# THE HYDROGEN – ONE OF THE ALTERNATIVE FUELS

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*Abstract:* In this paper the author presents the future of an alternative fuel – the hydrogen. The paper starts with a short history of the hydrogen economy and after that it is described the hydrogen generation, storage and utilization and the fuel cell. The main part of the paper retells about hydrogen energy achievements (vehicle engines, residential heating systems, power station) and about the main obstacles on the implementation way of the hydrogen energy (lowering the cost of hydrogen energy production, creating affordable hydrogen fuel cells, effective hydrogen storage, infrastructure implementation and need for global safety and standard regulations in this field). The paper finishes with conclusions, the main conclusion being that hydrogen and fuel cells have the potential to change the world of energy technology, to solve several major challenges facing the world.

## 1. INTRODUCTION

At present, a new revolution of the energy sources is beginning to emerge. It is spoken about hydrogen utilisation instead of making use of the oil and its derivatives. The fight against the greenhouse effect requires the search for ecological solutions of the energy production. Hydrogen is the key to a clean energy future because it has the highest energy content per unit of weight among known fuels[2]. When is burned in an engine, the hydrogen effectively produces zero emissions; when it is powering a fuel cell, its only waste is pure water at 250°–300°C. Hydrogen is the only energy carrier that makes possible to power cars and boats or aircrafts using solar energy.

Implementation of the "hydrogen economy" will determine transformations, which were not being considered by of at the end of the XIX[th] century and the beginning of the XX[th] century when the last energetic revolution has occurred. People went from candle light or rush light to gas light, to electricity light; from cooking and heating in an inefficient fireplace or stove to gas and electric furnaces and stoves; from transportation by foot or by horse to travel by train, steamship, automobile and aeroplane. Health improved, daily life became safer, travel became faster and more comfortable, commerce and trade flourished – almost every aspect of life got better.

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[2] 1 kg hydrogen contains as much energy as 2.1 kg natural gas or 2.8 kg petrol. A light-duty fuel cell vehicle must store 11–29 lb (5–13 kg) of hydrogen to enable an adequate driving range of 300 miles or more. Because hydrogen has a low volumetric energy density (a small amount of energy by volume compared with fuels such as gasoline), storing this much hydrogen on a vehicle using currently available technology would require a very large tank-larger than the trunk of a typical car. Advanced technologies are needed to reduce the required storage space and weight.

## 2. HISTORY

Hydrogen was recognised in 1766 as a distinct substance by Henry Cavendish (1731–1810) and he has called it, “inflammable gas”. Receiving the name of hydrogen in 1783 from Antoine Laurent de Lavoisier (1743–1794), it was recognised as the most plentiful element in the universe.

Françoise Issac de Rivaz (Switzerland) designed in 1807 an internal combustion engine that was gas driven using a mixture of hydrogen and oxygen to generate energy (fig. 1)[i]. In the book “The Mysterious Island” published in 1875, Jules Verne (1828–1905) presented hydrogen as a fuel for the future.

Back in the year 1839 the foundation stone for today’s fuel cell technology has already been laid. It was the Welsh justice and physician Sir William Robert Grove (1811–1896). This discovery was presented in a letter (fig. 2) sent in 1842 to Michael Faraday. In 1896, William W. Jacques has published a description of his fuel cell supplied with coal or carbon gas in “Harper’s Magazine” (U.S.A.).

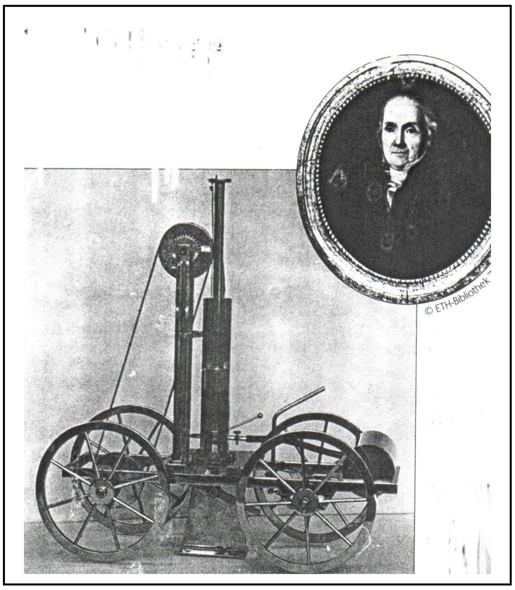
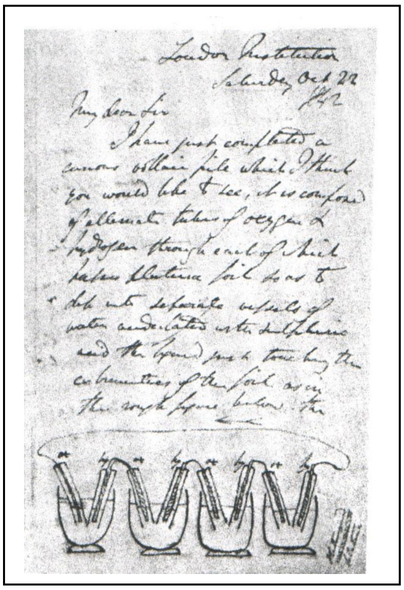



Fig. 1



London Institution
Saturday Oct 22
1842
My dear Sir
I have just completed a curious voltaic pile which I think you would like to see, it is composed of alternate tubes of oxygen & hydrogen through each of which pass platinum foil so as to dip into separate vessels of water acidulated with sulphuric acid and the liquid just touching the extremities of the foil as in the rough figure below. The

Fig. 2

Hydrogen as a fuel has been suggested to have the capability to create a hydrogen economy. The term *hydrogen economy* was coined by John Bockris[3] during a speech he delivered in 1970 at General Motors (GM) Technical Center[ii].

[3] In 1970 electrochemist John O’M. Bockris published *Energy: The Solar – Hydrogen Alternative*, describing his envisioned hydrogen economy where cities in the United States could be supplied with solar energy.

The third Rome Club report, published in 1976, acknowledged the concept of the "Hydrogen economy". Under the title "Hydrogen Civilisation", the report stated: "It may that in the beginning of the XXI$^{st}$ century to be present at the juxtaposition of the two energy distribution systems, that are almost equal as importance: the first for electricity, the second for hydrogen, the last being produced by nuclear energy (fission or fusion) or solar energy[iii]."

### 3. HYDROGEN GENERATION AND UTILISATION

The production of hydrogen is not really new. At the moment 500 billion cubic metres of hydrogen are produced, stored, transported and used worldwide every year. This is happening mostly in the chemical (and petrochemical) industry. According to the declarations of the International Agency for Energy (IAE), the preparing of the hydrogen all over the world needs about 2% from the whole energy consumed in the world, that is approximately the equivalent of 170 million petroleum tones every year.

Hydrogen can be separated from hydrocarbons through the application of heat – a process known as *reforming*. Currently, most hydrogen is made this way from natural gas. An electrical current can also be used to separate water into its components of oxygen and hydrogen. This process is known as *electrolysis*. Some algae and bacteria, using sunlight as their energy source, even give off hydrogen under certain conditions. Hydrogen can be produced from abundant domestic resources including natural gas, coal, biomass and even water. In Japan, the Natural Resources and Energy Agency is urging to use coke oven gas from steel production as the primary source for hydrogen energy. Production of hydrogen from water requires more energy than is released when the hydrogen is used as fuel. Free hydrogen does not occur naturally, and thus it must be generated by electrolysis of water or another method. A reduction in carbon dioxide emission connected with hydrogen fuel is directly achieved only if the energy used to make hydrogen is obtained from non carbon-based sources. Hydrogen can be produced also from renewable sources and can be used to store energy from intermittent energy sources.

A relatively new method[4] to produce electrical energy is based on converting in the fuel cells the thermal and chemical energy of certain substances. Fuel cell constitutes, by definition, a very efficient technology and an exciting potential

[4] Matei G. Marinescu (1903–1983), former corresponding member of the Romanian Academy, studied the hydrogen fuel cell in the years '50 of the XX$^{th}$ century and pointed out the way to select the electrodes for such fuel cell. He developed experiments for obtaining the electrodes by electrolyte sediment of the platinum. The world's first direct-hydrogen fuel cell power system producing more than 50 kilowatts of electrical power without an air compressor was developed in 1999 by International Fuel Cells, within the above mentioned DOE contract with Ford. This system generated enough power to propel a lightweight mid-size car. The power plant weighted about 140 kg, had a volume of 250 $cm^3$ and could easily fit under the hood of the car.

power source of the future as far as the fuel is converted directly into electrical energy two or three times more efficient than the thermodynamically conversion. The hydrogen fuel cell has a great ecological perspective, produces low noise and is reliable and durable (since they have almost no moving parts).

The ordinary isotope of hydrogen, H, is known as Protium, the other two isotopes are Deuterium (a proton and a neutron) and Tritium (a proton and two neutrons). Deuterium and Tritium are both used as fuel in nuclear fusion reactors. Deuterium is used as a moderator to slow down neutrons and Tritium is also used as a radioactive agent in making luminous paints and as a tracer. Tritium is readily produced in nuclear reactors and is used for the production of the hydrogen bomb. Big quantities of hydrogen are used for the fixation of nitrogen from the air in the Haber ammonia process and for hydrogenation of fats and oils, due to lower costs incurred in the process. It is used in large quantities in methanol production, in hydrodealkylation, hydro cracking and hydrodesulphurization.

Liquid hydrogen is important in cryogenics and in the study of superconductivity, as its melting point is only 20 degrees above absolute zero and metallic hydrogen may be met stable; others have predicted it would be a superconductor at room temperature.

## 4. HYDROGEN STORAGE

Hydrogen gas can be stored at high pressure. Tanks for the storage of pressurised gas differ by their construction according to the type of application, which determines the required pressure levels. For the most part, stationary tanks have relative lower pressure levels (about 350 bars). The requirements for mobile applications are quite different and pressure is increased up to 700 bars. Pressure tanks used to be made from steel. This is a solution applied almost in all existing hydrogen auto vehicles-powered. But these tanks are expensive, uncomfortable and very heavy (more then 90% of the heavy of filled tank). Modern pressure tanks[5] are made from composite materials (coal-fibre composite materials with thin internal aluminium linear).

Another possibility to store hydrogen is to use metal hydrides that can liberate hydrogen in certain environment condition (high pressure, temperature between 150 and 300°C). This storage technology uses certain metal alloys, which are storing hydrogen like a sponge. Thus the metal forms metal hydrides that adsorb the hydrogen. Referring to the volume, metal hydride storage has a very high storage capacity but this storage is quite heavy and therefore they cannot be used in mobile applications. In addition, they are very expensive because of the

[5] Storage technologies under development include high-pressure tanks with gaseous hydrogen compressed at up to 10,000 pounds per square inch, cryogenic liquid hydrogen cooled to –423°F (–253°C) in insulated tanks, and chemical bonding of hydrogen with another material (such as metal hydrides).

high costs of materials. It is also possible to store hydrogen in liquid state. The method supposes a very high energetic consumption and to cool the gas at a temperature about –253°C. Cryo-tanks can be produced with very high quality today. The losses resulting from the gradual heating up of the liquid hydrogen in the tank (waste steam losses) can be kept very low. The storage of liquid hydrogen is especially suitable to be used in vehicles because the space requirement of liquid hydrogen tanks is the lowest. For the refuelling of these vehicles automatic robots already exist.

Stationary liquid/storage will only be used when hydrogen is really requested in liquid form, e.g. in fuel stations. For all other applications the high amount of energy requested for the liquefaction should be avoided wherever possible.

When it is necessary to store large amounts of hydrogen in a future energy economy, it can be stored under a pressure of up to 50 bars into subterranean cavern storage. In France, in USA and in Germany natural gas is stored in such caverns and it is supposed that this method could be used for the storage of hydrogen in the future.

In November 2009, Scientists at the Carnegie Institution found, for the first time that high pressure can be used to make a unique hydrogen-storage material. The discovery paves the way for an entirely new way to approach the hydrogen-storage problem. The researchers found that the normally underactive, noble gas xenon combines with molecular hydrogen ($H_2$) under pressure to form a previously unknown solid with unusual bonding chemistry. The experiments are the first time these elements were combined to form a stable compound. The discovery debuts a new family of materials, which could boost new hydrogen technologies. A team of scientists found that an external electric field can be used to store hydrogen just as an internal field can store hydrogen due to charge polarization caused by a metal ion.

Using an external electric field as another variable in our search for such a material will bring a hydrogen economy closer to reality (fig. 3). This is a paradigm shift in the approach to store hydrogen. Thus far, the efforts have been on how to

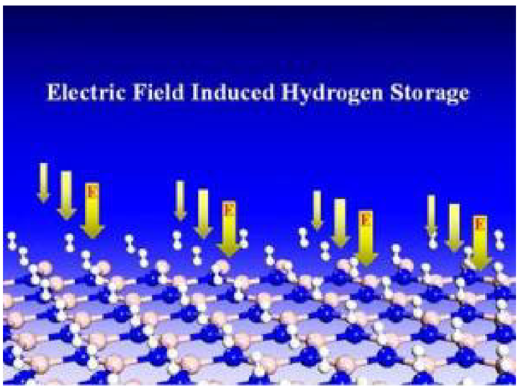



Fig. 3

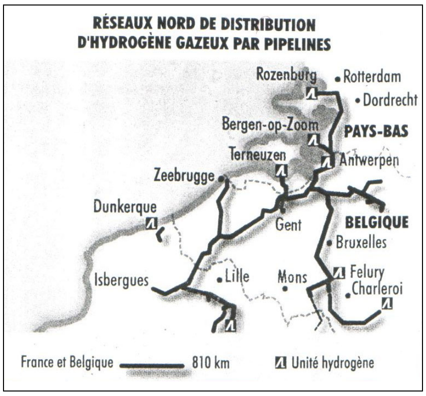



Fig. 4

modify the composition of the storage material. This work will help researchers create an entirely new way to store hydrogen and find materials that are most suitable. The challenge now is to find materials that are easily polarisable under an applied electric field. This will reduce the strength of the electric field needed for efficient hydrogen storage.

## 5. FUEL CELL

Fuel cells are a promising technology for use as a source of heat and electricity for buildings, and as an electrical power source for electric motors propelling vehicles. Fuel cells operate best on pure hydrogen. But fuels like natural gas, methanol, or even gasoline can be reformed to produce the hydrogen required for fuel cells. Some fuel cells even can be fueled directly with methanol, without using a reformer. A fuel cell has a simple structure consisting of three layers, one on top of the other: the first layer is the anode, the second an electrolyte and the third layer is the cathode. Anode and cathode serve as catalysts for the process produced in the electrolyte. The layer in the middle consists of a carrier structure, which absorbs the electrolyte. In different types of fuel cells different substances are used as electrolyte. Some electrolytes are liquid and some are solid with a membrane structure. The electrolyte allows the ions to pass, but not the electrons. A fuel cell combines hydrogen and oxygen to produce electricity, heat, and water.

The process for production of electric energy using fuel cell is the exact reverse of the electrolysis process (fig. 5). During the process of electrolysis, through the application of the electric power, the water is decomposed into the component gaseous: oxygen and hydrogen. The fuel cell takes exactly these two gaseous components and converts them into water again.

The fundamental mode of operation of a fuel cell consists in the following: When there is hydrogen at the anode and oxygen at the cathode, a hydrogen molecule is decomposed into two hydrogen atoms and in the same time electrons are set free. The resulting hydrogen ions move through the electrolyte, which is permeable for them and at the cathode they oxidise with oxygen and form the water. To make possible the generation of water the electrons donated at the anode in the beginning are needed. The electrolyte is not permeable for electrons and, if an electric conductor connects two electrodes, electrons are transported from anode to cathode generating a usable current. This process is running continuously as long as there is enough hydrogen and oxygen at anode and cathode. Most fuel cells are operating with air, so there is no need to store oxygen. One fuel cell generates only low voltage and it is necessary to stack several cells to get the requested voltage. Such arrangement is called “fuel cell stack” (fig. 6). Fuel cell stacks function like electrical batteries, except that instead of being recharged with electric current, they are simply fed by a continuous supply of hydrogen gas and air. There are different types of fuel cells, which are differentiated by construction and mode of operation the main types of fuel cells are: (The hydrogen alkaline fuel cell; the proton exchange membrane fuel cell; the phosphoric acid fuel cell; the melted carbonate fuel cell; the direct methanol fuel cell).

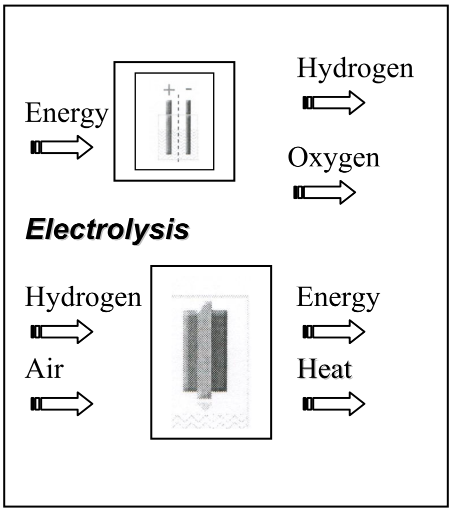



Fig. 5

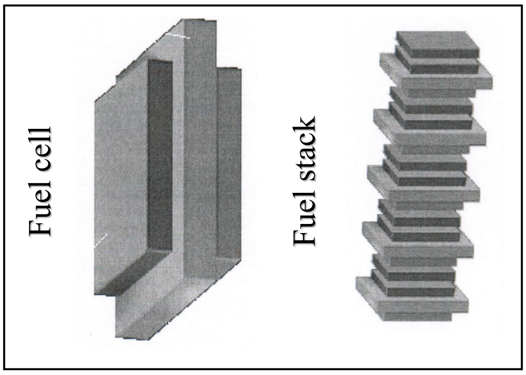



Fig. 6

Fuel cells are exciting potential power source compatible with renewable energy sources. Wind electrolysis seems, at present, to be the least costly and most promising renewable energy source for producing hydrogen. New windmill generators are capable of producing vast amounts of power. When the wind is not blowing, the accumulated hydrogen represents a real environment for the stored energy, allowing their electrical output to be steady and reliable. Hydrogen fuel cells power the shuttle's electrical systems, producing a clean byproduct – pure water, which the crew drinks. Today hydrogen fuel cell has a lot of different practical applications,

**6. HYDROGEN ECONOMY ACHIEVEMENTS**

Hydrogen, already a sizeable business as a chemical feedstock and a space fuel[6], has attracted big business interests as a power generation and transportation fuel. National and international companies are seeing hydrogen as a new pathway to diversify their traditional fuel businesses, because in the end the hydrogen will become the foreign currency of the future energy system. Hydrogen is high in energy, yet an engine that burns pure hydrogen produces almost no pollution.

[6] NASA has used liquid hydrogen since the 1970s to propel the space shuttle and other rockets into orbit.

6.1. VEHICLE ENGINES

Because the fuel cells convert fuel directly into electricity, they are by definition a hybrid-electric vehicle technology. Efficiency is expected to be about 50% in automotive use. Currently, however, fuel cells are very expensive because they are not produced in mass production and the widespread refuelling infrastructure required by the most efficient fuel-cell cars does not exist so far. A fuel-cell-powered car can either carry its own supply of hydrogen in a pressurised tank, or derive the hydrogen on demand from natural gas or any liquid fuel in a chemical reactor called a "reformer".

Hydrogen powered engine (fig. 7[iv]) is currently equipped with Nickel-Metal-Hydride (NiMH) batteries which offer the best performance in terms of environmental suitability and energy storage capacity. The NiMH batteries are well protected by three separate units and the vehicle will continue functioning even if a fault occurs in one of the units. The battery is placed between the hydrogen fuel-cell stack that converts hydrogen fuel into electricity, and electric motors that are located inside the wheels, providing four wheels drives.

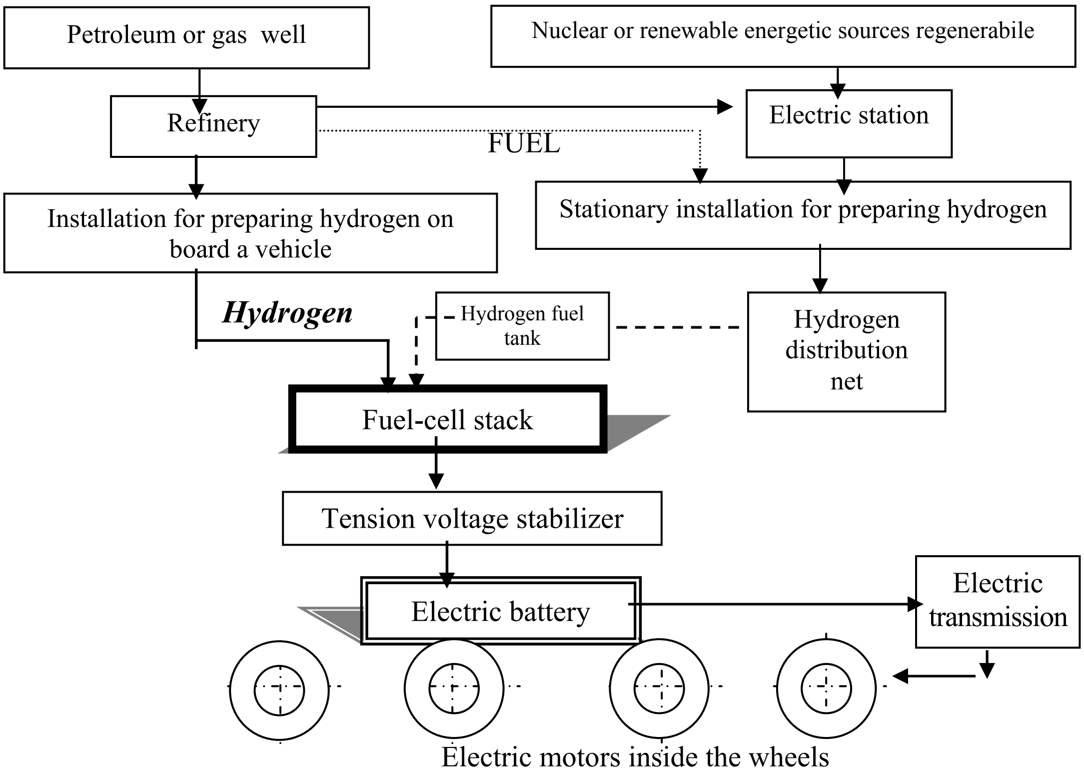



Fig. 7

A constructive characteristic of the hydrogen-powered vehicle is the integration of the fuel cell with drive-by-wire technology, replacing the previous predominantly mechanical systems for steering, braking, throttling and other functions with electronically controlled units. This frees up space because electronic systems tend to be less bulky than the mechanical ones. By-wire system performance can be programmed using software. In addition, with no conventional drive train to limit structural and styling choices, automakers will be free to create dramatically different designs to satisfy customer needs.

General Motors came up with a concept called Autonomy, driveable prototype that had been presented at the Paris Motor Show in September 2002. The Autonomy concept and the Hy-wire (for hydrogen-powered vehicle by wire) prototype were created, literally from the wheels up. Using the hydrogen fuel cell instead of internal combustion engine enabled the use of a flat chassis, which gives designers great freedom to create unique body styles. Driven by wire technology similarly liberates the interior design because the driving controls can be radically altered and can be operated from different seating positions[v].

At the North American International Auto Show – January 6, 2003, Rick Wagoner, president and Chief Executive Officer of General Motors Corporation, underlined: "By combining fuel cell and by-wire technology, Autonomy offered a vision of the future, and the incredible potential of fuel-cell propulsion. If our vision on future is right, and we are convinced it is, Autonomy can reinvent not only the automobile, but also the whole industry. Autonomy is not only a new chapter of the automobile history; it is the second tome, the first one being the former century. The XX$^{th}$ century has been the thermal engine; the XXI$^{st}$ century will be the century of the fuel cell. Autonomy concept offers a vision on the potential of the founding of the hydrogen economy"[vi].

In the printed version of September 2003, "The Hydrogen & Fuel Cell Letter" Journal published the photography of the 1,800 hp GM diesel-electric switching locomotive that has been converted to a fuel cell-powered version by a consortium led by the Fuel cell Propulsion Institute, Denver (U.S.) in a five-year project[vii]. Another example of a fuel cell-powered vehicle is Mitsubishi presented in „The Hydrogen & Fuel Cell Letter" Journal, October 2003[viii].

### 6.2. RESIDENTIAL HEATING SYSTEM

A fuel cell turns 50–60% of its hydrogen energy into highly reliable, premium-quality electricity and the rest into pure water heated to about $300^0$C. That is an ideal temperature for heating floor space or water and for cooling and dehumidifying. In some buildings, these "building services" are worth almost enough money to pay for natural gas and a reformer to make the hydrogen.

By exploiting the real estate market, therefore, fuel cells can get into mass-production and cut costs to levels competitive in hydrogen fuel-cell-powered vehicles. But each hydrogen-powered vehicle then becomes a 30–40 kW power station on wheels. It is parked about 90–95% of the time, usually in habitual places. Such a hydrogen-powered car can be leased for an annual fee and when the car is parked, there is a possibility to plug it in both to the electricity grid and to a little snap-on pipe that brings surplus hydrogen out from the reformer in the building (since that is not kept fully occupied all the time, it makes a little extra, avoiding the need to set up a whole new infrastructure of reformers dedicated purely to cars). The car is not plugged to recharge its battery, on the contrary, while the car's owner sits at his desk or rests at home, his power-plant-on-wheels is silently sending kilowatts back to the grid. The car's owner is automatically getting credited for that production at the real-time price (which is pretty high during the daytime). And so he is earning enough money to pay almost half of his lease fee.

The German Company MTU CFC together with U.S.A. Company "Fuel Cell Energy" has developed from 1997 a medium station "Hot Module" that has a size of 9x2, 5x3 $m^3$ and a weight of 15 tons and that can generate 225 electrical kWh and 120 equivalent thermal kilowatts (steam and warm water), at a target price of 1000-1200 U.S.A.$/kWh.

The European Company "Vaillant" – leader in heating technology – together with American Company "Plug Power" (specialised in fuel-cell stack production) has obtained since **2001 the** certification for construction of the mini heating systems based on fuel-cell stacks. Such minis stem generates four electrical kWh and nine equivalent thermal kilowatts.

### 6.3. POWER STATION

In 2001 Siemens Westinghouse, multinational giant from Orlando-Florida (U.S.A) has put into operation two electrical stations SOFC, each of 250 kW and in 2002 in Italy an electrical station of 320 kW was installed. Programs for construction of prototypes of the electrical station based on fuel cells are also developed in Canada, Germany and Holland.

Mobile phones or mobile computers could be the first apparatus that use the fuel-cell-mini stacks (at present such mini stacks are in the technological designing stage). This case of utilisation will be developed not from the ecological point of view but for getting the operational autonomy of the mobile apparatus. Company like Motorola, Samsung or Toshiba declared their interest to finance the production of fuel-cell-ministacks for mobile apparatus[ix] apparatus. In order to periodically refuel the vehicle or to change the interchangeable hydrogen tanks, it is possible to use the existing hydrogen distribution network that is used by the chemical and petrochemical industry or to build new specialised distribution network of gas pipeline for hydrogen. In Europe there is a North distribution network of gas pipelines for hydrogen and in U.S.A. there is a distribution network of pipelines along the Golf Coast. In the Ruhr Basin and in Leuna there has been a pipeline grid for hydrogen of a length of over 100 km for several decades. Worldwide there are about 1000 km of hydrogen pipelines in operation the existing infrastructure for hydrogen manufacturing and distribution (Fig. 4.) Air Liquid hydrogen net from Belgium, Holland and France[x]) produces, in principal, through reforming the natural gas, about 540 billions $m^3$ hydrogen.

The European fuel cell infrastructure has been developed continuously, Vanderborre Hydrogen Systems (HS), of Oevel, Belgium, announced in November 2002 that it had signed two agreements to provide electrolyses for two fuelling station to be built as part of the 10-city, 30 – bus Clean Urban Transport for Europe (CUTE).

On the Műnchen airport, the first station for fuelling liquid hydrogen is operating since 1999 and during 2001–2002 in countries like Belgium, Spain; Germany stations for hydrogen distribution have been built. In November 2002, Berlin urban transit agency (BVG) has built its first hydrogen fuelling station with its French partner Total Final Elf Group at a bus depot in the Wedding district. The station provides both cryogenic liquid hydrogen as well as gaseous hydrogen at 250 bars. German Industrial gas specialist delivers cryo-hydrogen stored in an 18 cu.m.tank to fuel buses. Current throughput was about 1 standard $m^3$/hour, but BVG planed to increase it 100 times by 2004.

Iceland's minister of industry and commerce attended the ceremony in Reykjavik for the opening of the world's first hydrogen fuelling station built at an existing commercial retail site on Iceland's official First Day of Summer, April 24th 2003.

## 7. OBSTACLE ON THE IMPLEMENTATION WAY OF THE HYDROGEN ECONOMY

A question is raised: Is justified or not the shown enthusiasm related to hydrogen economy potential? The people that expressed their reserves about the future of hydrogen future are considered to be frightened by progress as our great-grandparents were scared by train.

In reality, at the present technological development level it seems that those that expressed their reserves have more correctly evaluated the existing possibilities.

The authorised annalists try to conserve their objectivity and they are reserved when they are discussing if the hydrogen economy has a good hand. Their scepticism is based on the present problem of the production, distribution, safety and storage of the hydrogen.

Let's remember that there is a hydrogen industry and that its pressure group cannot be neglected. Consideration is being given to entire economy based on solar and nuclear generated hydrogen. Public acceptance, high capital investment and the high cost of hydrogen with respect to today's fuels are but a few of the problems facing such an economy. In the present, the main problems on the implementation way of the hydrogen economy are:

### 7.1. LOWERING THE COST OF HYDROGEN

Currently, producing hydrogen is four times more expensive than gasoline (when produced from its most affordable source, natural gas). The announced research programs seek to lower that cost enough to make fuel cell cars cost-competitive with conventional gasoline-powered vehicles by 2010 and to advance the methods of producing hydrogen from renewable resources, nuclear energy, and even coal.

The cost of fuel cells is dropping rapidly, from around U.S.A.$3000/kw in 1997 to about U.S.A$800 /kW in 1999, about U.S.A$600 /kW in 2002 and U.S.A$450 /kW in 2007. To be cost-effective, the fuel cells cost has to come down to around U.S.A $100/kw. How can enough fuel cells be sold to crank up the production volume high enough? An answer is, firstly, to use the fuel cells in buildings, as this will cover for example two-thirds of America's electricity[xi].

### 7.2. CREATING EFFECTIVE HYDROGEN STORAGE

Current hydrogen storage systems are inadequate for use in the wide ranges of vehicles that consumers demand. It is said that if the hydrogen storage problems were not solved, it would not be possible to establish a hydrogen infrastructure within the next 20 or even the next 30 years.

A rechargeable hydrogen tank must assure the autonomy of 450 km and each tank should allow, with successive recharges, more than 230,000 km distance to be covered. The metal hydrid storage must function in temperatures from –40 to $45^0$C. At low-temperature metal hydrid storage has a small capacity, the adsorption and the disruption speed is slow, but emissions can be avoided completely. The hydrogen metal hydrid storage at high-temperature assures a high storage capacity but this kind of storage causes unwilled emissions. Actual technical storage means cannot avoid losing hydrogen gas. About 3–4% from liquefied hydrogen stock will still "boil off" every day. Although the vehicle will use most of this boil off, it would be a concern for cars parked for several days between trips. In conclusion, storing the hydrogen on board eliminate the reformer that significantly reduces weight, cost, complexity, fuel consumption and emissions. In the same time, storing the hydrogen on board means less safety.

### 7.3. CREATING AFFORDABLE HYDROGEN FUEL CELLS

Currently, fuel cells are ten times more expensive than internal combustion engines. It is a necessity to reduce the cost to affordable levels.

There are different biological processes hydrogen is set free in or is produced as an intermediate product. Hydrogen is produced by algae or by microorganisms. These methods of generating hydrogen are still in the development stage but they are an additional option for a future hydrogen economy.

Authorised annalysts point out that the high energy-conversion efficiency of fuel cells will reduce energy consumption. Installed in cars, though, today's fuel cell power plants achieve only about 9.5–12 l/100 km on a gasoline-equivalent basis, because much of their energy must be expended for functions other than moving the car. First, the hydrogen fuel must be extracted from something else, such as a fossil fuel, and then it must be stored, usually by pressurising or liquefying it. The upshot is that in vehicles, fuel cells are less efficient than ordinary gasoline engines. High temperature fuel cells promise higher overall efficiency but they are a long way off.

### 7.4. INFRASTRUCTURE IMPLEMENTATION AND IMPACT ON ENVIRONMENTAL CONDITIONS

Codes and standards ensure the safe use of hydrogen and fuel cells. Research and production structure includes, among its subgroups pressurised hydrogen, safety valves and metal hydrides.

In the literature it is spoken without restraint that an energetic system based on hydrogen is pollution free. But, in reality, for example, like any vehicle powered by electricity, a hydrogen-powered vehicle will have an impact on air quality that is determined partly by the local fuel mix for power generation and partly by their efficiency over the whole fuel cycle. And over that entire cycle, a fuel cell car running on hydrogen from electrolysis requires three times as much electricity as does a battery car charged from the grid.

Given that the creation of a potentially costly hydrogen generation/distribution worldwide network is a prerequisite to commercialising fuel-cell cars and trucks, strong advocacy from local and national leaders in the public and private sectors is crucial. It is not possible to have large numbers of fuel-cell vehicles without adequate fuel availability to support them, but we will not be able to create the required infrastructure unless there are significant numbers of fuel-cell vehicles on the roadways.

To evaluate in a correct way the positive hydrogen economy impact, the reasoning cannot be stopped here, because it is necessary to adapt all car parks and to make a pattern of the future evolution of this park and of the necessary infrastructure. Even if a hydrogen economy positive vision emerges immediately, a longer time will be necessary to feel the effect on the entire car park penetrated by new hydrogen technologies.

## 8. CONCLUSIONS

- The use of hydrogen as an energy carrier will change many facets of our life in future. Together with the fuel cell, hydrogen has the potential to revolutionise the whole energy economy.

- The success of hydrogen and fuel cell potential depends on the development of science and technology in the field. At the international level there is a necessity to get a vision for a hydrogen economy, changing the way we produce and use energy.
- Hydrogen and fuel cell have the potential to change the world of energy technology to solve several major changes facing the world dependency on petroleum extractions or imports, poor air quality and greenhouse gas emissions. But in our days the hydrogen economy is more hype than revolution.

[i] Jean Orselli et Jean-Jacques Chanaron "Le lobbying en faveur de l'hydrogéne est bien organise. A qui profite le spectacle?", La Recherce, October 2002.

[ii] http://en.wikipedia.org/wiki/Hydrogen_economy#cite_note-o.

[iii] Benjamin Dessus "La voiture à hydrogène", La Recherche, October 2002.

[iv] St. Iancu, "Motorul cu hidrogen o revolutie sau o promisiune?", Inventica şi Economia, noiembrie-decembrie 2003.

[v] "Vehicle of change", Scientific American, October 2002.

[vi] Hydrogen, Fuel Cells & Infrastructure Technologies, http://www.eren.doe.gov/hydrogenmandfuelcells/feature.html.

[vii] "The Hydrogen & Fuel Cell Letter" Journal September 2003.

[viii] "The Hydrogen & Fuel Cell Letter" Journal October 2003.

[ix] Gabriel Martin, "La pile a combustible", La Recherche, Juin 2003.

[x] Jean Orselli et Jean-Jacques Chanaron "Le lobbying en faveur de l'hydrogène est bien organisé. À qui profite le spectacle?", La Recherche, October 2002.

[xi] Electricity generation http://www.rmi.org/hypercar/dox?what_e5.html.