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USE OF GREEN HYDROGEN IN DEVELOPED COUNTRIES AND PROSPECT IN BANGLADESH FOR SUSTAINABLE DEVELOPMENT IN ENERGY SECTOR

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ABSTRACT

Bangladesh is one of the fastest growing countries in the world. We all know that energy is the most important key of development. Most of the countries largely rely on fossil fuels to meet the energy requirements. Fossil fuels are not environmentally safe. Green House Gas (GHG) is a major concern for climate change. To achieve sustainable development goals many countries have already shifted towards renewable source of energies like Solar, Wind, and Geo-thermal and so on. Solar Photo-voltaic technology has become very popular throughout the world. Bangladesh has the highest number of solar home system users in the world. The country is also popularizing the use of bio-gas. Storage is a major concern for renewable energy applications. Green hydrogen is becoming popular day by day. Industries are producing hydrogen in various ways but these are not compatible in terms of nature's conservation. Solar energy can be used to produce hydrogen without leaving any emission behind. However, the price of hydrogen is an important factor. Development of local technology for low cost hydrogen generation systems would increase the use of this clean energy source in the under-developing countries like Bangladesh. In this paper diversified use of hydrogen is being discussed. This research work aims to find the potential and suitable applications of hydrogen locally. Hydrogen can be used for various energy applications. Chemical, food and metal industries have high demands for hydrogen. Electricity can be produced from hydrogen by using fuel cells. Bio-gas can be upgraded by hydrogen. Hydrogen can be used for heating applications. Burning hydrogen with proper safety concerns is safe for environment as it has no Carbon-di-oxide emission. Hydrogen can be used for small or large scale heating replacing fossil fuel to reduce harmful environmental impact caused by fossil fuels. Electricity can be used to produce and converted into hydrogen as an energy storage. Green Hydrogen could share the energy need of Bangladesh and may help achieve the sustainable development goals. This research identifies the potential cost effective production of hydrogen using renewable energy and its applications for Bangladesh which might be benefited from green hydrogen.

Keywords: Energy Sector. Green hydrogen, Low-cost local technology, Reducing emission, Sustainable development.

Introduction

Being a densely populated country, Bangladesh has many serious issues. Energy crisis is one of these. Per capita energy consumption in Bangladesh is very low, 311 kWh in 2014 [1]. Continuous supply of energy is a must to support business and day to day activities of mass people. In an average about 77.9% people has access to electricity [2]. Every government faces critical challenges to meet this crucial necessity. For past decades the energy sector of Bangladesh is

in a bit stable condition. Installed electricity generation capacity has reached to 21,419 MW in September, 2019 [3]. However, sustainable growth and infrastructure development is yet in primary stage. To strengthen and stabilize this sector government has already diversified and de-centralized the resources. Gas is the major source to produce electricity and transport with fossil fuel. About 75% energy demand is covered by natural gas. House hold heating is met largely by biomass in rural areas. Natural gas by central distribution company and private cylinder suppliers operate in urban and sub urban areas in the country. Import of electricity is contributing to the national grid. Coal and nuclear power plants are under construction. Renewable energy resources are also being used in standalone and centrally connected mode [4]. Number of Solar home systems is the highest in Bangladesh with fifth in small Bio-gas plants. A very few wind turbines are installed in coastal region. Government has planned to increase renewable energy share up to 10% in energy mix within 2030.

In 2014, 0.46 Mt of carbon-di-oxide emission per capita has been recorded [5]. In contrast to the world picture this amount is not very significant at all but the increasing rate is alarming. It is moving forward at an average rate of 5.17 % annually. Major emission source in Bangladesh are various industries, fossil fuel based power plants, transport vehicles and households. Use of natural gas is contributing to reduce emissions but this resource is depleting. Alternative of natural gas must be accommodated before it gets finished. Bangladesh is not importing liquid propane which creates a dependency on external parties and suppliers. Hydrogen can contribute to support the need of natural gas requirements [6]. Some countries are directly feeding hydrogen gas into existing distribution line to support the supply [7]. This type of establishments require state of art safety mechanisms.

In Bangladesh, at present hydrogen is produced in a non-renewable method. These industrial methods are comparatively low cost but study shows that green hydrogen production is becoming more price competitive day by day [8]. As Bangladesh is a solar abundant country and photovoltaic technology has success story, proper developments and extensive research on green hydrogen might open a new door to a promising energy resource.

In this paper, worldwide situation of hydrogen exploitation, importance and advancement of its applications are discussed. It identifies difficulties and gaps to promote this scope in Bangladesh with the identification of sectors.

Green Hydrogen Worldwide

Green hydrogen is a new term in the field of hydrogen technology. Green hydrogen is produced using renewable energy sources and does not emit any harmful greenhouse gases. It is mainly the electrolysis of water. Electrolysis requires electrical energy to breakdown the water molecules into hydrogen and oxygen. The electricity is supplied from renewable sources like Solar or Wind. **(Ref Fig- 1)**

In 2018, several carbon capture and storage projects are announced in Europe. This facilitates 100 MW capacity water electrolyzer for hydrogen production [9]. In Netherlands, a 20 megawatt of

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electrolyzer is planned to be established for the large scale conversion of sustainable electricity into green hydrogen. The project is in evaluation phase and final decision to come in 2019. The facility will produce 3000 tons of hydrogen per year which can run about 300 hydrogen buses [10]. Successful completion of this project aims would lead the development of a 100 MW capacity installation which will convert and store sustainable energy in the form of hydrogen gas. Netherlands has a 1 MW facility already in operation. AkzoNobel and Gasunie are jointly investigating this project.

The cost of green hydrogen is expected to be competitive by the year 2030 in Australia, Germany and Japan [11]. To acquire this phase these countries need to modify their policy into renewable energy (RE) friendly level. In contrast to that Bangladesh has already established tolerable RE policy. Investor can be benefitted while running projects in Bangladesh. However, development of low cost technology is required using locally available materials. Analysis shows that by 2025, worldwide green hydrogen production will expand up to 3205 MW and will reach up to 252 MW by 2019. So, this is the high time for Bangladesh to put some effort on green hydrogen as other countries have advanced miles ahead.

Worldwide Scenario of Hydrogen Production and Application

World's highest amount of hydrogen producer is the United States. About nine million metric tons are produced yearly in US. California, Louisiana, and Texas are the three states which are considered major in this area. About 95% hydrogen is produced from natural gas through Steam Reforming Method [12]. Almost 100% hydrogen is used in refinery, metal and food industry. The National Aeronautics and Space Administration (NASA) is a mentionable single user of hydrogen in US. In USA, fuel cell based application are becoming popular day by day. Fuel cells are used to produce electricity from hydrogen [13]. Two types of application of fuel cell are common, in vehicles and stationary installation for electricity production. The Number of fuel cell vehicles (FCVs) are increasing. More than 350 FCVs are in operation from 2016 in California [14]. About 50 hydrogen refuelling stations are established to support these vehicles. In this state, fuel-cell based distributed power generation crossed over 210 MW using 480 fuel cells. Connecticut has approved a 63.3 MW fuel cell station. This would be the world's largest installation [14]. It has 35 MW already and planned to have 20 MW. There are 600 companies in US operates for hydrogen and fuel cell network there. In 2015, about 726 million USD has been accounted in investment and revenue in this field [15]. More new jobs are created resulting an increase labour income and local tax. The list from US includes New York, Colorado, Hawaii, Massachusetts, New Jersey and Ohio for hydrogen and fuel cell endeavours and business. As of 2019, FCVs exceed 6500 in USA. **(Ref Fig- 2)**

Source: U.S. Energy Information Administration, Form EIA-860, Annual Electric Generator Report

France has announced its aim for the withdrawal of diesel and gasoline vehicle sell by 2040 to gear up the Paris Climate Agreement [16]. The country decided to invest USD 100 million to achieve green goal and establish hydrogen energy sector. It also plans to become a leader in

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hydrogen production for the green transportation plans.

There are ten countries trying to move towards green hydrogen to replace the use of fossil fuels. The countries are Australia, Canada, China, France, Germany, Japan, Norway, South Korea, U.K. and U.S. At present, Australia has negligible exposure to green hydrogen but it aims to establish 5 GW combined solar and wind power plant to produce solely green hydrogen and look forward to export. Australia's primary focus is toward Japan and South Korea as they are profound importer of fuels.

China is speeding their motivation towards hydrogen economy. They aimed to increase the number of fuel cell vehicles up to million within 2030. By 2025 they would establish 100 hydrogen refuelling station for 5000 FCVs. They have already exempted taxes for fuel cell vehicles and targets to have 100 fuel cell and component manufacturers to support the future demands.

Japan is the global leader for hydrogen fuel cell vehicles. Efforts from Toyota and Honda are remarkable for developing the fuel cell vehicles and further development of this technology. Being an important application of hydrogen fuel cell vehicles pivot the need of green hydrogen. Due to the fact that the country accounts the most liquid natural gas imports. To reduce this they are trying to shift the need towards renewable hydrogen. They have set a global target for 10,000 hydrogen refuelling stations within next ten years [17].

Norway has potential to produce hydrogen using hydro-power. They have already encountered an accident in hydrogen refuelling station which is the first in the world. The country is using fuel cell to operate ferries which is a pioneering development [18].
Concerning the safety issues and incident of Norway, South Korea has set a goal for 850000 FCVs within 2030 and 3000 by this year. It has plan to subsidise also. About 1.8 billion USD is to be handed to FCV and refuelling sector [19].

World's top offshore wind market is in United Kingdom (UK). Taking this advantage into account United Kingdom has planned to invest about 15 billion USD on 4 GW offshore wind power production facilities for renewable hydrogen production.

Developed and economically stable countries are very much interested for green hydrogen production and applications. It is mainly taken into account as an emission reduction strategy. It is expected that by 2040 world's energy production and usage scenario would experience a change which will be led by green hydrogen as these countries are investing and creating scopes for renewable hydrogen technology. Currently the major demand for hydrogen is not for energy, however these endeavors and developments of applications are creating demands for hydrogen in energy sectors.

Demand potential of Hydrogen in Asian Countries

There is no conventional study on demand and supply chain of Hydrogen in Asia region, however, the future demand is estimated using various resources and some studies done by regional organisations. These materials include the Economic Research Institute for ASEAN and East Asia's (ERIA) energy outlook, as well as the latest hydrogen utilisation and technology trends, and other demand estimation documents [20]. The analysis

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identifies three major sectors for hydrogen utilization. These are mainly Electricity generation, Industry and transport. Table 1 shows country wise future demands. These countries are mainly ASEAN and East Asian. **(Ref Table- 1)**

The data is obtained using three scenarios. Percent mix of hydrogen into currently used fuels is categorized as scenarios. Categories are set to have 5%, 10% and 20% mix of hydrogen with fossil fuels. In these countries, electricity generation is mainly done by coal and natural gas. It has been expected that 20% of new coal-fired electricity generation will be converted to natural gas and H_2 mixed fuel fired generation [20]. This will be same for existing natural gas based electricity generation. **(Ref Fig- 3)**

In industries, 20% of natural gas consumption for industrial purposes will be replaced by natural gas and H2 mixed fuel. **(Ref Fig- 4)**

Transport is mainly using gasoline and diesel. Passenger Fuel Cell Vehicle, Fuel Cell Bus and Fuel Cell Train will replace some portion of Gasoline and diesel demand into H_2.

The same data and analysis is unavailable for Bangladesh but the scenario clearly shows the future plans of regional courtiers toward Hydrogen economy. Bangladesh has to move towards it with other neighbours. **(Ref Table- 2)**

Sectors for Hydrogen applications in Bangladesh

Like other East Asian countries Bangladesh is also largely dependent on fossil fuels for the energy production. Starting from the electricity generation to industry, household and transport sector the country is using Kerosene, Diesel, Petrol, Octane and Natural gas. Recently LPG and LNG are imported [21]. In rural areas people are largely dependent on bio mass based energy conversion techniques. As we can see that the most of the other countries in this region have potential to use hydrogen as a mix fuel in future for all the important sectors like power generation, transport and industries there must be an impact on Bangladesh Energy sector also.

Bangladesh mostly uses natural gas to produce electricity. It is above 50%. On the other side this natural resource is depleting quickly. Mixing hydrogen with natural gas can save up to 20% by the help of currently available technologies. This sector is a major concern as most of this gas resource is provided for electricity generation. Hydrogen can be used in transport sector also. Fuel cell passenger vehicles and buses are performing well and became a matured technology though further development is going on. **(Ref Fig- 5)**

Bangladesh has petroleum refinery sector which uses hydrogen in their production process. Eastern Refinery Limited is such a company. It collects light and heavy crudes, refines and supplies fuel oils to marketing companies. This industry has an installation of Steam Methane Reforming (SMR)-Hydrogen production plant. The production capacity is 790 metric ton/year. However, due to some technical reasons the plant is inoperative at present. Hydrogen is a crucial element for processing crude oils. Due to the unavailability of ready hydrogen some category refinement is not being done here [21]. There are other 7 govt. refineries and 14 private refineries which are mainly

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fractionation plants. These plants do not use hydrogen in any of their refinement process.

Sulphur content of Bangladeshi fuel is comparatively high. Currently, the upper limit of sulphur content in diesel used in Bangladesh is 2500ppm. This high sulphur content is partly responsible for particulate matter which is a major pollutant from diesel-run vehicles.
Around 3 million tons of diesel is needed annually in Bangladesh. Of them, 15% which is 0.4 million tons is produced by Eastern Refinery Limited (ERL) per year and the rest 85% is imported from abroad.

The sulphur in diesel produced by the ERL is around 5000ppm while it is 2000ppm in the imported diesel. Thus when these two are blended the resultant blend has a sulphur content of around 2500ppm.

In 2012, the World Health Organisation declared that diesel pollutants are carcinogenic, which means the particles could cause cancer. These pollutants can also reduce visibility by creating smog and may be responsible for acid rain. ERL has also proposed setting up a 1.4 million tons de-sulphurization unit which will be able to produce 350ppm sulphur diesel.

Scopes in Bangladesh

In rural areas, mostly bio-mass is used for cooking and heating applications. Bi-mass creates smokes and it is the main reason for indoor air pollution. Women and female children in rural who uses biomass in kitchen are in high risk of chronic obstructive pulmonary disease (COPD) [22]. Improved cooking systems might reduce the health risks well as would improve the environment. Bio-gas plants are playing an important role to fight reduce kitchen smokes and micro particles. However bio gas contains 30 to 35% carbon-di-oxide in composition with sulphur-di-oxide [23]. Hydrogen can be used to improve bio-gas by the help of hydrogenotrophic methanogens. This process can increase the methane percentage nearly 85-89% [24].

Fertilizer industries are using hydrogen gas to produce urea. They are using Steam methane reforming method to produce hydrogen. This process releases vast amount of carbon-di-oxide. Apart from this hydrogen is used in food industry for hydrogenation of fat and oil, in chemical industry for methanol, hydro alkylation, hydrocracking, hydro-de-sulphurization, hydrochloric acid production. In metal industries, hydrogen is used for reduction of metallic ore. In engineering workshops, hydrogen is used for welding. Each of the said industries are operating in Bangladesh and day by day the number is expanding. The requirement of hydrogen is also increasing in Bangladesh as rest of the world. So, there is huge scope of green hydrogen to lead the local market.

As like other developed countries transport and power generation sectors can also use hydrogen as a primary fuel mix to produce energy.

Conclusion

Green hydrogen production largely dependent on low cost solutions. Major parts of this system are renewable power source with low cost electrolysis methods. Bangladesh is a solar boon country. Solar panels are readily available in local markets along with system components like charge controllers, inverters etc. This technology has huge potential in Bangladesh for renewable hydrogen production. Research and development is

going on to integrate low cost electrolyzers for hydrogen generation. Government has subsidies on renewable energy project and has user friendly policies however some important aspects of this particular establishment to be addressed. Hydrogen is a very useful element and can be used in energy sector.

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Fig.1: Green hydrogen production and usage (source: www.greencarcongress.com)

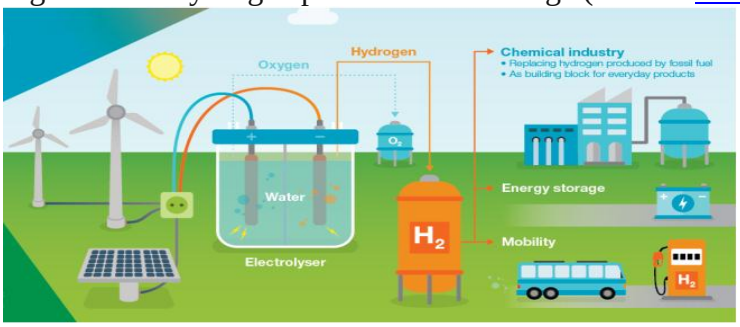
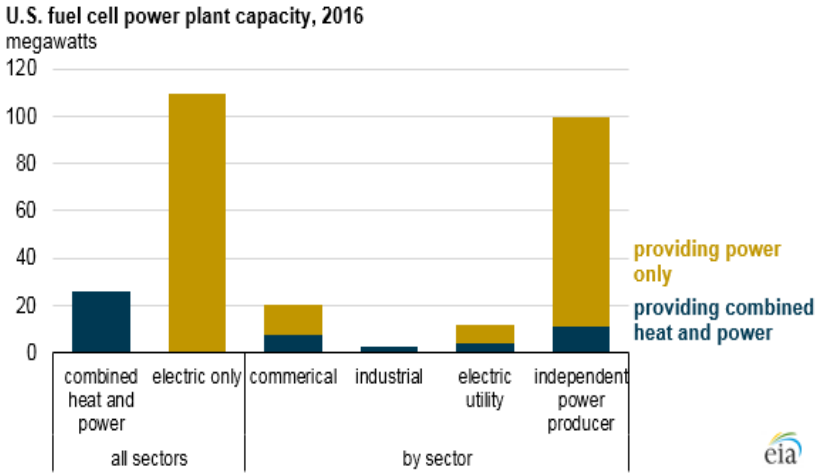


Fig. 2. : Fuel cell usage in USA



Source: U.S. Energy Information Administration, Form EIA-860, Annual Electric Generator Report

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Fig. 3: Hydrogen Demand Potential in 2040, by ASEAN Countries.

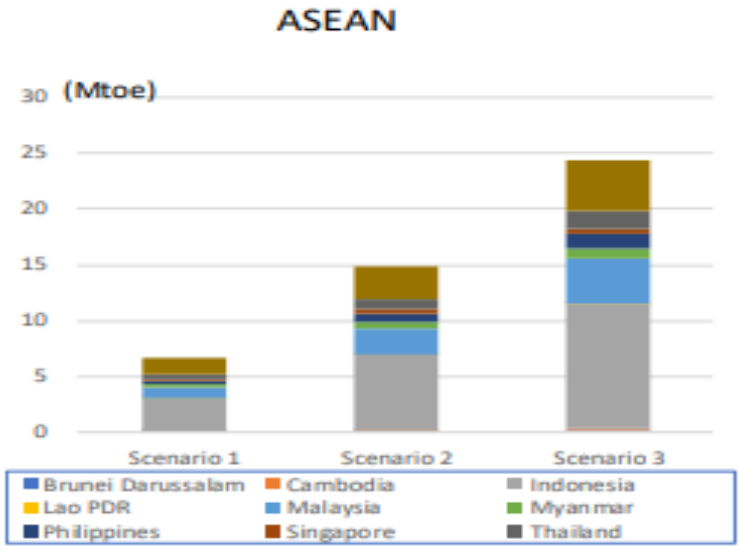

Fig. 4: Hydrogen Demand Potential in 2040, by East Asian Countries

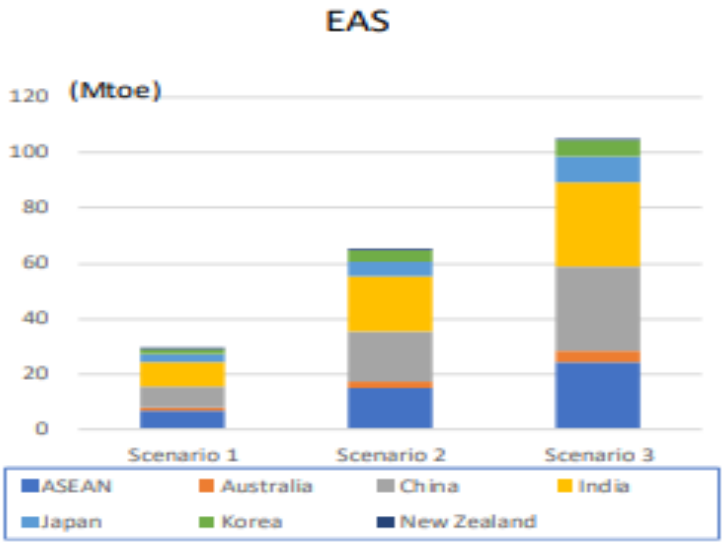

Fig.5: Bangladesh's Electricity Generation Mix (SREDA, 2017)

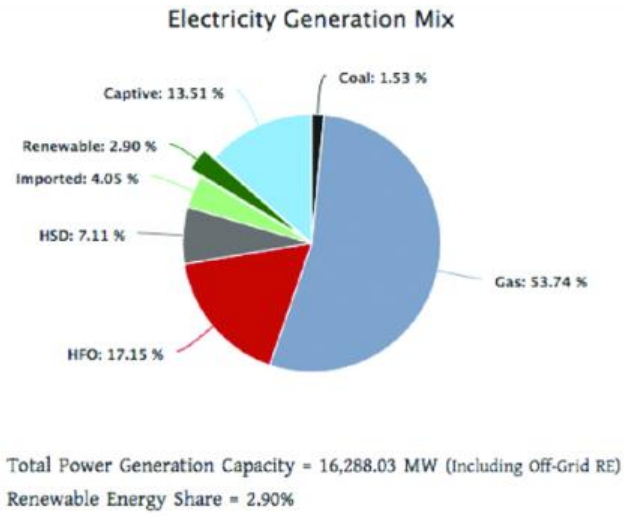

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Table 1: Hydrogen Demand Potential by Country in 2040 (in Mtoe)

Country	Electricity	Industry	Transport	Total
China	29	10.8	16.8	56.6
India	44.5	4	11.1	59.6
Myanmar	0.6	0.2	0.9	1.7
Philippines	1.8	0	0.8	2.6
Indonesia	7.7	1.1	7.5	16.3
Malaysia	3.4	1.6	2.5	7.5
Singapore	0.6	0.2	0	0.8
Thailand	1.4	1.2	0.6	3.2
Viet Nam	6.4	0.8	1.7	8.9
Cambodia	0.2	0	0.2	0.4
Brunei Darussalam	0.2	0	0	0.2
Japan	12	1.8	3.2	17
Republic of Korea	9.2	1.3	1.1	11.6
New Zealand	0.2	0.1	0.3	0.6
Australia	4.2	1	1.9	7.1
Other than ASEAN	99.2	19.1	34.3	152.6
EAS Region Total	125.4	24.6	48.6	198.6

Table 2: Fuel replacement scenario in Transport sectors.

Fuel to be replaced	Type of Country	H2	Gasoline	Diesel	Scenario
Gasoline by Passenger FCV	OCED	2%	98%	0%	Case1

		10%	90%	0%	Case2
		20%	80%	0%	Case3
	Non OCED	1%	99%	0%	Case1
		5%	95%	0%	Case2
		10%	90%	0%	Case3
Diesel by Fuel Cell Bus	Japan	0.05%	99.50%	0%	Case1
		0.10%	99.90%	0%	Case2
		0.20%	99.80%	0%	Case3
	Other Countries	0.025%	99.975%	0%	Case1
		0.05%	99.95%	0%	Case2
		0.10%	99.90%	0%	Case3
Diesel by Fuel Cell Train	All type	5%	0%	95%	Case1
		10%	0%	90%	Case2
		20%	0%	80%	Case3

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