SOLAR PV- HYDROGEN AS A CLEANEST AND RENEWABLE FUEL FOR THE FUTURE

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Abstract:
It is believed that the "greenhouse effect" will lead a worldwide climate change with unpredictable but probably dangerous for human beings in most parts of the world. The "greenhouse effect" is a result of a rising atmospheric concentration of carbon dioxide emissions and other the "greenhouse gases". The growing economy in the world will lead to a rapid increase in CO_2 -emissions in the future, which will have important implication for any international effort to cut CO_2 -emissions to reduce the risk of global warming. Hydrogen has now established itself as a clean choice for an environmentally compatible energy system. It can provide sustainable future for building, industrial, and transport sector of human activities. The most important property of hydrogen is that it is the "cleanest fuel". Its combustion produces only water and a small amount of NO_X , no acid rain, no greenhouse effect, no ozone layer depletion, and no particulates aerosols. It seems then ideally suited for the conversion to renewable energy. On average, it has bout 20-30% higher combustion efficiency than fossil fuels and can produce electricity directly in fuel cells. In combustion with solar PV- and hydro-electrolysis, it is compatible with land area requirements on a worldwide basis. If fossil fuels combustion environmental damage is taken into account, the hydrogen energy system is already cost effective and become a practical solution to sustainable energy development.

Keywords: PV (Photovoltaic) system; renewable energy; hydrogen energy; storage; cost

1. Introduction

Since 1950, developed countries cumulatively produced more than 80% of worldwide GHG (Greenhouse Gas) emissions. Between 1950 and 1990, North America alone contributed 40 billion tons of carbon while Western and Eastern Europe contributed 75 billion tons. Developing countries produced only 24 billion tons of carbon emissions during the same period [1]. At present, per capita emissions in developed countries are also about ten times higher than those of developing countries. Since the late 1960, the world has been concerned about depletion of non-renewable energy resources and the pollution caused by their use.

Today, fossil fuels meet about (88%) of the world energy demand, mainly oil (38%), coal (30%) and natural gas (20%). Electricity account for about (12%) of which hydropower contributes 7% and nuclear energy 5% [1]. Even if the world known reserves of oil and natural gas will last for decades and coal, perhaps, for centuries, their depletion is still ineluctable and the foreseeable increase of consumption under population and standard of living pressure can eventually shorten these terms. On the other hand, the consequences of fossil fuel burning on the CO_2 content of the atmosphere, and the so-called greenhouse effect, are of great concern for the next generations. Substitution of fossil by renewable energy sources is the solution to these problems. On the long term, mankind has no other choice. A quarter of century of research and development has prepared the conversion in the energy

scenarios. Building and industrial sectors are more or less ready for this conversion. However, transportation which uses four times the energy used in housing and causes about ten times the air pollution because of its total reliance on petroleum, is still in an unfavorable situation. A storable and transportable energy vector is an absolute necessity to make this conversion. Hydrogen is one of the solution studied for this application [2]. Even in the building and industrial sectors, shortcomings of the renewable energy sources, namely their spatial and time dependent variability, plead for an ideal intermediary energy carrier which should be storable, transportable, pollution-free and independent of the variability of the energy source. Again, the so-called "Solar Hydrogen" could well meet the above prerequisites.
Fig. 1 shows the present energy-system and fig. 2 shows the future energy-system [3].

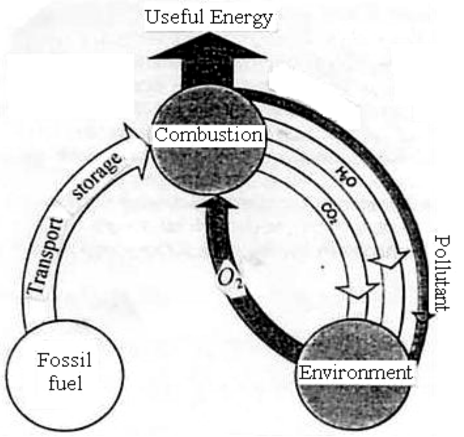


Fig. 1: Present energy-system

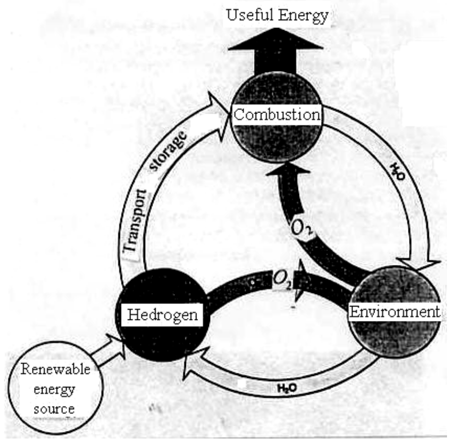


Fig. 2: Future energy-system

As energy-carrier, hydrogen must be used with security. Therefore, the question of the security of hydrogen poses itself in the comparison with natural gas (methane) and gasoline. Although hydrogen differs strongly in some characteristic parameter from these, in the future as well as for liquid as also gaseous hydrogen a certain energetic utilization is guaranteed. These show the results of the safety-research. Table 1 shows safety specification property of hydrogen, methane and gasoline [3].

Table 1: Safety specification property of hydrogen, methane and gasoline

Characteristic Parameter	Hydrogen	Natural Gas	Gasoline
Minimum Heater Value (*kWs/g*)	120	50	44.5
Self-Ignition Temperature (°*C*)	585	540	228-501
Flame-Temperature (°*C*)	2045	1875	2200
Ignition Limit In Air (*Vol.%*)	4-75	5.3-15	1.0-7.6
Minimal Ignition Energy (*mWs*)	0.02	0.29	0.24
Combustion Speed In Air (*cm/s*)	265	40	40
Detonation Limit (*Vol.%*)	13-65	6.3-13.5	1.1-3.3
Detonation Speed (*km/s*)	1.48-2.15	1.39-1.64	1.4-1.7
Theoretical Explosion Energy $(kgTNT / m^3GAS)$	2.02	7.03	44.22
Diffusion Coefficient In Air (cm^2 / s)	0.61	0.16	0.05

2. Renewable hydrogen production

Presently hydrogen is mainly produced by steam reforming of natural gas or by coal gasification, thus from non-renewable sources, virtually produced from fossil raw materials with fossil energy and water. The chemical water-fission can only run out with high reaction-temperatures. The necessary heat for the high reaction-temperatures is won by partial combustion and fossil raw materials. Approximately remains 2/3 of the input energy of petroleum, natural gas or coal as chemical energy of the hydrogen. In order to fully benefit from its unique properties, hydrogen must be produced from renewable feedstock water using clean and renewable forms of primary energy. Different methods of renewable hydrogen production are being developed. So far, water electrolysis is the only method available for large-scale hydrogen production. It can be used in combination with photovoltaic cells as well as with hydro, wind, wave, tide, solar thermal and ocean thermal electricity.

The reaction-equation equals then: Water + energy ➔ hydrogen + oxygen

An experimental 10 kW PV-electrolysis plant in Germany has indicated a low specific energy consumption $(3.84 kWh/Nm^3)$, good gas purity, fast dynamic response and a wide range of operation [4]. An interesting individual stand-alone application can be quoted in France [5], using wind energy to produce electricity for home needs. As soon as the needs are fulfilled, the excess is converted to hydrogen by electrolysis of rain water and stored in floating tank. When wind is lacking, hydrogen is burned in an internal combustion engine to produce electricity. A concept of hydro-hydrogen clean energy system is under investigation in a 100 MWe international project. The goal of this investigation is to prove the feasibility of the conversion of Canadian hydropower into hydrogen, the maritime transport of liquid hydrogen to Europe and storage, distribution and use there [6].

3. Solar hydrogen production

For the solar hydrogen production with photovoltaic and solar-thermal power plants, a suitable location with high solar-radiation is necessary. Solar cells can change solar-radiation into electric energy directly. This is enabled by the photovoltaic effect, which absorbs photons in a semiconductor and is generated electric charge carrier. The effectiveness of this energy-conversion is dependent strongly on the used material**.** Fig. 3 shows schematic construction of a solar cell and fig. 4 shows scheme of an alkaline electrolysis-cell [3].

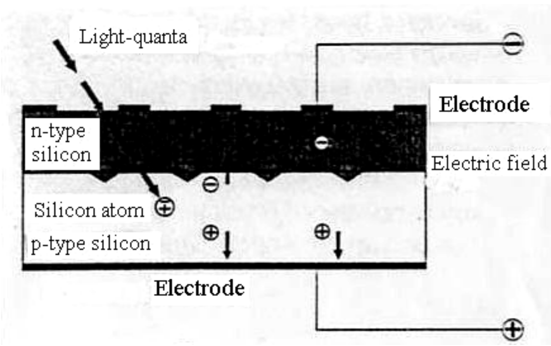


Fig. 3 Schematic construction of a solar cell

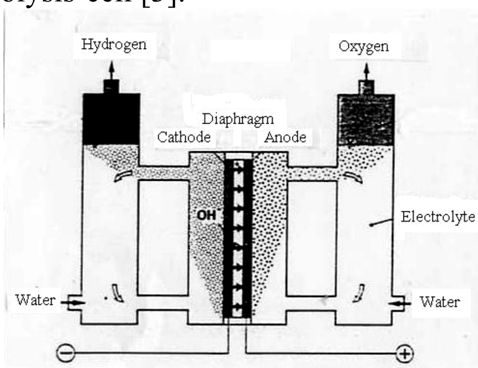


Fig. 4 Scheme of an alkaline electrolysis-cell

The most effective technology for the production of hydrogen from water is the electrolysis, the analysis of water with direct electric current into its components hydrogen at the cathode and oxygen at the anode. Fig. 5 illustrated the solar hydrogen-installation with application in Neunburg – Germany [3].

4. Hydrogen storage and transport

Storability of energy as hydrogen is one of its most important properties in renewable energy systems. Hydrogen as a storage medium has a high mass energy density (Wh/l) and depends on the pressure, but it is generally high compared with an electrochemical storage such as lead acid batteries. Applications in automotive and vehicles are used tank for gaseous and liquid hydrogen [8].

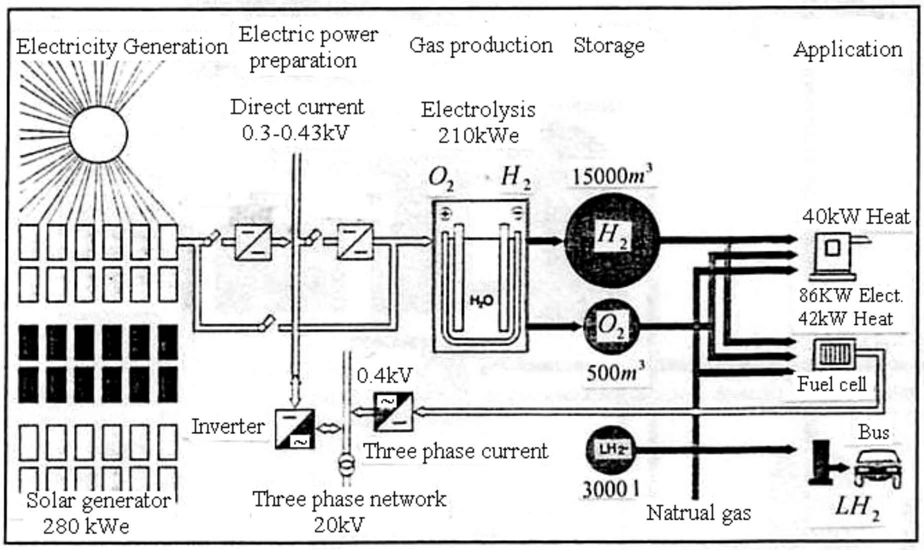


Fig. 5 Scheme the solar hydrogen-installation with applications [3]

Fig. 6 shows three different types of tank-storage of hydrogen for automotive and vehicles (tank under pressure - tank liquid gas - tank metal hydride compound) [7].

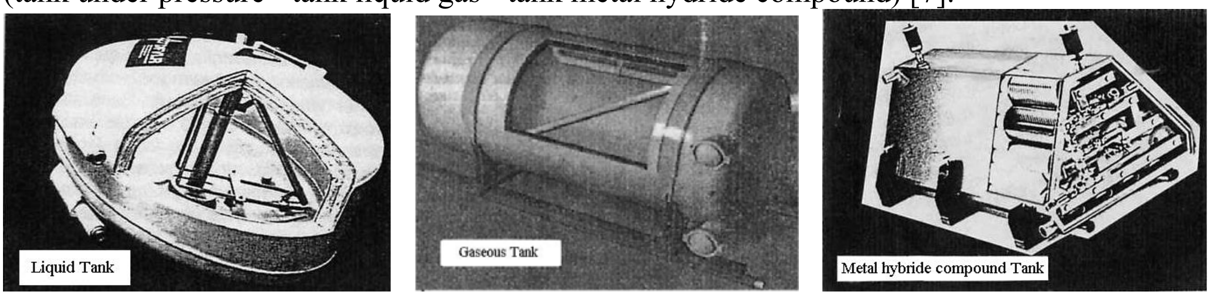


Fig. 6: Three different types of tank-storage of hydrogen for automotive and vehicles

Storage of gas is feasible and already practiced, in large scale, in man-made caverns. Underground storage can also be recommended in aquifers, depleted oil and natural gas fields. Storage of liquefied hydrogen in pressurized insulated containers and cylinders is also common practice. It is in this form that transport in supertankers is still studied. Transmission from storage to consumers by means of underground pipelines, in gaseous form, will be the normal follow up of the extended gazoduc network used nowadays for natural gas. This existing situation will be a plus in the progressive substitution of natural gas by hydrogen in the near future. Mixture of both is already studied in automotive applications. Using some of its unique physical and chemical properties, storage, transport and end use problems can be solved by concentration in metal hydrides, liquid organic hydrides or activated carbon. This solution is specially valuable for mobile application.

5. Hydrogen utilization

Hydrogen is suitable for motive power, both in internal combustion engine and in electrical powered vehicles. Hybrid vehicles, lorries and buses, are already on road in many countries. Proton Exchange-Membrane Fuel Cells can convert hydrogen into traction several folds more efficiently than today's drivelines convert gasoline. In addition to its clean burning advantages against any fossil fuel combustion, hydrogen is suitable and efficient for the production of electricity directly in fuel cells or indirectly through gas and steam turbines driven generators. Combined cycles, heat and electricity production, are seriously studied.

6. Economically and safety of hydrogen

Hydrogen properties make it safer than any other fuels. It dose not spill around, the flame goes directly upward, burns fast, radiates less energy and dose not create toxic suffocating fumes. Solar-energy and hydrogen are still relatively uneconomical but cost effective.

It does not go to cost everything about business-economic, but inexhaustibility and risk-poverty solar Photovoltaic (PV) system and solar hydrogen is qualities, that become always more valuable in future. An important step proceeded to the cost lowering is therefore modern fabric automated for solar and hydrogen technologies in industrial standard.
The effective expense of surface transportation for various energy sources includes both environmental and production costs shows table 2 [7].
Fig. 7 shows the capital cost of electrical storage options as a function of the length of time energy must be stored at the specified power level [7].

Table 2: Effective energy cost of surface transportation
LH_2: Liquid Hydrogen GH_2: Gaseous Hydrogen

Various Energy **(Dollar per Billion Joules)**	Internal Combustion Engines	Fuel Cells
Gasoline	21.40$	-
Synthetic Natural Gas	24.81$	-
Synthetic Gasoline	34.97$	-
Coal-GH_2	20.86$	10.17$
Hydro-GH_2	12.31$	6.00$
Solar-GH_2	15.53$	7.48$
Coal-LH_2	25.36$	-
Hydro-LH_2	14.67$	-
Solar-LH_2	18.70$	-

The most important property of hydrogen is that it is the "cleanest fuel". Its combustion produces only water and a small amount of NO_X. Fig. 8 shows the estimated emissions for five types of motor vehicles [7].

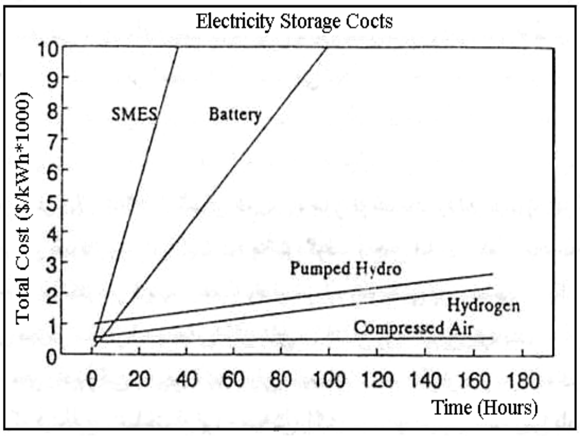


Fig. 7: Electricity Storage Costs

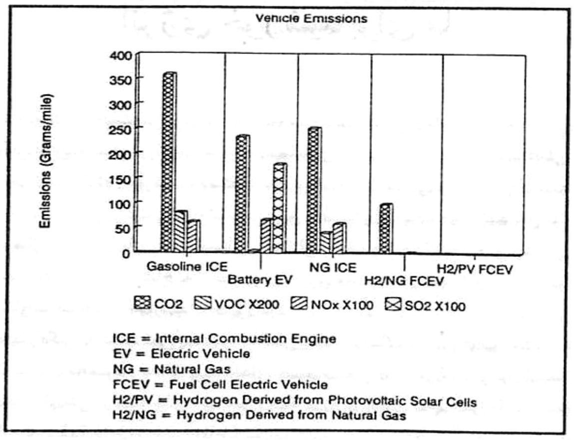
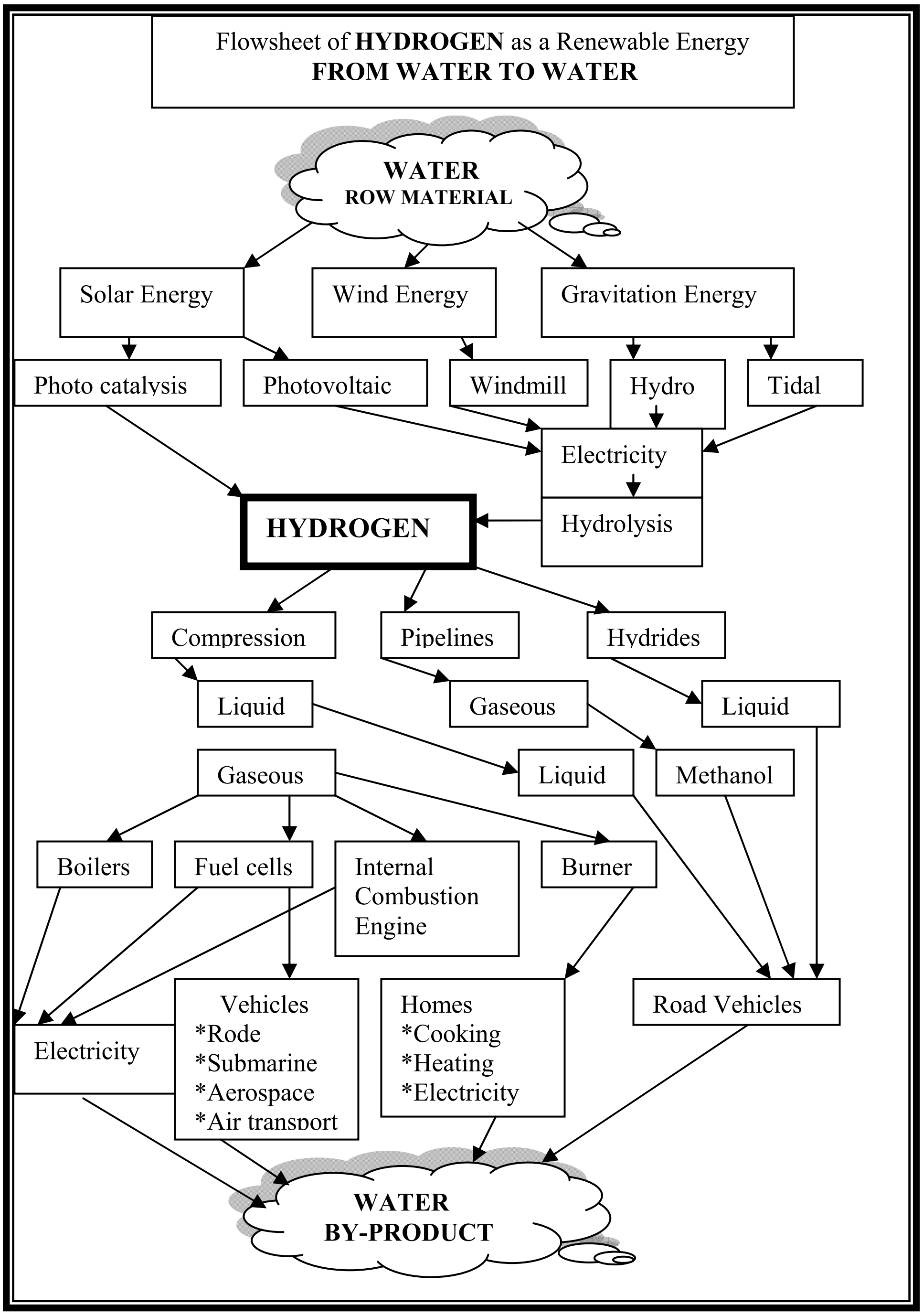


Fig. 8: Estimated emissions for various types of motor vehicles

7. Conclusion

Hydrogen has now established itself as a clean choice for an environmentally compatible energy system. It can provide a suitable future. On average, it has about 20-30% higher utilization efficiency than fossil fuels. In combination with solar PV- and Hydro-Electrolysis, it is compatible with land area requirements on a worldwide basis. If environmental damage is taken in to account, the hydrogen energy system is already cost effective. As illustrated in the appended flowsheet [6], it seems then ideally suited for the conversion to renewable energy.



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HİDROGEN GƏLƏCƏYİN TƏMİZ VƏ ALTERNATİV YANACAĞIDIR

MƏHƏMMƏD CAVAD ÖHRAVİ

Məqalə günəş enerjisindən istifadə edərək hidroliz üsulu ilə əldə edilən hidrogen yanacağının gələcək energetika üçün perspektivlərinə həsr olunmuşdur

ВОДОРОД КАК ЧИСТОЕ И ВОЗОБНОВЛЯЕМОЕ ТОПЛИВО БУДУЩЕГО

МОХАММАД ДЖАВАД ОХРАВИ

В статье представлены данные о перспективах водородного топлива, полученного путем гидролиза воды с использованием солнечной энергии, для будущей энергетики.