Fuel Cell and Renewable Hydrogen Energy to Meet Household Energy Demand

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Abstract

Energy is an inescapable part of today's society and economy. Accomplishment of every work depends on the sufficient and incessant supply of energy. But the conventional fossil energy sources like oil are ultimately limited. Moreover, the increasing demand and flinching supply of oil has made the sustainable energy supply more vulnerable. So this vulnerability of conventional source of energy conducts the thinkers to think about reliable sources of fuel like fuel cell and renewable energy. It can forestall the minus impacts of global climate change, the growing risk of supply interruptions, price fluctuations and air pollution that are associated with today's energy systems. Bring in the hydrogen economy by hydrogen and fuel cell in the minor level like household activities can be a promising solution of energy crisis in a quite unique way which also can ensure our concerns over energy supply security and climate change.

Keywords: *Fuel Cell, Household power, Hydrogen Energy and Renewable energy*

1. Introduction

Global energy demand is springing up so scurrying in the last few decades. Global primary energy annual growth rate is 1.8% within the period 2000 to 2030 [1]. This rapid increasing rate is met largely from traditional fossil fuels. These fuels emit different gases which very harmful for the environment. But ultimately these fuel reserves are depleting and the energy price become increasingly expensive. Latterly, the CO2 emission level of developing country is 20% per capita then of the major industrial nations [1]. But within the year 2030 this will be more than half of the world's CO2 emissions. Moreover, Energy security is a cardinal topic. Fossil fuels like crude oil, natural gas is unevenly distributed which is sometimes governed by the ecological, economic and political factors. These factors lead the price of fuel to a high place and on the other hand the environmental policy demands to reduce the toxic gas emission. A combined energy policy is necessary by highlighting the energy demand, energy supply, fuel production, fuel transmission and distribution, energy conversion and the consequences on energy tools manufacturers and the minor users of energy systems. To meet this goal our aim is to establish a renewable efficient system by hydrogen and hydrogen powered fuel cell from the end user level like household. In the long run hydrogen based fuel cell system for the end user has a great impact on all other sectors. Some developing countries are struggling to provide a sustainable energy supply to its citizen [10]. But for giving the top priority to the industrial sector sometimes the domestic users are deprived by getting interrupted power supply. For any power deficit country sometimes it's very difficult to provide power uniformly to all the sectors. So at

that case the domestic user can think the fuel cell and renewable hydrogen energy beside national power grid for power demand in household activities. Uninterrupted energy supply to all the sectors of any country has a great advantage on the economy. So if the developing countries make an effort to give an uninterrupted power to its citizen then it should be an optimum system to introduce hydrogen and fuel cell to the domestic user without hampering the industrial sector power.

This paper highlights the need for strategic planning and enhanced effort on research, development and deployment of hydrogen and fuel cell technologies. It also makes wide-ranging recommendations for a more structured approach to developing countries for education and training and also for developing political and public awareness. Energy supply security is the major concern for the developed as well as developing countries. The technocrats have already observed the limitation of nonrenewable fuels. So in this case hydrogen based energy system is a great potential which can secure a stable future, but designing an efficient, effective and friendly system for transition is a little bit tortuous. We have to initiate now to scrutinize that path to secure a sustainable future. In the initial stage of this research global current energy status by source has been depicted. But this energy consumption is different in different region and also different in sectors. So this paper tries to give a good sense by giving some visual statistics about the global energy scenario. The paper also shows some comparison of energy consumption in different sector. Our main goal of the research is to reveal the importance of renewable and hydrogen and fuel cell in the household activities. So a typical household energy consumption structure has also shown. The paper also shows a typical house load and then the necessary installation to meet the energy of that house by hydrogen and fuel cell.

2. Global Primary Energy Consumption

Currently global energy mainly mixed with coal, gas, oil, nuclear and renewable energies. At present the large scale of fossil fuel is a cardinal feature of industrial sectors. It is regarded as essential for the growing, distribution and preparation of foods, for construction, manufacturing, communication and organization and many other activities. There was estimation in 1992 which revealed that global annual primary energy consumption is 400 EJ which is equivalent of 9500 million tons of oil per year [4]. So in the electricity generation the use of oil becomes vulnerable to sustainable supply. Coal contributes 40% of electricity production and gas accounts 20% of the electricity production [2]. Nuclear energy contributes 6% to the global energy and 13% to the electric energy [2]. The non-fossil and non-nuclear energy sources already accounted 3.300 TWh from total 18800 TWh electricity productions by the year 2005 which is 18% of the total. From this amount of energy around 2800 TWh are from hydroelectricity. The non hydro contributes approximately 500 TWh which is around 3% of the total electricity generation. We rate renewable energy as a best for the electricity scarcity solution. But currently the use of hydrogen energy and fuel cell in the domestic level become a promising alternative to retain the sustainable society.

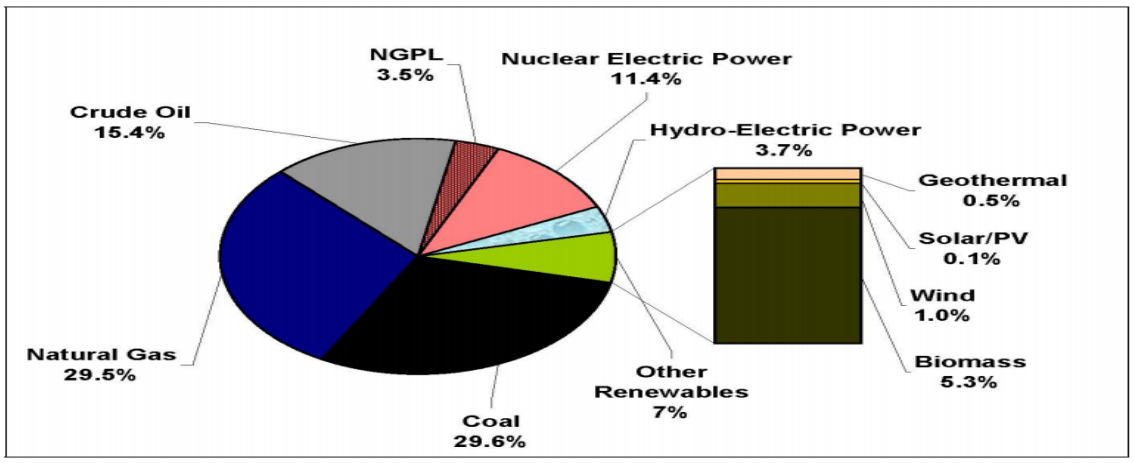

Figure 1. World Primary Energy Consumption by Source, 2010 [3]

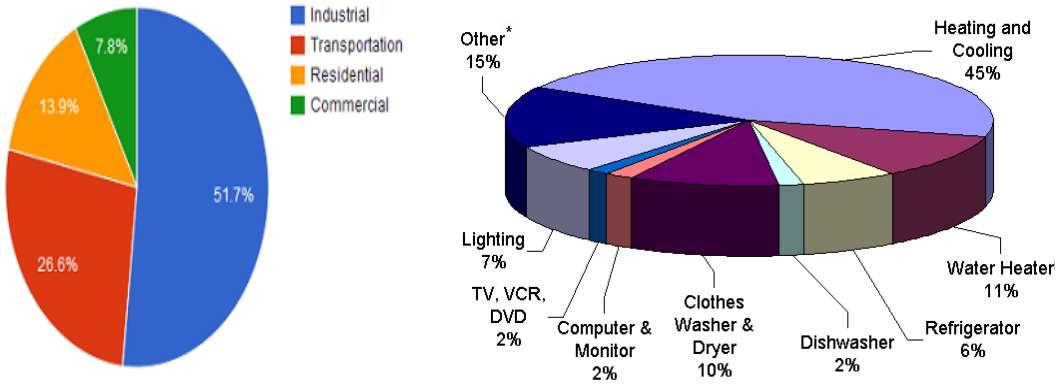

Figure 2. Global Energy Consumption by Sector (2012) & Typical Home Energy Consumption [5-6]

3. System Block Diagram

Fuel cell and renewable hydrogen energy can be a best alternative for the domestic user as it has several advantages over other kind of fuel. A hybrid system based on the hydrogen technology needs a hydrogen production unit which is called electrolyser. There are also some other cardinal unit like hydrogen storing unit (tanks), a hydrogen utilizing unit (PEM fuel cell), a control system, PV generator and also secondary battery or super capacitor for short term energy storage. A typical block diagram of that system is depicted below.

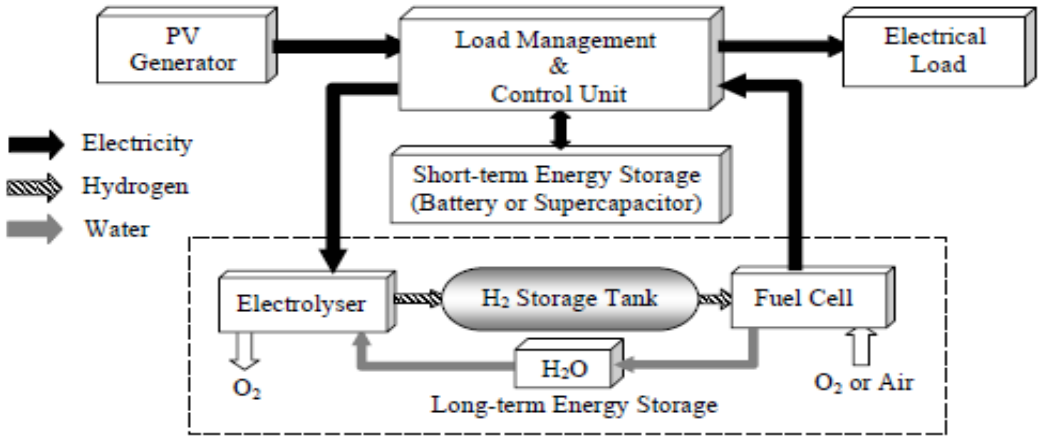

Figure 3. Block Diagram of Fuel Cell and Renewable Hydrogen Energy System

4. Fuel Cell for Domestic Power

Hydrogen fuel cells are now one of the most promising power sources as it is known as the green and clean energy. Not only for the domestic purposes but it also used in the spacecraft and other commercial and industrial purposes. But in the domestic purposes it was used rarely earlier for its cost consideration. Some appliances prices are falling down and in the upcoming years the fuel cell will become a promising power source to the domestic users. The principle to work a fuel cell is a little bit similar with a battery. But the fuel cell is more convenient and efficient than battery because it doesn't need any charging. As long the fuel will be continued to supply the output will also be continued to give as heat and electricity. Basically it has an electrolyte and two electrodes are placed beside that electrolyte [9]. Oxygen goes through one electrode and Hydrogen through the others and finally produces electricity, heat and water. Air or Oxygen enters the fuel cell through the cathode and hydrogen enters through the anode. Hydrogen atom splits into proton and electron by catalyst and passes through the cathode. On the other hand proton goes through the electrolyte. Before returning to the cathode electron makes a separate current [4]. A fuel cell system has a fuel reformer unit which can utilize the hydrogen. It can take hydrogen from natural gas, methanol and gasoline, actually from any hydrocarbon. Fuel cells internal process is a chemical process not any combustion process so it does not emit any poisonous gas which is very harmful for the environment.

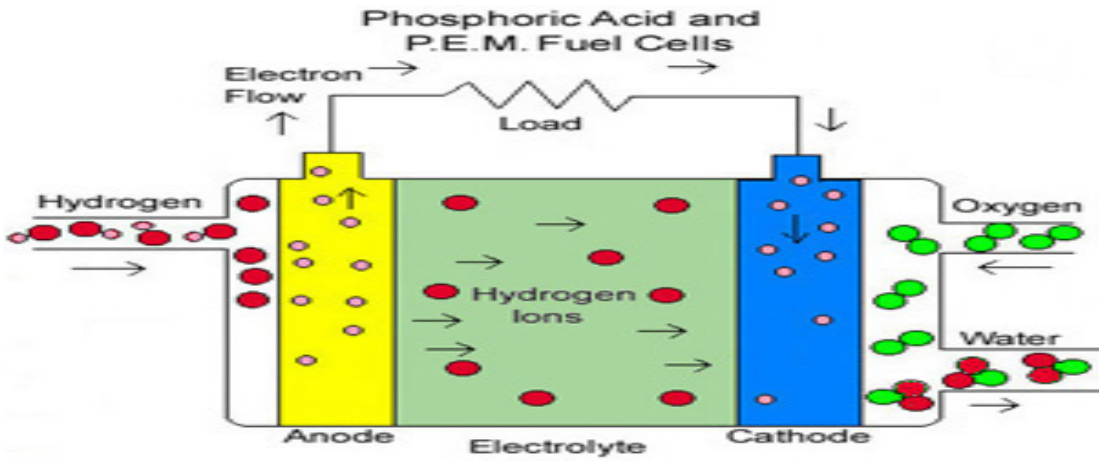

Figure 4. Basic Hydrogen Fuel Cell System [7]

A fuel cell has two catalyst layer and a central electrolyte layer between them. Different material can be used to make it but the main working phenomenon is similar. In the fuel cell the hydrogen atom breaks into proton and electron. The separated proton goes through the electrolyte layer and the electron generates electicity and that goes through the external load of the circuit. After this process electron moves to the positive side of the electrolyte layer and there combines with the positive proton. After that it also combines with oxygen molecule and finally produces water in the positive cathode catalyst layer [9]. Fuel cell has a similarity with other power generating process. In most of the power generation system needs to rotate the prime mover or turbine. To rotate that turbine or prime mover some energy must be necessary either from nature or from fossil fuel or others. Alike that system fuel cell also need some input which is hydrogen and oxygen. Different ways can be applied to supply hydrogen and oxygen. In some system fuel reformer is used to extract hydrogen from another fuel source like propane and necessary oxygen can be extracted from the atmospheric air. In the industries a tank containing pure hydrogen and oxygen is installed instead of fuel reformer. But for the domestic user to use electrolyser to separate the water into hydrogen and oxygen is an efficient, smart process from the renewable energy standpoint. Hydrogen and oxygen from the electrolyser is stored in tanks and fed into either end of the fuel cell [9].

5. Typical Home Energy Analysis

A typical house with an area of 119 m^2 has been analyzed to have an idea about the energy consumption and to establish an appropriate fuel cell according to that load. For this energy calculation process the internal temperature of the room has been considered 20 degree Celsius. Moreover for maintaining an average temperature the air cooler and sometimes based on season heater has also taken into consideration. So the heat losses, temperature difference, air change rate, exposure to climate, efficiency of services, internal material heat losses have also taken into consideration.

$$Pf = U*A*DT*(1 + ZD + ZP)$$

Where, Pf = rate of fabric heat loss = heat energy lost/time (W), U = U-value of the element considered (W/m^2K), A = area of that element (m2), DT = difference between the temperatures assumed for the inside and outside, environments (oC), ZD = Interrupting operation coefficient, ZP = Orientating coefficient [4].

Moreover, ventilation losses should also take into consideration as we used heater as well as air cooler. Ventilation losses the heat as it emits warm air which is replacement by colder air. The rate of heat loss by such ventilation or infiltration is given by the following formula:

$$Pv = (cv*N*V*DT)/3600$$

Where, Pv = Ventilation heat loss rate (heat energy/time) (W), Cv = Specific heat capacity of air in volume = specific heat capacity X density (J/m3K), N = air infiltration rate of the room (per hour complete air changes number), V = Volume of the room (m^3), DT = Inside and outside air temperature difference (^{0}C) [4].

So considering all of these things annual energy consumption accumulating all month's consumption is shown below.

Table 1. A Typical Home Energy Consumption Analysis

Room	Area (m^2)	KWh/year (Approx)
Kitchen	23.50	1800
Living room	78.29	2376
Dining room	30.98	2184
Bedroom	36.10	2148
Toilet	16	1800
Guest room	34.13	2100
Total	219	12408

6. Hydrogen and Fuel Cell Installation Analysis

Recently the efficiency of an electrolyser is in the range of 65% - 80%. We assume that our electrolyser has an efficiency of 70%. To extract 1Nm^3 of hydrogen we need 2.995 kWh with 100% efficiency. As we mentioned before our device is 70% efficient. So the energy needed to produce 1Nm3 of hydrogen is 4.27 kWh [4]. As we have taken an arbitrary household power consumption for making a calculation which is 1034 KWh per month on an average. So to meet the demand of 1034 KWh we need to produce enough hydrogen according to the above relationship. Typical three different fuel cell specifications are depicted, each containing 56 cells which have approximately 48 V.

Table 2. Fuel Cell Comparison in Different Power [8]

Description	5.9 KW	3.3 KW	1.1 KW
Active area of Membrane	170 cm^2	100 cm^2	35 cm^2
Non-repeat unit's mass in total	5.1 kg	3.6 kg	3.3 kg
Repeat unit's mass in total	2.8 kg	1.8 kg	0.8 kg
Stack mass in total	7.6 kg	5.4 kg	4.0 kg
Volume of the total stack	7.8 L	5.3 L	3.2 L
Power density of stack (weight)	0.78 KW/kg	0.62 KW/kg	0.27 KW/kg
Power density of stack (volume)	0.76 KW/L	0.62 KW/L	0.34 KW/L
Stack cost in total	$244	$166	$124
Power cost	42 $/KW	47 $/KW	103 $/KW

7. Conclusion

This paper has illustrated the potential of fuel cell and renewable hydrogen energy to coup up the demand of household energy. A hydrogen and fuel cell storage system for electricity can be a smart process for an isolated house compared with a battery system. A system of hydrogen and fuel cell can not only work effectively but also to provide in the whole world a more environmental friendly solution for the future. The difference between the battery and the fuel cell system laid in the environmental concerns of the two systems. Moreover, it can also give a relief to the national grid of the developing country having power shortage if the domestic user uses this system.

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Khizir Mahmud was born (DOB-1989) in Tangail, Bangladesh. He received his Bachelor degree in electrical and electronic engineering from Chittagong University of Engineering & Technology (CUET), Bangladesh in 2011. He worked as lecturer in the department of Electrical & Electronic Engineering in America Bangladesh University, Dhaka, Bangladesh for one year. After that he admitted to the Northwestern Polytechnical University, Xi'an-710072, P.R. China for M.Sc. degree major in Electrical Engineering. His research interest includes electrical power, power generation, power factor, power quality and renewable energy.