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THE HYDROGEN IS HOPE AND REALITY

Lóránt SZABÓ

Environmental Engineering and Natural Science Department, Rejtő Sándor Faculty of Light Industry and Environmental Protection Engineering, Óbuda University, H-1034 Budapest, Doberdó u. 6, Hungary, szabo.lorant@rkk.uni-obuda.hu

Abstract: *This paper deals with green hydrogen production, conversion and end uses. Nowadays global energy consumption was increased increasingly due to the growing the population and standards of living style. Moreover, with increasing the global warming and environmental pollution, the development of renewable energy sources was becoming more essential. Hydrogen is one of the most promising clean and sustainable energy carriers and emits only water as a by-product without any carbon emissions. Hydrogen (H_2) is the simplest first chemical element of the periodic table. Hydrogen is the most abundant element in the universe, accounting for approx. 75% is hydrogen, but it occurs only in bound form in its compounds, from which hydrogen can only be produced by investing a large amountof energy (in the case of water decomposition it is 286 kJ/mol). On Earth, hydrogen only occurs naturally in compounds formed with other elements including in oxygen to form water (H_2O) and carbon to form hydrocarbons which are found in fossil fuels such as natural gas (predominately methane (CH_4)), coal and petroleum. Electrolysis isthe process of using electricity to split water into hydrogen and oxygen. This reaction takes place in a unit called an electrolyser. A fuel cell utilizes the chemical energy of hydrogen and oxygen to generate electricity without combustionor pollution. Fuel cell is not a new technology. Major industrial nations must look to a range of options to reduce theircarbon emissions and meet their various environmental targets. Of the many emerging solutions, hydrogen will have a significant part to play in our sustainable future as an efficient and clean energy carrier that can be utilised in new applications but also integrated into existing industrial processes in place of fossil fuels. The green hydrogen revolutionhas started, and we hope it will not be stopped.*

Keywords: *electrolysis, fuel cell, green energy, hydrogen, sustainable future.*

INTRODUCTION

Nowadays, the CO_2 emissions from the combustion of fossil fuels are 50 Gton/year, which is on average about 6 tons/person/year. CO_2 emissions exceed the amount bound by vegetation, the concentration of accumulating CO_2 greenhouse gases in the Earth's environment (atmosphere, seas) is increasing, which is the cause of climate change and warming (Figure 1).
Within the energy sources, the form of electrical energy is of paramount importance, and the electrical network allows excellent accessibility of the electrical network enables convenient, versatile use. Electricity must be available at all times according to consumption needs.
Figure (2) shows that the future energy supply will be dominated by electricity.

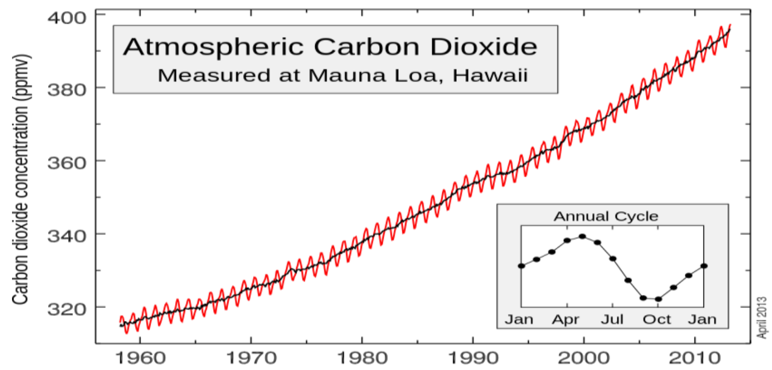

Figure 1. Greenhouse gases in the Earth's environment

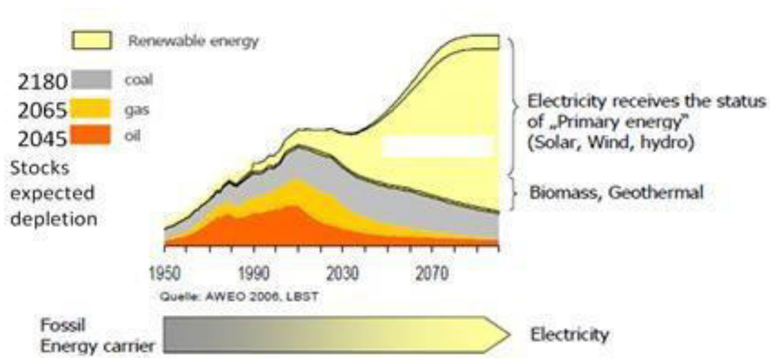

Figure 2. Future energy supply will be dominated by electricity

Reducing warming despite the steady increase in energy demand - the reduction of fossil fuels, which are still predominant in energy consumption – CO_2 emissions can be reduced by rapidly increasing renewable energies.

Hydrogen electrolysis by renewable electricity

Wind and solar capacity will increase rapidly (60 -80 GW/year) and renewable electricity costs will decrease. Figure (3) shows the global average cost of wind and solar technologies.

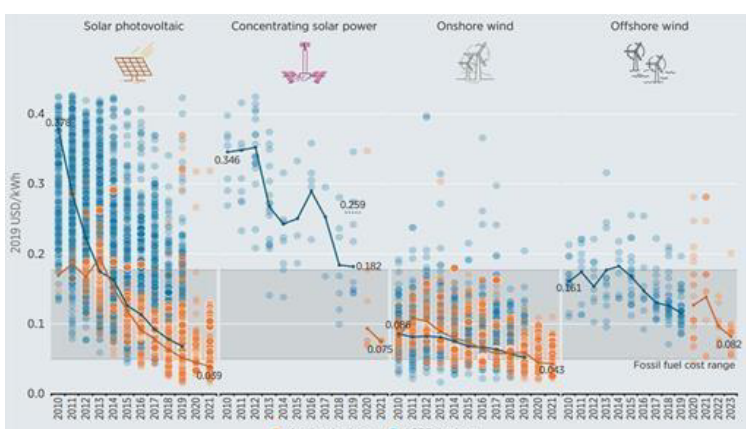

Figure 3. Global average cost of wind and solar energies

However, renewable electricity sources (water, wind, solar) are seasonal, time of day, weather dependent, so energy storage is a big challenge for the future. The developers also see opportunities in channeling surplus power into electrolyser plants. Overproduction of renewable electricity can be partially solved by rapidly expanding lithium-ion batteries and the decomposition of hydrogen by electrolysis. Thanks to the intensive development of batteries, the cost of specific storage energy has been reduced (Figure 4).

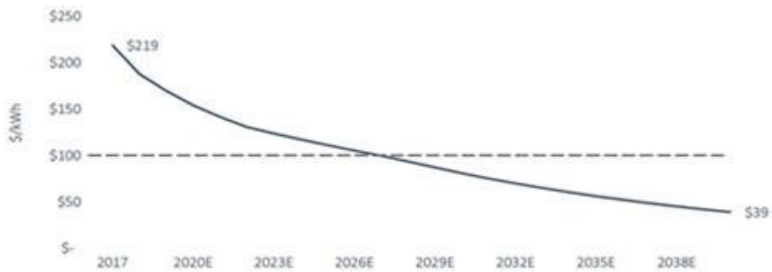

Figure 4. Battery pack price forecast from 2017 ($/kWh)

Electrolysers avoid carbon emissions by using electricity to split water into hydrogen and oxygen. Here is how a very simple electrolyser makes hydrogen gas from water (Figure 5).

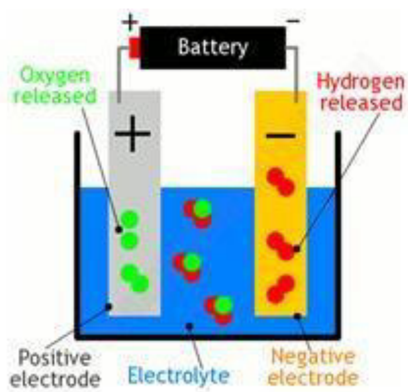

Figure 5. Working method of the electrolyser

Electrolysers avoid carbon emissions by using electricity to split water into hydrogen and oxygen. The cost of renewable hydrogen remains higher than hydrogen produced from gas renewable hydrogen costs, but falling wind and solar costs are closing the gap [2].

Hydrogen

Hydrogen can be compressed and held under very high pressures, or liquefied and held at cryogenic temperatures (Figure 6). Compression and cryogenic refrigeration increase H_2 energy density per unit of volume, but both are energy-intensive operations, and the vessels for both must be made of materials that can withstand high pressure and prevent hydrogen loss via permeation.

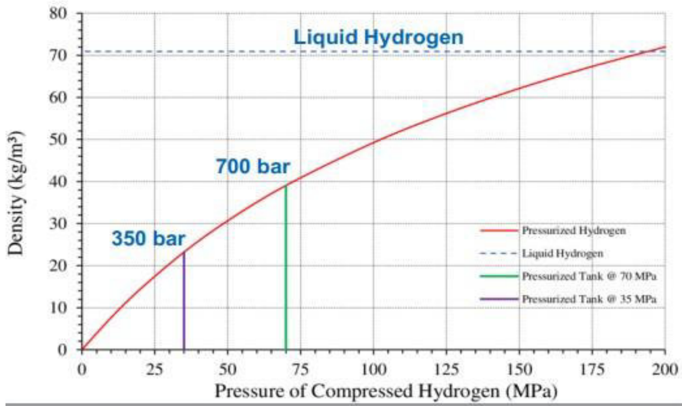

Figure (6) Hydrogen can be compressed under high pressures

The resulting robust containers do not "package" well in commercial trucks, let alone on passenger cars. Further, the cryogenic option requires continuous energy input to keep hydrogen at -253 °C. In the world of ground transportation, it's impractical for any use other than large-scale H_2 storage at vehicle refueling stations.

A third option would be quite welcome in automotive circles. It's technically possible to store hydrogen in a solid state at, notably, room temperature and normal atmospheric pressure. The method involves absorption or adsorption of hydrogen into certain metal halides. This method, however, is fraught with challenges and remains commercially impractical.

For the present, auto OEMs are focusing on compressed hydrogen gas, which currently offer the best cost vs. benefit ratio and the fewest practical barriers to implementation.

A fuel cell harnesses the chemical energy of hydrogen and oxygen to generate electricity without combustion or pollution (Fig. 7). Fuel cell technology is not new; NASA has used fuel cells for many years to provide power for space shuttles' electrical systems [1].

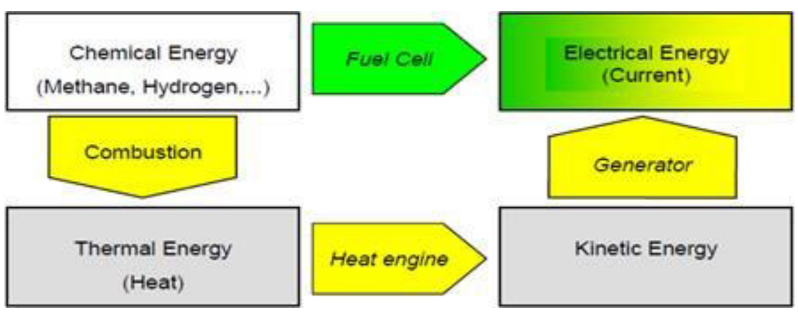

Figure 7. Fuel cell basics

Think of fuel cells as batteries that never run flat. Instead of slowly depleting the chemicals inside them (as normal batteries do), fuel cells run on a steady supply of hydrogen and keep making electricity for as long as there is fuel in the tank.

Hydrogen powered vehicles, fuel-cell

Most cars on the road today use an internal-combustion engine to burn petroleum-based fuel, generate heat, and push pistons up and down to drive the transmission and the wheels. Stricter regulations for CO_2 emissions (now 95 g CO_2 /km) require the development of new propulsion methods. There are really just two ways to power a modern car. Electric cars work an entirely different way. Instead of an engine, they rely on batteries that feed electric power to electric motors that drive the wheels directly. Hybrid cars have both internal-combustion engines and electric motors and switch between the two to suit the driving conditions (Figure 8).

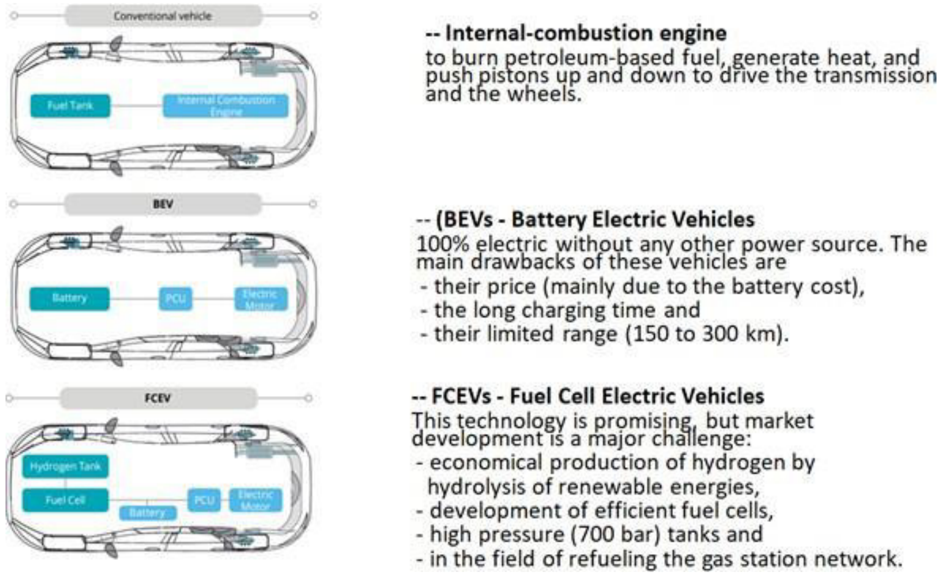

Figure (8) Propulsion system of vehicles

In the near future, the transition from a coal-based economy to hydrogen, the vehicle may also be powered by fuel cells. The type of fuel cell typically used in automobiles is a Proton Exchange Membrane (PEM), also called a Polymer Electrolyte Membrane fuel cell [2]. Working method of the PEM fuel cell can be seenin the Figure (9).

Fuel cells are a bit like a cross between an internal-combustion engine and battery power. Like an internal-combustion engine, they make power by using fuel from a tank (though the fuel is pressurized hydrogen gas rather than gasoline or diesel). But, unlike an engine, a fuel cell does not burn the hydrogen. Instead, it is fused chemically with oxygen from the air to make water. In the process, which resembles what happens in a battery, electricity is released and this is used to power an electric motor (or motors) that can drive a vehicle. The only waste product is the water, and that is so pure you can drink it!

Think of fuel cells as batteries that never run flat. Instead of slowly depleting the chemicals inside them (as normal batteries do), fuel cells run on a steady supply of hydrogen and keep making electricity for as long as there is fuel in the tank.

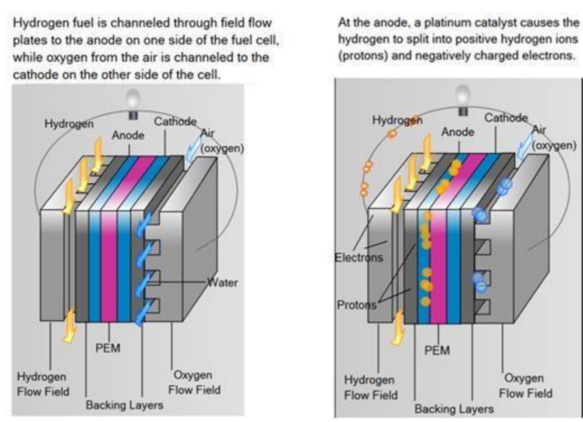

Figure 9. PEM fuel cells working method

What happens in a fuel cell is called an electrochemical reaction. It is a chemical reaction, because it involves two chemicals joining together, but it is an electrical reaction too because electricity is produced asthe reaction runs its course. Figure (10) shows schematic diagram of hydrogen drive [3].

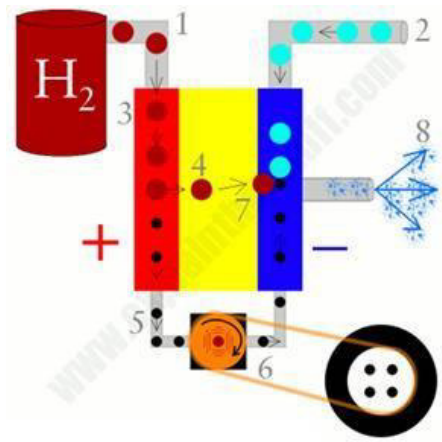

Figure (10) Schematic diagram of hydrogen drive

A fuel cell has three key parts similar to those in a battery. It has a positively charged terminal (shown here in red), a negatively charged terminal (blue), and a separating chemical called an electrolyte in between the two (yellow) keeping them apart.
This type of fuel cell is called a PEM (different people say this stands for polymer exchange membrane or proton exchange membrane because it involves an exchange of protons across a polymer membrane). It will keep running for as long as there are supplies of hydrogen and oxygen. Since there is always plenty of oxygen in the air, the only limiting factor is how much hydrogen there is in the tank [3].

Compressed gas tanks

The CHG (CHG - Compressed Hydrogen Gas) tanks and electrode substrates with mass production of FCVs expected to begin around 2021 and onward, Toray Group foresees accelerating growth in demand for extra-high pressure tanks suited to hydrogen fuel refilling. The hydrogen is highly flammable and transparent, this a growth business field where products for pressure vessel applications great business possibility challenge. The weight of the high pressure hydrogen tank is a crucial feature for vehicles, which is why Type IV (CFRP) tanks have been developed. The plastic (PA) lining inside is reinforced with carbonpatch spots spread on the dome part and then reinforced with carbon filament winding. The internationally reputed builders all agree on a pressure of 700 bar with a volume of 60 liters of hydrogen for about 2.5 kg ofhydrogen (Figue 11). Manufacturing technology is being developed to increase the hydrogen / tank weight ratio (2.5: 44 ~ 0.057) [1].

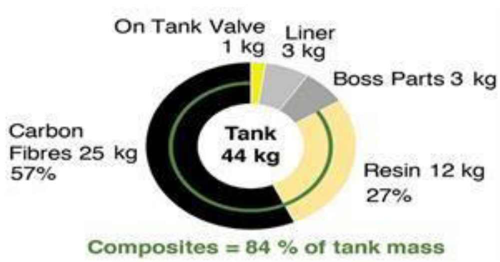

Figure 11. Mass distribution for a 60-litre tank

High-pressure CFRP-reinforced tanks for hydrogen-powered vehicles are key in the near future, carbon fiber can expect great market growth (Figure 12).

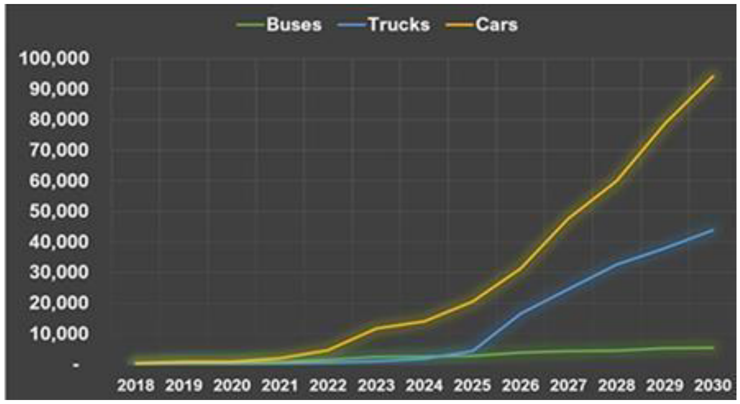

Figure 12. Projected carbon fibre usage (metric tons) in Type IV 700-bar compressed hydrogen tanks for the highest production volume fuel cell vehicles (FCV)

Application of hydrogen drive

The practical introduction of hydrogen propulsion on cars, buses, trucks, trains, ships and airplanes is all promising. In the case of airplanes, the use as a fuel in the liquefied state, cooled to -253 ºC, is also being investigated. For a hydrogen economy, hydrogen refueling stations will be needed to provide fuel for vehicles. This could easily be done by retrofitting existing fuel stations. Some of these are located awayfrom urban centers or outside populated areas. On-site wind-powered water electrolysis is a potential solution. The advantage is cost allocation, due to integration of systems with current infrastructures and effective use of energy.

The expected prevalence of hydrogen-powered vehicles by the end of the decade is shown in the table. The Table (1) shows that these 2030 projections are conservative, for example, less than1% of current car production will be FCV in 2030 [3].

Table 1. Projection of the car production [3]

	2030 FCEV Projection	2020 Vechicle Production	% of Current Production
Buses	17,633	270,000	6.5
HD Trucks	42,380	4,100,000	1.0
Cars	754,585	92,000,000	0.8

CONCLUSIONS

Hydrogen propulsion can look forward to a bright future in the coming decades due to decarbonization, continuous electricity supply, high growth in renewable energy and electricity storage. As green electricity gets cheaper in the future, low cost green hydrogen is coming. In parallel, as with solar and wind, the cost of hydrogen production is falling exponentially, as system sizes and production volumes grow, while performance improves. Technical conditions for the use of hydrogen in the new energy carrier and storage: economical production, storage and use of hydrogen from renewable energy (wind, solar) (fuel cell). The technology is technically feasible, and its economy today is still expensive compared to fossil fuels.

The development and application of new structural materials (CFRP) (wind vane structure, CHG tanks, hydrogen cell GDL-Gas Diffusor Leir carbon fiber porous structure materials in fuel cells are absolutely necessary for the success of energy developments. It is planned in Europe to accelerate renewable hydrogen development, targeting the deployment of 6 GW of renewable hydrogen electrolysers by 2024 and 40 GW by 2030 [3].

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