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HYDROGEN FOR A SUSTAINABLE ENERGY SYSTEM: A REVIEW

Hussein Abdel-Aal1[1], Mohamed Fahim[2], Maha Abdelkreem[3], Khaled Zohdy[3]

[1]*Professor Emeritus of Chemical Eng. / Petroleum Refining (retired), NRC, Cairo*
[2] *Professor, Pharos University, Alexandria*
[3]*Department of Chemical Engineering, Higher Technological Institute, Tenth of Ramadan City, Egypt*

Abstract

In this paper, we will try to shed some light on how to overcome the two challenging problems the world has been facing regarding energy, by using hydrogen for a sustainable energy system. These two main problems are:

1st: Fossil fuels,which meet about 80 % of our energy needs today, are being depleted fast.

2nd: The use of fossil fuels is causing major environmental problems.

Solution of these interrelated problems has been pursued through the use of what is called Sustainable Energy Resources (SER). Hydrogen is introduced as an energy carrier to utilize SER in an effective and non-polluting way. The analogy between hydrogen and blood circulation as energy carriers is established in this investigation; where hydrogen provides energy in an energy system while blood transports nutrients, and oxygen in human body to provide nourishment. Methods of hydrogen production have been presented. The pros and cons of using hydrogen in our system are illustrated. Data on the overall efficiency of conversion of solar energy to produce hydrogen using different options are cited with illustrations.

Key Words :: Hydrogen, Sustainability, Sustainable Energy, Efficiency of Hydrogen Production, Renewable energy sources

1. Introduction

1.1 Sustainability:

Sustainability requires consideration of three aspects (sometimes also known as perspectives, pillars). The three Pillars of Sustainability are a powerful tool for defining a completesustainability system. They are known as economic, social, and environmental pillars. If anyone pillar is weak then the system as a whole is unsustainable. Two popular ways to visualize the three pillars are as shown in Figure 1.

1.2 Sustainable energy:

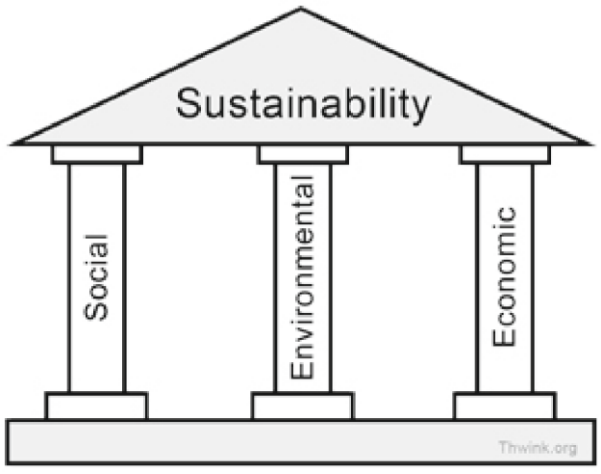
Sustainable energy is simply defined as the one that meets the needs of the present without compromising the ability of future generations to meet their own needs and ensure that our actions and decisions today do not inhibit the opportunities of future generations.

1.3 Technologies that promote sustainable energy:

Renewable energy and energy conservation measures are said to be the twin pillars of sustainable energy as given in Figure 2.[1-5].

2. The role of hydrogen as an Energy carrier

By blending scientific research, education and practical solutions, we scientists should be all working to help guide the world onto a path toward sustainability. We agreed that fossil fuels (oil, coal and natural gas) are not sustainable energy sources because they are limited in quantity and they cause long-term damage to the environment.



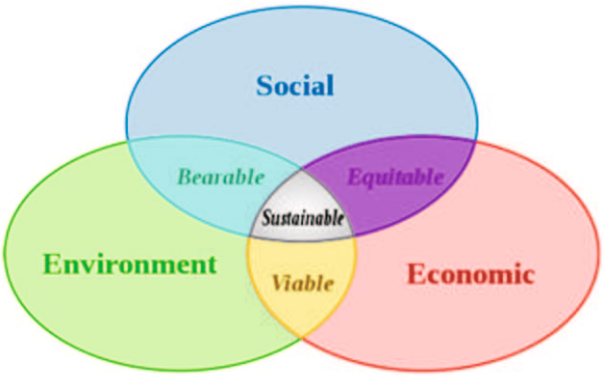


Figure 1- The three pillars: economic, social, and environmental for Sustainability

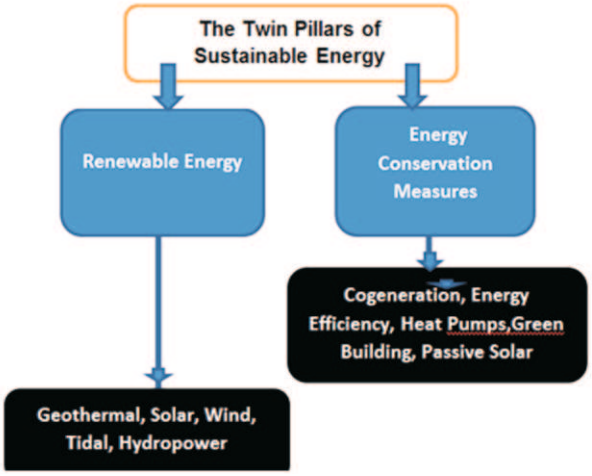


Figure 2- The twin Pillars for Sustainable Energy

Sustainable energy is defined as the energy which isreplenish able within a human lifetime and causes no long-term damage to the environment.On the other hand, by sustainable energy resources (SER), webasically mean Renewable Energy Resources listed above (RER). The two terms are fundamentally synonyms.

Now, we are in need to a carrier that captures energy from these RER and deliver it to consumers at end points. This carrier turns out to be hydrogen. Hydrogen is often cited as the solution to global energy problems and the perfect energy carrier for a sustainable society due to its' non - polluting nature and suitability to store and transport energy generated from renewable sources. This establishes the analogy between blood in human body and hydrogen in an energy system. Both carry energy. Both are defined as "energy carriers".Figure 3 is a schematic illustration of this analogy concept.[6]

Energy from RES: solar, Hydro, wind is used to split water producing hydrogen, which is utilized to produce thermal energy by direct combustion and/or electricity through fuel cells.

On the top of that, using hydrogen is justifiable because of the following merits:

- It is the most abundant element in the universe.
- It is found in many materials: water, crude oil, natural gas and biomass.
- It is non-polluting: when you burn hydrogen, you only get water.
- The use of hydrogen signals the march of what is named "Age of Energy Gases", as illustrated in Figure 4.

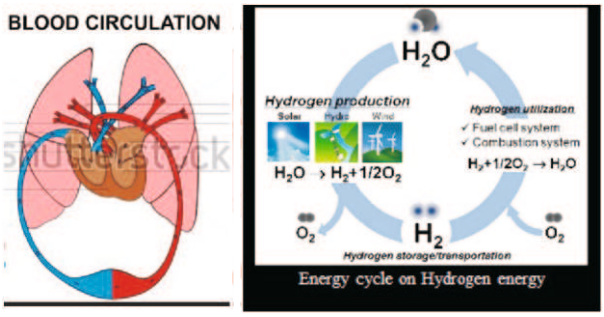


Figure 3- Analogy Concept for Hydrogen & Blood as Energy Carriers

Bloodcirculatory system: is an organ system that permits blood to circulate and transport nutrients, oxygen, carbon dioxide, hormones, and blood cells to and from the cells in the body to provide nourishment.

Hydrogen energy Cycle: is to split water into hydrogen and oxygen by applying RES, and use the hydrogen to provide thermal energy by direct combustion and/or electric energy by using fuel cells.

For example: Solar–Hydrogen energy cycle is an energy cycle where a solar powered electrolyzer is used to convert water to hydrogen and oxygen. Hydrogen and oxygen produced thus are stored to be used by a fuel cell to produce electricity when no sunlight is available.

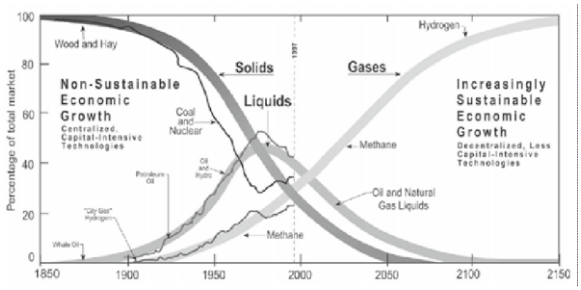


Figure 4- The Age of Energy Gases: Global Energy System Transition (after reference 7)

3. Methods of hydrogen production

To make hydrogen as a fuel, it must be liberated from its combined form: H2O, crude oil or natural gas. This separation process requires using energy. For example, to make one kilogram of hydrogen from water byelectrolysis requires 45-70 kWh of electricity, depending on the technology. This amount of electricity could power the average home for roughly two to three days.

According to the U.S. Department of Energy, 53 million metric tons were consumed worldwidein 2004. There are no natural hydrogen deposits, and for this reason the production of hydrogen plays a key role in modern society.Currently, the majority of hydrogen (~95%) is produced from fossil fuels by methane steam reforming (MSR) or partial oxidation of methane and coal gasification with only a small quantity by other routes such as biomass gasification or electrolysis of water. Fossil fuels are the dominant source of industrial hydrogen.Hydrogen can be generated from natural gas with approximately 80% efficient or from other hydrocarbons to a varying degree of efficiency. Specifically, bulk hydrogen is usually produced by the steam reforming of methane or natural gas. The production of hydrogen from natural gas is the cheapest source of hydrogen currently. Three major routes of production are shown in Figure 5.

4. Non-Fossil Energy Sources (Renewable) for Hydrogen Production

The three sources: Solar, Hydro, Wind are used to split water producing hydrogen, as shown earlier in Figure 3.The solar hydrogen energy cycle is illustraed by Figure 6.

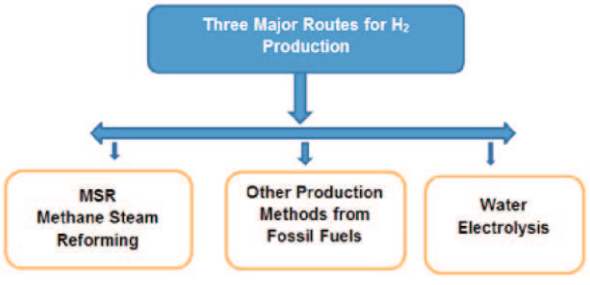


Figure 5- Three Major Routes of H2 Production

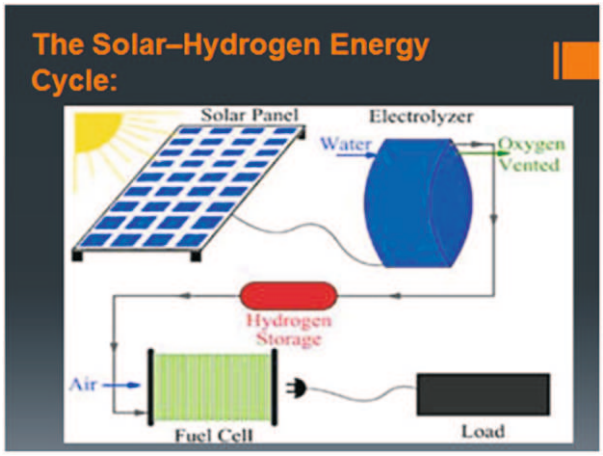


Figure 6 Solar Hydrogen using Water Electrolysis

5. Efficiency of Production of Hydrogen using Solar Energy

Having solar energy at hand, there is more than one option to generate electricity to be used in the production of hydrogen by electrolysis, as shown next (Figure 7). Hydrogen produced by solar energy is referred to as "Solar Hydrogen".

ata on efficiency [9]:

E1: Solar to E.E. = 20 % (43.5 % is the highest)

E2: Solar to thermal = 80 %

E3: Thermal to E.E. = 40 %

E4: Electrolysis = 50-80 %, use 70% as an average

E5: Hydrogen/E.E. (FUEL CELL) ≥90 %

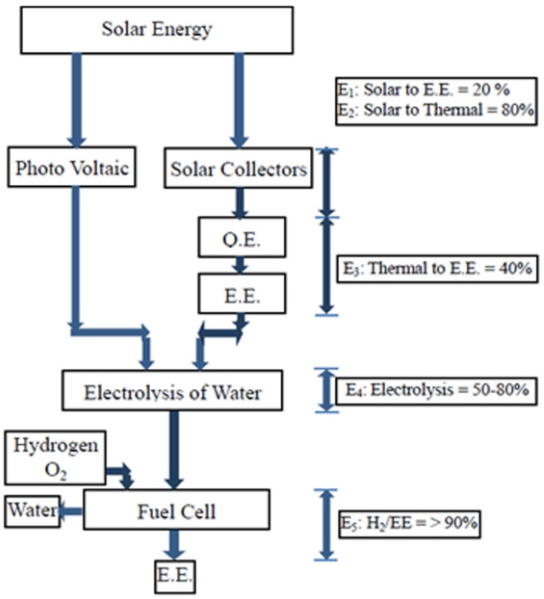


Figure 7 Options of Converting Solar Energy to produce Hydrogen by Electrolysis

It could be stated that a solar panel (PVC) with 20 % efficiency and an area of 1 m2 is rated to produce 200 watts of power. In 2013, the highest efficiencies have been achieved by using multiple junction cells at high solarconcentrations (43.5 % using 418 × the concentration) [8].

From the above, let us compare the following options to produce hydrogen from a sustainable energy source (solar energy):-

Option 1: To use E.E. produced by PVC for water electrolysis, E overall, for Hydrogen production

$= 0.435 \times 0.7 = 30\,\%$;

Option 2: To use E.E. produced by thermal collectorsfor water electrolysis, Eoverall

$= 0.8 \times 0.4 \times 0.7 = 22.4\,\%$.

6.Other Applications for Hydrogen

Hydrogen finds other numerous applications as a raw material in many chemical industries. For example, it can be used to manufacture methnol,ammonium fertilizers and others, as given by the case studies reported in references [10-16].

Conclusions

The accelerating trends of petroleum resource depletion and the global climate change with serious air pollution, motivate the search for sustainable energy sources. When we say sustainable energy, we are basically referring to (Renewable Energy Resources); particularly solar energy.Coupling renewable energy resources with hydrogen offers a promising solution toproduce hydrogen, or "hydrogen vector" by dissociating water.

The efficiency of producing hydrogen by water electrolysis using solar energy is a function of the path of its conversion to electricity. By using PVC, the efficiency of hydrogen production is 30%; while it is 24% when using the thermal option. However, researchers in USA, have raised questions over how the photoelectrochemical communitytests the efficiency of solar-to-hydrogen devices[17].

In order to demonstrate our advancement towards practical applications in the field of hydrogen, it has been reported that our planet may have only gained 27 hydrogen filling stations in 2012. However, California is hoping to have nearly 70 of its own in total by now.

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