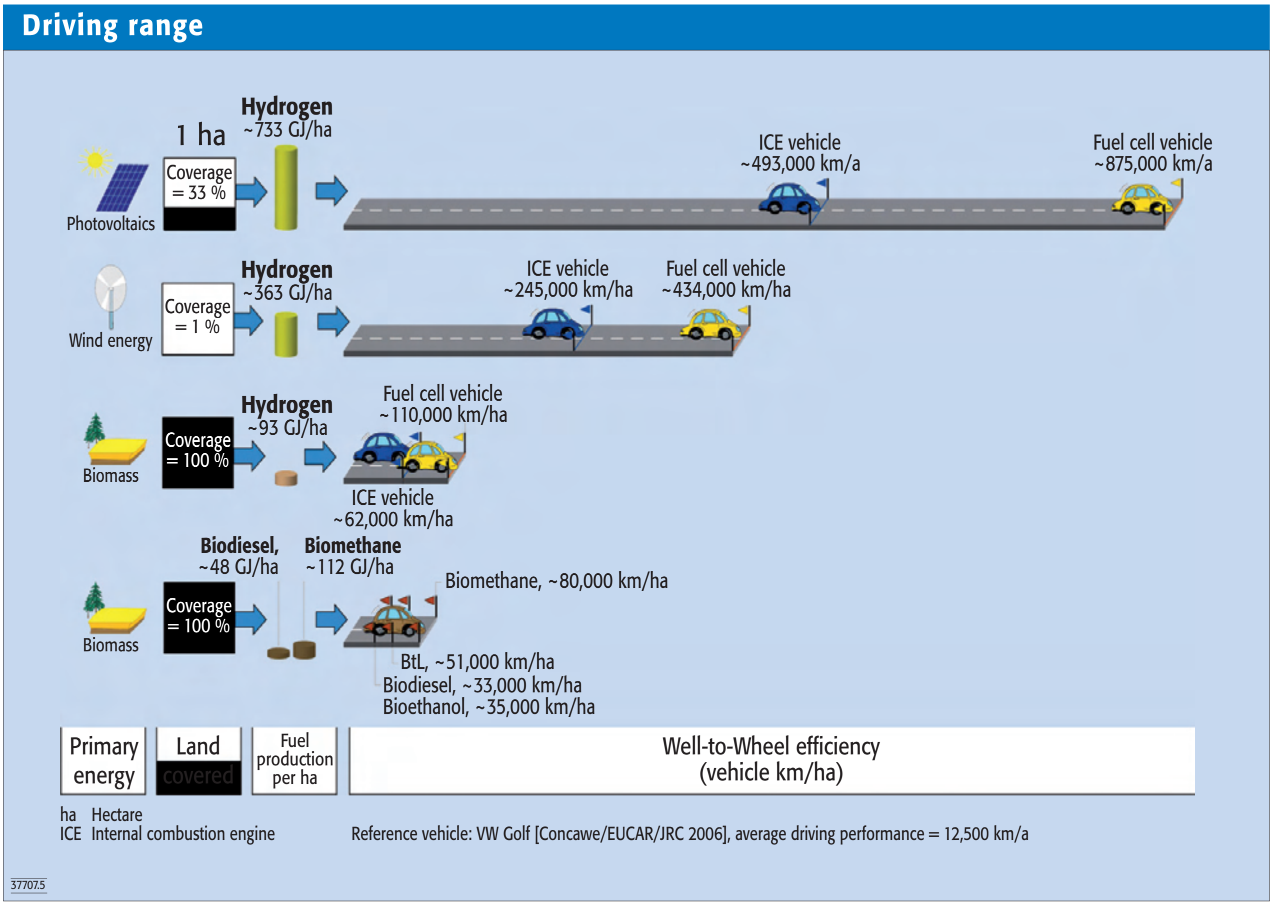

Figure 5. Driving range for vehicles with different powertrains

The EU potential lies in the order of 7 – 8 EJ/a.

Therefore it is not possible to substitute today's EU transport fuel consumption (approx. 15 EJ/a) or even a reduced demand of transportation fuel in the future completely by biomass from within the EU. A further increase of biofuel use requires the import of biofuels or biomass. But also on a worldwide level the potentials are limited and there are serious conflicts with the stationary sector for the energetic use of biomass and the food production chain worldwide.

As a result it can be concluded that biomass can only meet a relatively small fraction of the overall energy demand as negative environmental and social impacts should be avoided. The highest fraction of the future energy demand will be met by wind power and the direct use of solar energy.

Renewable electricity storage

With increasing share of renewable electricity our future energy system will require large scale storage systems for electricity. Today, pumped hydro power stations are the only widely used means to store electricity at industrial scale. But the potential for further extension and new installations is very limited. The only technology at present knowledge which has the potential for single storage systems in the 100 GWh range is the storage of hydrogen in underground salt caverns.

Hydrogen as storage for electricity

Hydrogen can be produced from electric power by high pressure electrolysers (≈ 3MPa). For efficient storage hydrogen has to be further compressed before stored in underground salt caverns at a pressure up to 30 MPa. For high power levels the most efficient conversion back to electricity can be achieved in combined cycle power plants. In the lower power range fuels cells can be applied. Round-trip efficiencies are expected to be in the range of 35 – 40 %. The achievable storage capacity of compressed hydrogen is more than one order of magnitude higher than the one of compressed air. The storage of compressed hydrogen in salt caverns being relatively cheap, this technology qualifies especially for long-term storage of bulk energy to be reused during long-lasting unavailability of wind energy.

Hydrogen as transport fuel

A further pathway for the utilisation of sustainably produced hydrogen will be its use in the transportation sector. The current discussions on CO_2 reduction and the availability of fossil fuels show, that car industry is speeding up with their efforts to develop hydrogen powered vehicles and that first vehicle sales can be expected for 2010 followed by a broad market entry from 2015 onward.

Furthermore, it can be observed that hydrogen propulsion in passenger cars is a twice as efficient end-use technology than today's direct injection engines and thus displaces conventional fuels and powertrains more efficiently than using hydrogen in stationary conversion units (combined cycle power plants or fuel cell systems) where it competes for the time being with almost as efficient natural gas-based end-use technologies.

Finally it should be mentioned, that these topics – large-scale storage of hydrogen, utilisation of hydrogen as a storage medium for electrical energy and the utilisation of surplus energy in the transportation sector – only played a subordinate role in RD&D activities in the past. Based on the above mentioned possibilities this technology can provide, it is urgently needed that both industry and politics attend to this topic and provide the required resources allowing to find suitable answers to the pending changes in the energy landscape.

Production costs

Energy costs are expected to increase during the next decades due to the depletion of fossil and nuclear energy sources and rising investments in new power plants and infrastructure.

Figure 4 shows rising costs for fossil energy sources and decreasing costs for renewable energies depending on the assumption that the break-even point between fossil and renewable electricity production will occur sometime between 2020 and 2030. Up to this date, the introduction of renewable energies will lead to higher average energy costs whereas after passing the break-even point, the growing contribution of renewable energy sources will reduce electricity costs compared to a purely fossil scenario.

Future challenges and the role of hydrogen

Hydrogen with the highest feedstock flexibility of any available energy carrier can provide a clean storage media and facilitate the transition from today's energy world into an energy world with growing fluctuating renewable electricity supply. Hydrogen therefore allows to extend significantly the use of renewable energy sources in the transport sector (*figure 5*). In particular, hydrogen used as an automotive fuel in hybridised fuel cell powertrains can provide superior well-to-wheel efficiencies compared to today's fuels and thus reduces primary energy consumption and greenhouse gas emissions.

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