Hydrogen on Demand

In Situ Made Hydrogen for Use on Demand

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***Abstract*- This paper proposes for study a new trend in hydrogen research, conventionally named *In Situ* Made Hydrogen for Use on Demand. Reasons for hydrogen on demand research were presented in the previous paper [8].**

The study refers strictly to a new technology, based on specific characteristics of a membrane and a catalyst, to produce higher quantity of gas, hydrogen and oxygen, with less input of energy, by increasing electrode-surface contact by more than 2 000 m^2 per gram of catalyst under normal temperature and pressure conditions. Water contact surface can be increased in the same space by adding more catalyst and increasing current flow do not increase the resistance on the electrodes[1. p. 17], in this case particles of carbon (C) playing role of an electrode. Thus, by experiment, new characteristics of Carbon (C) were identified.

Keywords- In Situ Hydrogen Production; Use on Demand; Electro-catalytic Membrane; Water Decomposition; Particle of Carbon; New Characteristics; Ecologic gas.

I. INTRODUCTION

The purpose of this paper is to solve storage, transport and distribution problems by taking an inclusive co-transformational value-added approach, by producing hydrogen *in situ* (on site) for use on demand, via an electro-catalytic membrane, which decomposes the water molecules efficiently, with low input of electric energy (9 V to 80 V and current electric up to 300 A) [8]. This paper refers to domestic [Photo 1, Photo 2, Photo 3, Photo 4] and industrial applications only [Photo5].

The research study refers to a membranary electrolytic procedure of *in situ* generation of a fuel gas (hydrogen and oxygen) from water, under normal temperature and pressure conditions, without requiring transport or storage, as well as the characteristics of this gas and device which make it useful to avoid risks of explosion during exploitation, for both domestic and industrial applications or for cars [9].

II. MATERIALS AND METHODS

Basic materials and methods were described in [9] by Morris, J. and Radu, M. (2010). *In situ* produced hydrogen (hydrogen on demand). This study it is based on patent application no: PCT/RO2011/000015 of CCMMM [9] with added explanatory notes and data for a better understanding of this novel work, including Photo 4 and Photo 5.

The membranary electro-catalytic system which is the object of the current invention eliminates the disadvantages of the previously presented inventions, through the fact that is formed of:

- A continuous source (DC) of pulsed current (**A**) with the frequency of 20 kHz (Fig.4);
- A force system **(B)** made up of a switched reluctance generator (**S**) and contactors ($\mathbf{C_1}$) and ($\mathbf{C_2}$);
- An automatic command module of the programming installation;
- A membranary electrolytic module (**C**).

The membranary electrolytic system, according to the invention, comprises several· generating modules, linked in series or in parallel to the same power· source and to the same regulatory system. The oxidation of the microelements introduced in the reaction environment leads to an intensification of the water decomposition process and, implicitly, to the increase of the hydrogen quantity.

This burning reaction of the microelements is similar to one taking place in the human body producing an excess of energy and simultaneously releasing a large quantity of hydrogen.

A. Membrane

The composite membrane (S) is 7-10 mm thick and is obtained by pouring between the catalyst and the promoters a solution of polysulphide 10-12%, polyethylene glycol (PEG) 0.1-0.2%, and the difference N-methyl-2-pyrrolidinone (NMP).

Two composite membranes which delimit and fix the catalyst and the promoters between the two concentric electrodes (Figs. 1, 2, 3) and a membrane which is fixing at the lower end and another mobile membrane at the upper side triggered by a string, ensure the pressure of the catalyst in the electrodes.

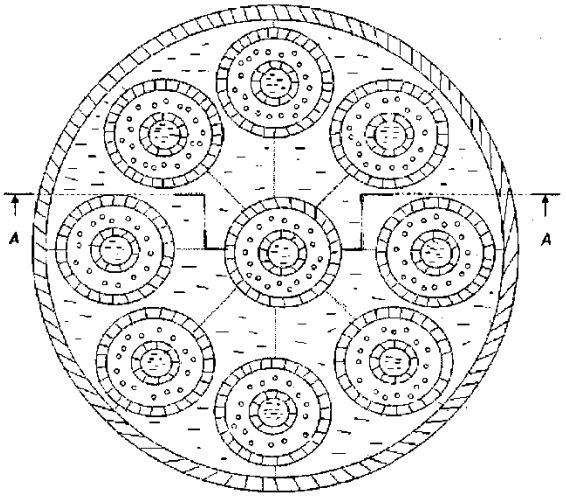

Fig. 1 Longitudinal section through the membranary electro-catalytic system for generation of ecological fuel gas from water

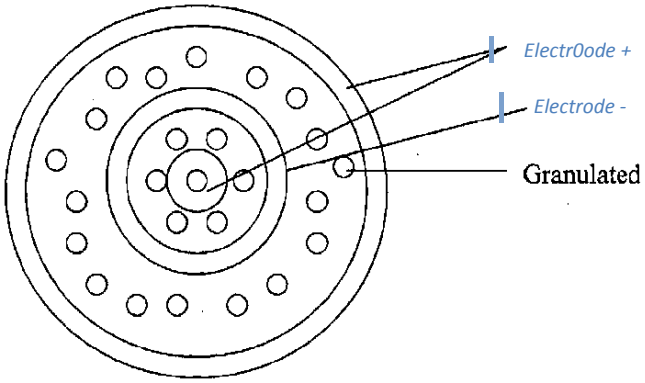

Fig. 2 Cross section of the membranary electro-catalytic system for generation of ecological fuel gas from water

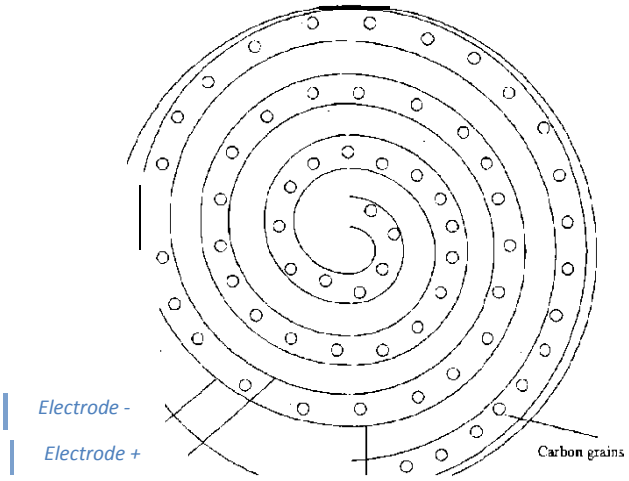

Fig. 3 Embodiment with spiral-shaped electrodes

B. Chemical Reactions Within the Process and Explanatory Notes Regarding Temperature and Pressure

In a chemical process where content of free energies is important to be calculated, "***standard free energy change*** (ΔG^0), *and the change in free energy that will occur if the reactants in their standard states are converted to the products in their standard states.*" [10].

In many existent so-called 'brown gas' devices, always it is a problem to keep temperature and thus, the pressure under control. The temperature and pressure are kept almost constant by the automation component of the device and by the water circulation from the cooling circuit, which has the role to absorb the thermic energy (Q), the cooling circuit being separate from the water that is part of the reaction process.

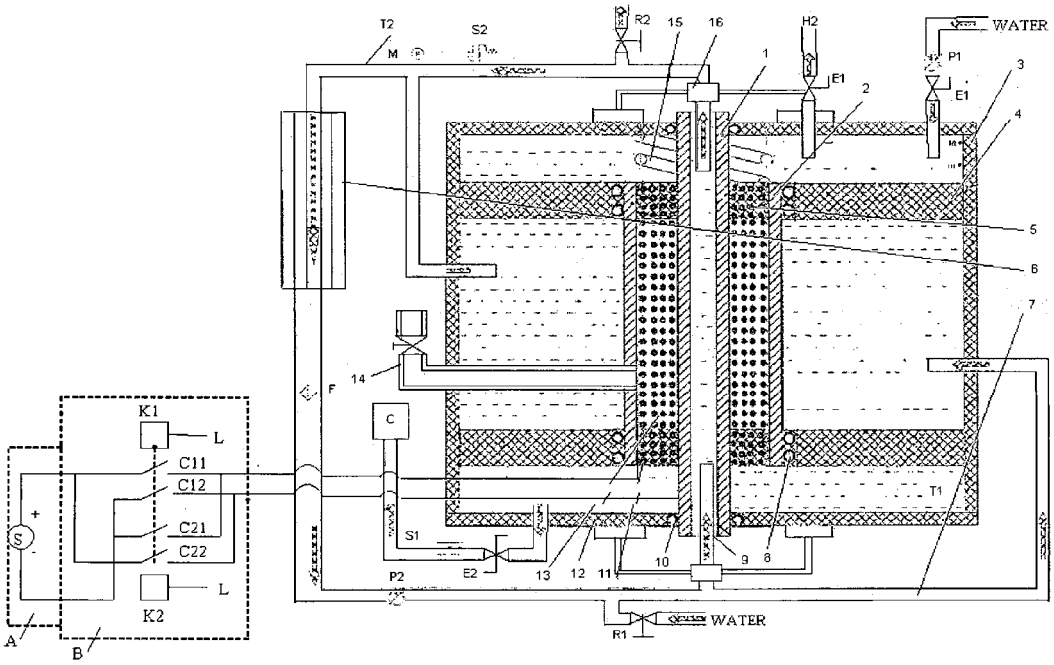

Fig. 4 Power supply scheme

Standard reaction (**1**) for starting the process is initiated by a high intensity of electric current (300 A) and a low voltage (80 V) of electrical current induced in the membrane's electrodes at 20 kHz (**see Fig. 1, 2 and 3**), where four molecules of water will react with carbon and will produce four molecules of hydrogen (H_2), one of carbon dioxide (CO_2) and one molecule of oxygen (O_2) plus a high quantity of thermal energy (Q).

$$\mathbf{4H_20 + C \leftrightarrow CO_2 + 4H_2 + O_2 + Q} \quad (1)$$

In this stage the thermal energy (Q) released is at its highest level because the distance between nuclei of the hydrogen atoms are at the farthest point/position. The energy will decrease until the distance reaches 0.074nm (0.74 Å) and then begin to increase again due to repulsions **[10].**

Then, part of the CO_2 is eliminated together with the H_2, O_2 and Q is coming down, and the other part reacts with the H_2O, increasing its conductivity by producing an electrolyte (H_2CO_3), proportionally with the cooling degree (**2**).

$$\mathbf{CO_2 + H_2O \leftrightarrow H_2CO_3} \quad (2)$$

Carbonic acid (H_2CO_3) loses one atom of hydrogen (H^+) and forms an ionic mixture (reactions 3 and 4).

$$\mathbf{H_2CO_3 \leftrightarrow H^+ + HC0_3^-} \quad (3)$$

$$\mathbf{HCO_3^- \leftrightarrow H^- + CO_3^{2-}} \quad (4)$$

Next chemical reactions (**5** and **6**) are happening due to a new cycle of an input of current electric, this time at a lower voltage (40 V) and the systems energy input at 20 kHz.

$$\mathbf{4H^+ + 4\,e^- \rightarrow 2H_2} \quad (5)$$

$$\mathbf{C + O_2 = CO_2 + 4e^-} \quad (6)$$

The final chemical reaction (7) is the end of the chemical reactions flow (Fig. 5).

$$\mathbf{H_2O + H_2CO_3 \rightarrow CO_2 + 2H_2 + O_2} \quad \mathbf{(7)}$$

By keeping the temperature of the system under control, the system keeps the pressure under control as well.

Output

+Mg (in the presence of)

$$\mathbf{CO_2 + H_2 + O_2 \rightarrow 2MgO + C + H_2 + O_2 + Q}$$

Where:

CO_2 + H_2+ O_2 are primary fuel gas, but also ecological fuel gas.

In order to regenerate the magnesium catalyst, hydrogen is passed over the magnesium oxide resulting pure magnesium and water.

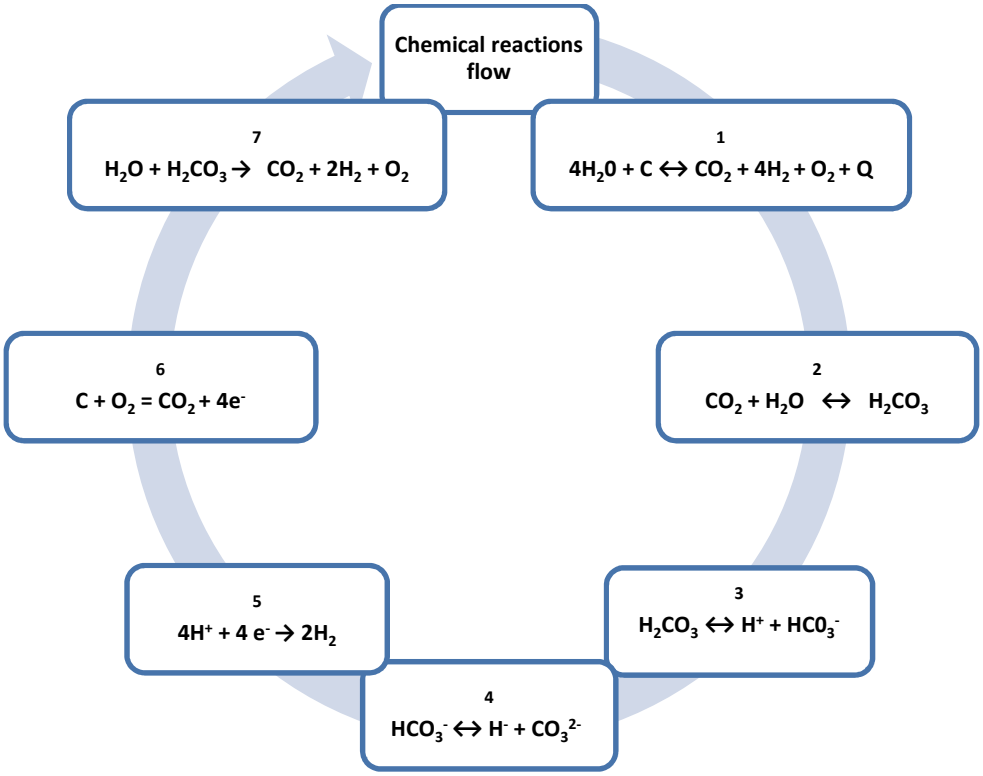

Figure 5 Chemical reactions flow.

An alternative to the use of magnesium is a liquid membrane (H_2O) where CO_2 is retained. In this variant, water must be as cold as possible and must be re-circulated so as to increase the CO_2 absorption degree.

The primary gas concentration is the following:

95-98% H_2

1.9-2.5% O_2

0.1-2.5% CO_2

The concentration of the ecological fuel gas obtained after purification through the composite membrane based on magnesium, is:

98 - 99% H_2

0.99 – 1.8% O_2

0.0l – 0.2% CO_2.

The electro-catalytic process can be accelerated through the use of 3d transitional metals (Fe, Ni, Cr, Cu) and Mg acting as promoter. Metals sediment on the cathode or are included among the carbon granules [9].

C. New Characteristics of the Main Catalyst, Carbon (C) Observed During the Experimental Work

During experiments, it was observed that carbon catalyst, under high frequency electric current has following properties:

- Carbon, in atomic form has high conductibility and releases high energy;
- Carbon, in atomic form sublimates from solid to gas;
- Carbon, in atomic form is stabilizer (for Hydrogen);
- Carbon, granule form is an excellent catalyst and homogenizer.

III. RESULTS

A continuous power source was used, of 80 V and 300 A, a generator module with 9 electrode pairs, capacitating 100 L of

water. The electrodes were connected to the source, ensuring the alternation of 40 de seconds by 20 de seconds of their polarity, thus obtaining:

- consumed electric energy: **7 kWh**;
- consumed water: **3.215 L**
- obtained caloric energy - **4 Nm^3 fuel gas**;
- **4 Nm^3 fuel gas** x 3.56939 kW/Nm^3 **14.278 kWh**]
- caloric energy (Q) - **4.7 kWh**. [1.462 kWh/L H_2O]

Total output: 14.277 kWh + 4.7 kWh = 18.977 kWh : 7 kWh results a coefficient of **2.711** (times).

$$\textbf{Output} = \frac{\textbf{14.278 W} \quad \textbf{4.7 W}}{\textbf{7 W f om}} \textbf{ x 100 = 271\%}$$

Data used:

- Caloric power of hydrogen (H) = 3.56939 kW/Nm^3
- 1 kg/L water (H_2O) = 1.244 Nm^3 gas (ecologic)
- 3.215 L water → 4 Nm^3 ecological gas

Results:

- 1 kg/L water will release: 1.244 m^3 x 3.56939 kW/Nm^3 = **4.44 kW** under form of Hydrogen + **1.46 kW** as thermal energy (heat) = 5.9 kW (total output energy) for 2.18 kWh (consumed energy).

The entire model is reported to:

$$\textbf{1 kg (L) water} = \frac{\textbf{. W}}{\textbf{2.18 W f om}} \quad \textbf{1} \quad = \textbf{271\%}$$

Due to the membrane's specific alternate frequency, membrane molecular arrangement and nano-Carbon ($_nC$) catalyst, the decomposition process has "***standard free energy change*** (ΔG^0), *the change in free energy that will occur if the reactants in their standard states are converted to the products in their standard states.*" [10], resulting in a higher production of hydrogen and oxygen gas in a limited space due to $_nC$ surface contact: >2000 m^2 per gram.

IV. PRINCIPLE OF FUNCTIONING AND PHOTOS

Burning together hydrogen and oxygen gases, the exit temperature of the flame from device is over 2000 ^oC. By adding oxygen (from air), the temperature of the flame increases to over 3000 ^oC. Thus, the high efficiency of these devices is easy to understand.

Photo 1 Exterior of 24 kWh device for domestic purposes: inlet for returning of hot water (**1**), inlet for gas/exit (**2**), water supply inlet (**3**), water evacuation inlet (**4**), hot water supply/exit (**5**).

NOTE: Automation of the system is neither part of this patent nor part of this paper.

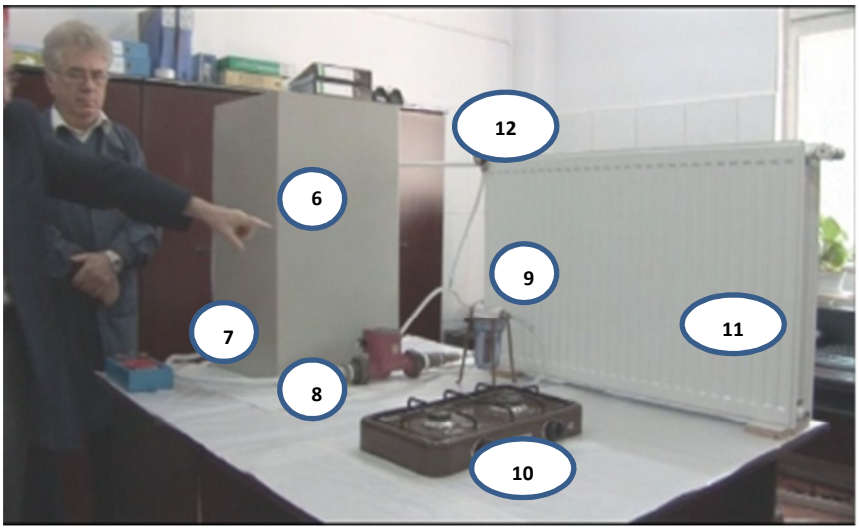

Photo 2 John Morris (left hand only) and Florian Cioroianu (photo) explaining the functioning of the assembly: 24 kWh power generator (**6**), power regulator (**7**, blue), external water pump for hot water (**8**, red), filter with water to stop the returning of gas to generator (**9**), cooking device (**10**), and heating radiator (**11**), pressure device (**12**). [The geyser and thermostat for radiator were not attached]

NOTE: Automation of the system is not part of this patent or part of this paper.

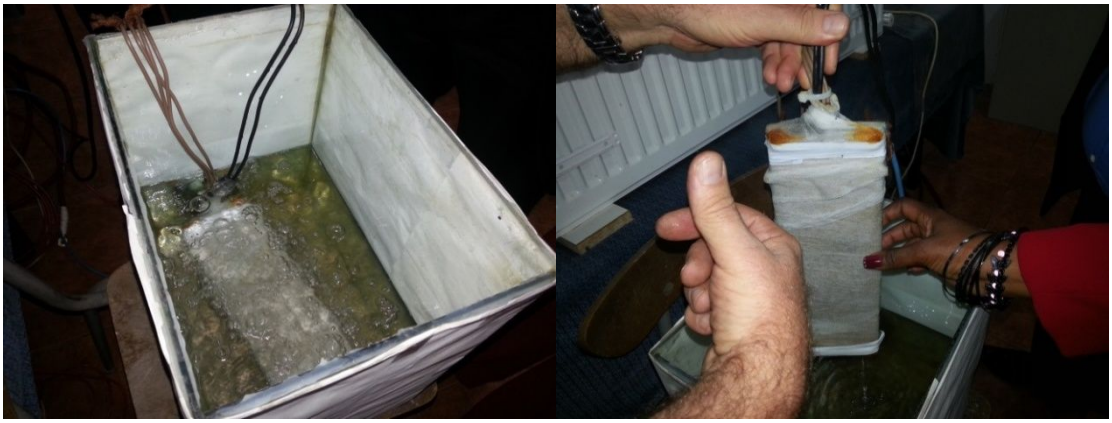

Photo 3 and Photo 4 Life demonstration that this membrane is working at room temperature

V. PROGRESS REPORT OF RELATED RESEARCH

A higher capacity device capable to produce ecological gas in bigger quantities under the same principle of functioning is under testing process.

For this device/installation, the basic research must be done in the same time with the experimental work, in order to coordinate functioning parameters of devices producing ecological gas in high quantities in conditions of a longer functioning time (endurance tests) and reliability of the system to permanent functioning and other unknown technological risks. This paper does not refer to complete automation of the system which will be subject for another research paper and a new patent.

Photo 5 Marin Radu (middle) explaining the functioning of a hydrogen burner (20 MW capacity) for a gas turbine (under testing).

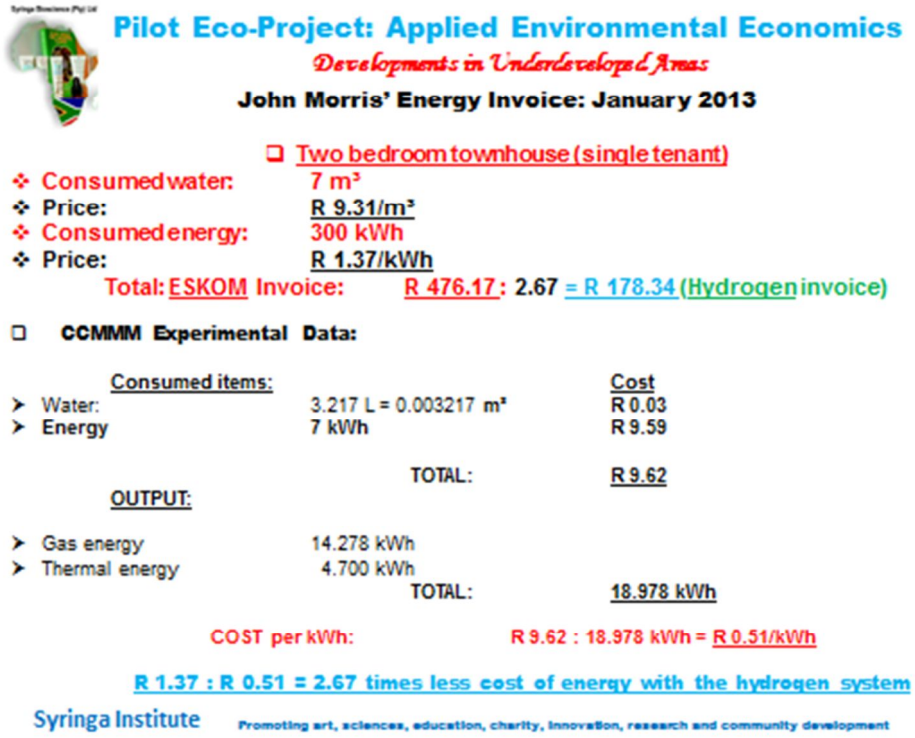

Figure 6 System's efficiency (Calculus grid vs. hydrogen invoice)

VI. CONCLUSIONS

It is clear that a new era is coming to revolutionize the world: Hydrogen Civilization. Hydrogen Civilization is based on Hydrogen Economy which can be economically sustainable only, if it is supported by an affordable production of hydrogen, made on site and, for use on demand.

Apparently, the technology presented in this paper responds to the critical needs for a real democratization of the energy market, from the bottom up, free from constrains of international cartels and free from the monopoly of national grids.

ACKNOWLEDGMENT

We would like to express our deepest gratitude to the Romanian Academy of Science for their support and for the certified tests done for our work, as well as, to all our colleagues from different branches of science, who supported us materially and morally during the past eight years of hard work and difficult experiences.

Also, many thanks to IJEE for publishing our results.

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Florian Cioroianu Born in Bailesti, Dolj, Romania on 12th March 1955.

An automation qualified engineer, busy to find enough time to finalise his Ph.D. Thesis " Optimization of technologies and equipment for obtaining and using hydrogen fuel, applicable to small capacity heating systems", at Transylvania University, Brasov, Romania. In fact, the hardware for the module presented in this paper is part of his Ph.D. study. Diplomas/Certificates: 15/2.

He is a hard working research-engineer who solved many of crucial 'small parts' of so many innovations at the Institute for Design and Automation (IPA) Bucharest, helping many inventors during many decades, to finalize their patents and prototypes. He occupied until 2009 the position as a General Manager for production in many large factories in Romania.

Mr Cioroianu has patience for detail and 'wideness' for unfinished ideas to become new innovations. He is an excellent team worker who published many (59) scientific papers in collaboration, and has nine gold medals and awards.

Marin Radu Born in Bailesti, Dolj, Romania on 8th July 1958

Ph.D. in Chemistry (2013), Polytechnic Bucharest, Romania, Ph.D. in Engineering Sciences (2006), Polytechnic Bucharest, Romania, Ph.D. in Engineering Sciences (2004), Polytechnic Bucharest Romania. Diplomas/Certificates: 175/3.

He is a broad-spectrum senior researcher with a huge experience in a variety of fields and a very strong team leader. Around, people are saying that Marin Radu is "smuggling ideas from the ambient environment". He is well known in Romania (and in Europe) as "the man who burns the water". Since 2003 he revolutionized the CCMMM S.A Bucharest (The Research Centre for Membranes and Macromolecular Materials) by developing new advanced research projects at European level.

He published 8 books, 92 scientific papers; he was speaker at 607 conferences and he has 346 unpublished papers. He has obtained 23 titles and prizes and 76 gold/silver/bronze medals.

Dr Radu is member of several organizations: World Forum of Researchers and Inventors (President), Federation of Inventors (France), International Academy of Energo-Information (Russia), and so on. Dr Radu has a big 'defect': he has not enough money to put in practice his ideas and his colleague's ideas.

John Morris Born in Tulcea, Romania on 22nd of August 1951.

Ph.D. Management of Technology and Innovation (2012), The Da Vinci Institute for Technology Management, Johannesburg, South Africa. Diplomas/Certificates: 5/3.

He worked for 18 years for the Romanian Industrial Group of the Army as a Senior Production Planner for a large number of projects in a variety of fields. He has huge experience in large projects for anti-desertification (Iraq), afforestation (Egypt), rural industrial corporation (Botswana), biodiesel (Ghana) and he is a founder and CEO of Business and Trade Systems S.R.L (Romania), Syringa Bioscience (Pty) Ltd, Syringa Institute, African Hydrogen (Pty) Ltd and Syringa Institute for Advanced Applied Studies (Pty) Ltd in South Africa. He is a published author (From Ravage to Resource (2009), BookSurge, U.S.A., and has published 16 scientific papers in several international journals of sciences (Elsevier). He has three unpublished books in permanent review with new practical ideas. He registered 6 patents, 27 new medicines, 3 products for agriculture (soil) and has ready for registration over 70 new medicines, obtained mostly from alien invasive plants (IAPs). He is a practical environmentalist who adds value to under-utilized resources and presented posters and various papers at many international and national conferences.

Dr Morris is member of AOCS (American Oil Chemists Society), ESS (European Society for Sonochemistry), IAHE (International Association for Hydrogen Energy), III (Institute for Inventors and Innovators, South Africa). He has obtained several awards, including "Henri Marie Coanda" Gold Medal for innovations (novel products for medicine) in Applied Biotechnology. Dr Morris is working mostly with students from South African universities who need one-year in-service training (experiential training), in various fields of applied sciences.

In South Africa, Dr Morris is well known as a tough team leader and as an appreciated motivational speaker.

Characteristic for all three authors is the fact that they believe that the entire world is moving into Hydrogen Civilization. Hydrogen Civilization is based on Hydrogen Economy. To be affordable and efficient, a hydrogen economy needs innovations that will make a new order in the energy market, an order that will democratize the energy market from the bottom up, without cartels and without monopolies.