International journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.2., Issue.4, 2014

REVIEW ARTICLE

ISSN: 2321-7758

USING BIOGAS AS THE FUTURE FUEL SUBSTITUTE TO PRODUCE HYDROGEN – PROBLEMS AND FEASIBLE SOLUTIONS

PAVEL SENGUPTA*, AILEEN SENGUPTA
Dr. Sudhir Chandra Sur Degree Engineering College, Dum Dum, Kolkata, West Bengal;
Techno India College of Technology, Rajarhat, Kolkata, West Bengal
Department of Mechanical Engineering; Department of Electronics and Communication Engineering

Article Received: 20/07/2014 | Article Revised on: 26/07/2014 | Article Accepted on:28/07/2014

PAVEL SENGUPTA

ABSTRACT
Hydrogen is widely regarded as the ultimate fuel of the future and favored for its easy storage and cheap transportation over long distances. It is industrially produced by steam reforming of hydrocarbons, which is the dominant technology for its direct production. Many other methods include electrolysis or thermolysis. However, these technologies use vast amounts of non-renewable energy as coal and natural gas. It also requires huge quantities of water. Biogas possesses characteristics which can be utilized as an effective means for future production of Hydrogen energy. This study will show how coal and natural gas can be substituted by biogas and hence save huge amount of fossil fuels and cost. The study uses the anaerobic digestion of biomass to produce marsh gas methane in a digester as a source of methane. This will result in enhanced use of green energy, pollution control, reduced fossil fuel dependency and massive reduction in cost to produce hydrogen energy.

Keywords: Biogas, Biomass, Hydrogen storage, Energy, Fuel substitutes, Renewable

INTRODUCTION

With the global demands of fossil fuels rising, its sources are getting depleted faster and the cost is rising. In the current crisis of fossil fuels, new and novel methods to reduce fossil fuel use are being implemented by more and more countries, all over the world. Hydrogen production for hydrogen energy uses a significant part of fossil fuels. Hydrogen produced by steam reforming uses methane as a natural gas source. Alternate methods to reduce this dependence on fossil fuel are currently absent in India. Also, the production and use of biogas as an alternate fuel source and its applications lie primarily as a substitute for petroleum products. Hydrogen production for hydrogen energy is one of the effective uses of biogas. This not only curbs the need for fossil fuels to produce hydrogen, but also increases biogas applications to produce other sources of energy for our future use.

For predictions of world fuel resources, natural gas and petroleum have a short life of another 40 years while coal will last for another 200 years only. Then, nuclear and breeder reactors will serve part of the energy needs of the world. Hydrogen, however, will last forever. Its use has already been demonstrated in many areas such as gas turbines, aircraft, rockets, IC engines, fuel cells and industrial conversion of coal to methane/methanol. The *advantages* of hydrogen as a fuel are:

- Its energy per unit mass is highest among all fuels
- Combustion with oxygen results only in water without any pollution
- Can be burnt directly in turbines
- Oxidized with oxygen in fuel cells
- Stored as gas, liquid or solid hydrides
- Cheap and easy transportation
- During off-peak hours, excess power available in conventional power stations can be used to generate and properly store it for future use

Theory

Currently the dominant technology for direct production of hydrogen is steam reforming of hydrocarbons especially natural gas. Hydrogen is produced industrially in the following ways [1]:-

- Catalytic steam reforming of natural gas
- Chemical reduction of coal (water gas reaction)
- Industrial photosynthesis
- Ultraviolet radiation
- Partial oxidation of heavy oils
- Thermal decomposition of water, utilizing thermo-chemical cycles
- Electrolytic decomposition of water

Disadvantages of current implementation: -

- Fossil fuels are the dominant source of industrial hydrogen production
- Most of the conventional processes of hydrogen production require coal, natural gas, oils or heavy oils which are nonrenewable sources of energy
- Hydrogen is also generated from natural gas (primarily methane) and other hydrocarbons with varying degrees of efficiency
- Certain processes (steam reforming) generates carbon dioxide as a product, which is unwanted
- Water is the key component for the production of hydrogen
- These processes are dependent on conventional sources of energy and thus costly

Present advances in technology are not addressing the problem of using natural gas which is a nonrenewable resource. However, as the need of nonconventional energy sources arises, the present technologies are being rethought, making the methods under study feasible.

Table 1. Typical Composition of Natural Gas

Typical Composition of Natural Gas

Methane	CH_4	70-90%
Ethane	C_2H_6	
Propane	C_3H_8	0-20%
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen sulphide	H_2S	0-5%
Rare gases	A, He, Ne, Xe	trace

Biogas is produced by anaerobic digestion with anaerobic bacteria or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops. Biogas can be produced from regionally available raw materials such as recycled waste.

Table 2. Typical Composition of Biogas

Typical Composition of Biogas		
COMPOUND	MOLECULAR FORMULA	PERCENTAGE
Methane	CH_4	50–75
Carbon Dioxide	CO_2	25–50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1
Hydrogen Sulphide	H_2S	0–3
Oxygen	O_2	0–0

ANALYSIS

Certain methods of reducing consumption of Natural Gas for Hydrogen Production with the proper substitution of Biogas are as follows:

Methane biogas as a Substitute for Methane (Natural Gas) in Steam Reforming Process

Process and Associated Problems

Steam reforming of natural gas is the present and most widely used method of hydrogen production. It also consumes huge amounts of natural gas. Fossil fuels are the dominant source of industrial hydrogen. Hydrogen can be generated from natural gas with approximately 80% efficiency 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. At high temperatures (700–1100 °C), steam (H_2O) reacts with methane (CH_4) in an endothermic reaction to yield syngas.

$CH_4 + H_2O \rightarrow CO + 3H_2$

$\Delta H = +206\ kJ\ mol^{-1}$ (1)

In a second stage, additional hydrogen is generated through the lower-temperature, exothermic, *Water Gas shift reaction*, performed at about 360 °C:

$CO + H_2O \rightarrow CO_2 + H_2$

$\Delta H = -41\ kJ\ mol^{-1}$ (2)

Essentially, the oxygen (O) atom is stripped from the additional water (steam) to oxidize CO to CO_2. This oxidation also provides energy to maintain the reaction.

Additional heat required to drive the process is generally supplied by burning some portion of the methane. Integrated steam reforming or co-generation is possible by combining steam reforming and steam and power cogeneration into a single plant.

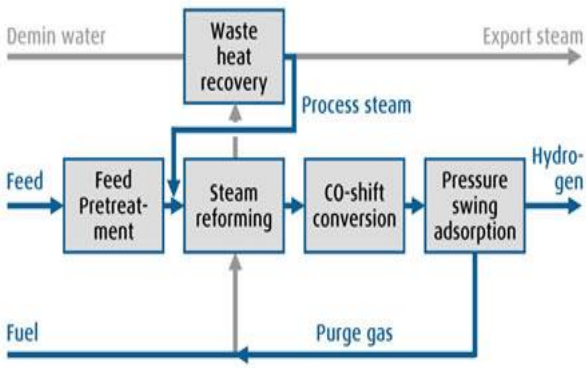

Fig 1: Steam Reforming Process Flowchart

1) Steam reforming generates carbon dioxide (CO_2) which comes under CO_2 sequestration. Since the production is concentrated in one facility, it is possible to separate the CO_2 and dispose of it without atmospheric release, for example by injecting it in an oil or gas reservoir, although this is not currently done in most cases.

Feasible Solutions

1. The methane (natural gas) can be substituted by methane biogas. The methane obtained from a digester can be stored in a tank and supplied directly to the hydrogen production process.
2. Biogas is principally a mixture of methane (CH_4) and carbon dioxide (CO_2). The carbon dioxide generated from the steam reforming process can be directly utilized to produce biogas thus increasing methane production and decreasing the time required.
3. The whole process forms a cycle with no loss or wastage of materials.
4. Hydrogen producing plants can be built around biogas generating plants and thus it increases the possible locations of hydrogen production.
5. Cheaper compared to steam reforming of natural gas.
6. No modes of pollution occur.
7. The water can be recycled from the biomass left as slurry.

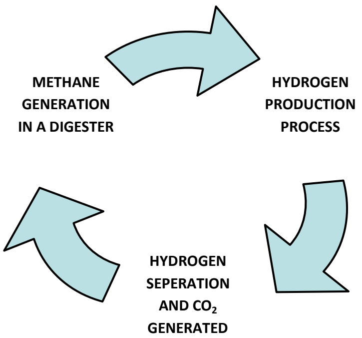

Fig 2. Proposed Process in a Simple Flowchart

Future of Coal Gasification and Methanol to Gasoline (MTG) Conversion
Process and Associated Problems

Coal gasification requires the coal to be changed into syngas and methane. Syngas or synthesis gas is a fuel gas mixture consisting primarily of hydrogen, carbon monoxide, and very often some carbon dioxide. Hydrogen produced from this process is very costly as coal is limited and costly. The entire process requires coal as the primary commodity.

The MTG conversion uses an alternative path to the Fischer-Tropsch process by converting the natural gas to syngas, conversion of the syngas to methanol which is subsequently polymerized into alkanes over a zeolite catalyst. It was developed by Mobil in the early 1970s. Methanol is made from methane (natural gas) in a series of three reactions consisting of equations (1), (2) and

Synthesis: $2H_2 + CO \rightarrow CH_3OH$

$\Delta H = -92\ kJ\ mol^{-1}$ (3)

The methanol thus formed may be converted to gasoline by the Mobil process. This process requires natural gas or methane and converts it to produce hydrogen.

Feasible Solutions

The entire process of production of hydrogen from coal can be substituted by the direct utilization of methane biogas. Coal will not be required anymore for conversion to syngas and methane. Thus, it is a step reduction in the production of hydrogen. This direct method of utilization of methane biogas can reduce costs and permanently stop the requirement of coal for hydrogen production. Pollution is also significantly checked.

The MTG conversion process requires the conversion of the natural gas to syngas, conversion of the syngas to methanol and its further use to generate gasoline. Natural gas can be replaced with methane biogas. Direct conversion of methane to methanol by the equation

$CH_4 + ½O_2 \rightarrow CH_3OH$

$\Delta H = -128.45\ kJ\ mol^{-1}$ (4)

This not only eliminates the use of natural gas but also reduces the cost significantly. The conversion of methane biogas to and methanol to gasoline are the only two steps required now. The price of gasoline will thus reduce significantly. Pollution will be far lesser with this method.

In both the processes we are substituting the non-renewable energy sources with the renewable energy source of biogas.

CONCLUSION

The *Department of Energy, USA* expects that hydrogen production from natural gas will be augmented with production from renewable, nuclear, coal (with carbon capture and storage), and other low-carbon, domestic energy resources. This case study can become one of the feasible solutions.

- Significant reduction in fuel costs throughout
- Reduction in use of fossil fuels primarily coal and natural gas
- Significant reduction in pollution
- The set up cost of digester around a hydrogen production plant is high initially but will serve in the long run
- Biogas is cheaper than natural gas and coal
- Biogas is produced from waste materials and waste management can be done
- Broader applications of methane biogas include production of different chemical compounds from methane and hydrogen
- Cost of thermal energy storage devices and other applications involving direct use of hydrogen will decrease
- Fuel Cell Electric Vehicles (FCEVs) [2] can become cheaper and thus feasible
- These are all theoretical aspects which require more research for further implementation

References

[1]. Power Plant Engineering (3rd Ed) by P.K. Nag
[2]. http://www1.eere.energy.gov/hydrogenandfuelcells/production/natural_gas.html
[3]. http://large.stanford.edu/courses/2013/ph240/yoo2/
[4]. http://upload.wikimedia.org/wikipedia/commons/thumb/4/4c/FLOWCHART.JPG/500px-FLOWCHART.jpg
[5]. https://biogas.ifas.ufl.edu/FAQ.asp
[6]. http://www.sciencedaily.com/releases/2013/04/130408084900.htm
[7]. “Cost and Performance Analysis of Biomass-Based Integrated Gasification Combined-Cycle (BIGCC) Power Systems”, Kevin R. Craig, Margaret K. Mann, National Renewable Energy Laboratory, USA
[8]. http://en.wikipedia.org/wiki/Coal_gasification
[9]. http://en.wikipedia.org/wiki/Hydrogen_production
[10]. http://www.ika.rwthaachen.de/r2h/index.php/Deciding_to_form_a_Hydrogen_Community
[11]. http://www.lindeengineering.com/internet.global.lindeengineering.global/en/images/D01005_44319_4535.jpg
[12].]www.data:image/jpeg;base64.jpg
[13]. http://www.sierrainstruments.com/rep_news/wordpress/wpcontent/uploads/2013/09/Table-12.jpg