International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Global Clean Energy Revolution: A Review

Nidhi Badgotra
Bharghva college of Engineering and Technology, Samba, J&K, India-184121
Email address: nidhi.hep@gmail.com

***Abstract*—**Renewable energy is derives directly from the sun, or from heat generated deep within the earth. Included in the definition are electricity and heat generated from solar, wind, ocean, hydropower, bio-fuels and hydrogen derived from renewable resources. Currently, fossil fuels as the main energy source to fulfil world's energy demand is depleting very fast. Their waste products are also causing global environmental problems. So our environmental policy is demanding a reduction in greenhouse gases and toxic emissions. A coherent energy strategy is required, addressing both energy supply and demand as well as taking account of whole energy life cycle. One of the solutions is to replace the existing fossil fuel energy systems by the non-fossil fuel energy systems. Bio-fuel is one of the non-fossil fuel sources. Bio fuels are important because they replace petroleum fuels. Bio energy derived from bio-fuels like bio ethanol is by far the most widely used bio fuel for transportation. These bio fuels like biodiesel, isopropyl alcohol, ethanol, etc. is converted into electrical energy using a fuel cell. This review topic provides an introduction to biological fuel cells along with their applications. On the basis of the review suggest, the need of these sources and importance of their study in view of global warming.

***Keywords*—**Bio-fuels; fossil fuel; green houses gases; global warming.

I. Introduction

The following sections provide a review of areas of research in the main renewable-energy technologies, other advanced energy technologies (fuel cells), the development of hydrogen infrastructure and also supporting technologies, such as energy storage, which are necessary to allow grid integration of renewables. The number of people affected by energy shortage is likely to increase several folds, because of increasing global energy demands. For these reasons, many researchers have been working on the exploration of new sustainable energy sources that could substitute fossil fuels. Hydrogen is considered as a viable alternative fuel and "energy carrier" of future [1].For renewable energy generation, solar based hydrogen energy generation may be difficult during cloudy weather. Hence for uninterrupted energy supply, solar based systems should be supported by alternative mechanism of energy production. So, bio-fuel based systems may help towards this objective.

A. Bio energy

Bio energy is energy derived from bio fuels. And, bio fuels are produced from biomass resources. Biomass can be used to produce energy by:

- combustion gasification of biomass to produce electricity and/or heat;
- pyrolysis of fuels to produce electricity/heat and/or products such as oils;
- extraction or hydrolysis and fermentation to produce liquid bio fuels (bio ethanol and biodiesel) for the transport sector;
- anaerobic digestion to produce bio-gas, which can subsequently be burned to produce electricity and/or heat.

A variety of biomass feed stocks can be used, including:

- forestry residues (as a by-product of timber and pulp production);
- agricultural residues (e.g. straw from cereal production);
- agro processing residues (from crop processing);

It appears to have significant economic potential provided that fossil fuel prices increases in the future [2]. Overall, bioenergy has been utilized for cooking, heating, and lighting since the dawn of humans. The energy stored in annually produced biomass by terrestrial plants is 3–4 times greater than the current global energy demand. Biomass energy is a variety of chemical energy. This energy can be recovered by burning biomass as a fuel [3].

B. Bio-fuels

Bio fuels are gaseous, solid or liquid fuels that are produced from biomass (dry waste, cane sugar, wood pulp etc.) through combustion or fermentation. Solid bio fuels include firewood, wood chips, wood pellets, and wood charcoal. The global consumption of firewood and charcoal has been remaining relatively constant, but the use of wood chips and wood pellets for electricity (bio power) generation and residential heating doubled in the past decade and will increase steadily into the future. Liquid bio fuels cover bio ethanol, biodiesel, pyrolysis bio-oil, and drop-in transportation fuels. Biodiesel from oil seeds reached the 5670 million gallons/yr. production capacity, with further increases depending on new feedstock development. Bio-oil and drop-in bio fuels are still in the development stage, facing cost-effective conversion and upgrading challenges Bio-fuels that have been identified as potential fuel for fuel cells are landfill gas, anaerobic digester gas, biomass gasification, bio diesel, and ethanol etc.

Conventional combustion technology is expensive and has limited development potential for biomass electricity. However, advanced technologies that convert the biomass to gas or liquid before combustion show the potential for lower overall costs. In the short term, co-utilisation with fossil fuels in an existing boiler is potentially the lowest-cost option, though it is limited to areas with existing coal plant. Technologies are mature, with major challenges being of an

Nidhi Badgotra, "Global clean energy revolution: a review", *Journal of Scientific and Technical Advancements*, Volume 1, Issue 3, pp. 199-202, 2015.

engineering nature in process/plant design and cost reduction (particularly for gasification and pyrolysis). For renewable energy generation, solar based hydrogen energy generation may be difficult during cloudy weather. Hence for uninterrupted energy supply, solar based systems should be supported by alternative mechanism of energy production. So, bio-fuel based systems may help towards this objective. In micro scale power generation is to scale down electrochemical devices such as batteries and fuel cells where fuel cells directly convert chemical energy into electrical energy [4]. A prototype system relying on short term storage require hydrogen path-consisting of electrolyser, hydrogen tank, and a fuel cell [5]. And there are no barriers to the introduction of hydrogen and fuel cells either from a technological perspective or from a safety point [6]. Bio-fuel can be useful during cloudy weather to demonstrate the functions of renewable fuel cell for electricity production. Bio energy can also be derived from bio-fuels like bio-ethanol, isopropyl alcohol and biodiesel, etc. Isopropyl alcohol is an aliphatic alcohol and miscible in water so that according to Fig. 1, electrical energy generation from isopropyl alcohol bio-fuel may be used to energize small DC load in a short period of time to run different appliances.

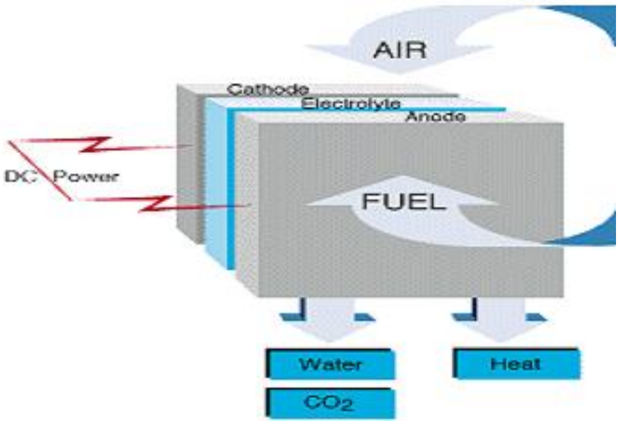

Fig. 1. Bio-fuel based energy production.

And, these new concepts also increase the fuel economy as they avoid burning a part of bio-ethanol, bio-diesel, etc., for producing the reforming reaction. It allows testing of an energy management strategy to best satisfy the power demand. No other energy generating technology holds the combination of benefits that fuel cells offer. Some of the benefits are as follows.

- High energy security due to abundant of fuel source availability
- High supply security due to efficient, modular, and fuel flexible structure
- Physical security due to evenly distributed resources in nature
- High reliability
- High quality power and high efficiency (85%)
- Environmental friendly.

Thus bio-fuel based fuel cell system is a good candidate for future usages for generating renewable energy [7].

C. *Fuel cells*

Fuel cells are electrochemical devices, similar in principle to primary batteries that convert the energy of a chemical reaction directly into electricity, with heat and water as byproducts (figure 2). They are different from batteries in that the fuel and oxidant (oxygen or air) are stored externally, enabling them to continue operating for as long as fuel and oxidant are supplied. In the short to medium term (2015–2030) fuel cells are likely to use fossil fuels such as natural gas, coal, gasoline and methanol, but in the long term they may use hydrogen and bio fuels. These fuels would produce no CO2 emissions at the point of use and, although there would be CO2 emissions associated with hydrogen production from fossil fuels, these could be sequestered, or hydrogen could be produced using “carbon-free energy sources” (i.e. renewables or nuclear power). Fuel cells offer higher efficiencies than conventional thermal combustion technologies, operate quietly and cleanly (giving localised air-quality benefits compared with conventional combustion engines) and have a modular construction that is easily scalable [8]. These features mean that fuel cells are attractive for a range of potential applications, including combined heat and power (CHP), distributed power generation and transport.

A renewable fuel cell is unique because it can act as both an electrolyser and an electrical power source. When applying an electric current, the device acts as an electrolyser that produces hydrogen and oxygen from de-ionized water. When applying a load, the electrolyser becomes an electrical power source. Polymer electrolyte membrane fuel cellsoperate at relatively low temperatures, around 80°C (176 F).Low temperature operation allows them to start quickly (less warm-up time) and results in less wear on system components, resulting in better durability. Fuel cells are also attracting interest for providing portable power for laptop computers, mobile telephones, etc. The different fuel-cell technologies all face similar development challenges [9].

Fuel-cell performance depends fundamentally on the electrochemical reactions that occur within the core fuel cell stack. Fuel-cell systems are complex and currently costly, because of the expensive materials required for catalysts, electrodes and membranes, and because of the numerous peripheral devices required. Key areas of Research and Development are:

- Solid-state properties (including electrical properties) of materials;
- new materials for membranes, catalysts and other components (e.g. specialised substrates, ceramics);
- Physical forces, mechanical forces, micromechanical properties and particle technology;
- modelling of mass and heat transfer;
- Scale-up of fuel-cell stacks and systems.

Nidhi Badgotra, “Global clean energy revolution: a review”, *Journal of Scientific and Technical Advancements*, Volume 1, Issue 3, pp. 199-202, 2015.

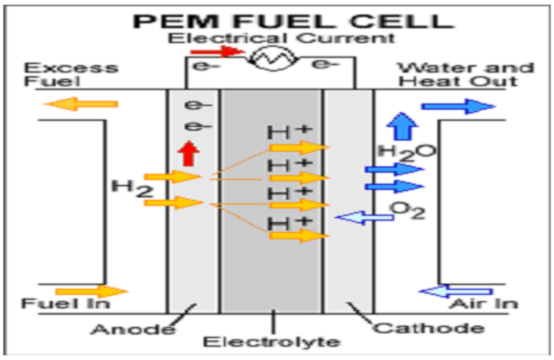

Fig. 2. Schematic of a proton exchange membrane fuel cell. Source: US Department of energy efficiency and renewable energy website: http://www. eere.energy.gov/ hydrogenandfuelcells/ fuel cells/fc_types.html.

Hydrogen infrastructure

Hydrogen is not a primary fuel but it can be used as an energy carrier, with the advantage that it has no emissions of CO2 or other pollutants at the point of use. Whether there are CO2 emissions at the point of production depends on the method used (box 3.7). Hydrogen is widely considered to be an essential part of a low-carbon future because of its potential role (in conjunction with fuel cells) in the transport sector.

1) Polymer Electrolyte Membrane Fuel Cells

Polymer Electrolyte Membrane (PEM) fuel cells also called proton exchange membrane fuel deliver high power density and offer the advantages of low weight and volume compared with other fuel cells PEM fuel cells are the good candidates for small-scale distributed stationary power generation [10]. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. They need only hydrogen, oxygen from the air, and water to operate and do not require corrosive fluids like. They are typically filled with pure hydrogen supplied from storage tanks or on-board reformers PEM fuel cell uses a thin, permeable polymeric membrane as the electrolyte as shown in Fig. 2. The membrane is very small and light and in order to catalyse the reaction, platinum electrodes are used on either side of the membrane. Within the PEM fuel cell unit, hydrogen molecules are supplied at the anode and split in to hydrogen protons and electrons. The protons pass across the polymeric membrane to the cathode while the electrons are pushed round an external circuit in order to produce electricity. Oxygen (in the form of air) is supplied to the cathode and combines with the hydrogen ions to produce water. Compare to other electrolytes which require temperatures up to 10000°C to operate effectively. PEM fuel cells operate at very low temperatures of about 800°C allowing rapid start-up. The efficiency of a PEM unit usually reaches between 40 to 60% and the output of the system can be varied to meet shifting demand patterns. Typical electric power is up to 250 kilowatts. Generally, there are three main application fields for PEM fuel cells such as transportation, stationary, and portable applications. The development direction of PEM fuel cells in each nation is bound up with their social and industrial environment as well as their structure of energy supply and demand .

There are also some disadvantages associated with PEM operation. Although the low operating temperature of the unit is usually seen as an advantage, in some instances temperatures as low as 800°C are not high enough to perform useful cogeneration. Furthermore, in order to achieve the most effective operation of the unit, the electrolyte must be saturated with water. Control of the moisture of the anode and cathode streams therefore becomes an important consideration. Jang Ho. Wee et.al introduced and discussed the challenges and some of the latest research on the application test of PEMFC to real systems such as transportation, residential power generation and portable computers [11]. Thounthong et.al presented the utilization as a super capacitor as auxiliary power source in a distributed generation system, composed of a polymer electrolyte membrane Fuel cell (PEMFC) as the main energy source[12].

Hydrogen storage

Established methods of hydrogen storage are compression, adsorption in metal hydrides, and liquefaction (box 3.8) [13]. Disadvantages of liquefaction and compression are the energy requirement (up to 30% of the energy in the hydrogen) and significant safety concerns.

Box 3.6: Fuel cell types

- *Polymer Electrolyte or Proton Exchange Membrane Fuel Cells (PEMFCs)* operating at 100–120 °C and fuelled by hydrogen are being developed for transport, stationary and portable power applications. Transport applications include fuel-cell engines to drive cars and buses, and auxiliary power units (APUs) powering the electronics on a vehicle.
- *Direct Methanol Fuel Cells (DMFCs)* are similar to PEMFCs, except that they operate directly on methanol without the need to reform it to hydrogen first. DMFCs are at an earlier stage of development but may offer advantages in transport and portable applications where the weight and volume of systems is important.
- *Molten Carbonate Fuel Cells (MCFCs)* operating at about 650 °C are being developed for combined heat and power (CHP) and distributed generation applications. They are typically fuelled by natural gas although there is also some research being undertaken into biogas systems.
- *Solid Oxide Fuel Cells (SOFCs)* are also being developed for CHP and distributed generation applications, where their high temperature operation (800–1000 °C) gives the opportunity of combination with gas turbines to give very high electrical efficiencies of up to 70%. A lower-temperature version of the SOFCs operating at 650–750 °C is being developed for vehicle APUs and stationary power applications. There is currently little interest in Europe in operating MCFs or SOFs on coal gas, unlike the situation in the US.

There are also a number of Phosphoric Acid Fuel Cell demonstration plants and some research activity on Alkaline Fuel Cells.

R&D priorities are the development of new materials and systems to enhance the efficiency of storage and to reduce costs. A new method, still at an early stage of development, is

Nidhi Badgotra, “Global clean energy revolution: a review”, *Journal of Scientific and Technical Advancements*, Volume 1, Issue 3, pp. 199-202, 2015.

a solid-state storage solution in which hydrogen is reversibly chemisorbed (at near-ambient pressures and temperatures) into a lightweight material with a large specific surface area like activated or nanostructured carbon and carbon nanotubes, or nonporous materials such as zeolites (box 3.9) [7]. The best materials currently have a hydrogen storage density of 150 kg·m–3), but theoretically this can be improved by 50%.

Box 3.7: Hydrogen production methods

- *Reforming of carbonaceous gases (e.g. natural gas):* This is a mature technology. CO_2 is produced during this process.
- *Electrolysis of water:* New steam electrolysis systems that reach higher total energy efficiency compared with existing alkali and proton exchange membrane electrolysis are being developed. Their main advantage is that a substantial part of the process energy is added as heat, which is much cheaper than electric energy. R&D for these systems includes thermodynamic systems modelling and materials development (including catalysts). If electricity from renewables or nuclear sources is used for electrolysis then there are no associated CO_2 emissions.
- *Biological production:* Several types of algae and bacteria can also produce hydrogen by photosynthesis or by fermentation. Particularly interesting possible applications include use in sewage treatment works. Biological methods based on these are generally, however, still at relatively early R&D stages.
- *Photoelectrolysis:* This is another prospective technology for hydrogen production, still at the early stages of R&D, and it involves the use of a solar cell to split water directly, without the use of electricity.

II. Conclusion

The world’s energy systems, markets, and values “are rapidly changing in response to climate disruption — and those mitigation efforts may be starting to move the needle.” That's the top conclusion of the first of a pair of annual Clean Energy Canada assessments, released last month.

The report authors urge Canadian policy makers to treat clean energy as a trade priority, collaborate with leaders such as the United States, China, and India, and play a constructive role at December’s Paris climate summit. From Tesla’s Gigafactory, to the surge in wind and solar, to a clean energy economy that is growing while carbon pollution stabilizes, the top 10 trends offer a snapshot of a revolution in progress. And PEM fuel cell provides appreciable stable voltage over time. During cloudy weather, solar based electricity generation system supplies low output power. So in order to maintain uninterrupted energy supply the bio fuel cell system may be attached to solar system.

References

[1] K. Kapdan and F. Kargi, “Bio-hydrogen production from waste materials- A Review,” *Enzyme and Microbial Technology*, vol. 38, pp. 569-582, 2006.
[2] M. Balat and H. Balat “Recent trends in global production and utilization of bio-ethanol fuel,” *Applied energy*, pp. 2273-2282, 2009.
[3] A. Demirbas, “Biodiesel, A realistic fuel alternative for diesel engines,” *Professor of Energy Technology*, Springer, pp. 111-119, 2008.
[4] N. T. Nguyen and S. H. Chan, “Micro machined polymer electrolyte membrane and direct methanol fuel cells,” School of Mechanical AND Aerospace Engineering, Nanyang Technological University, Singapore, pp. R1-R12, 2006.
[5] J. Wingens, G. Krost, D. Ostermann, and U. Damm and J. Hess, “Applications of photo-electrochemical hydrogen production for autonomous solar based electricity supply,” *DRPT*, Nanjing China, pp. 2470-247, 2008.
[6] D. Santoso, F. D. Setiaji, and D. Susilo,“Demonstration of renewable electrical energy generation based on solar-hydrogen fuel cell technology,” *International Conference on Instrumentation, Communication, Information Technology and Biomedical Engineering*, Bandung, Indonesia, pp. 1-6, 2011.
[7] Food and Agricultural Policy Research Institute, University of Missouri Report No. 07-09 (September 2009); Renewable Identification Number Markets.
[8] K. Rabaey, G. Lissens, S. D. Siciliano, and W. Verstraete, “A microbial fuel cell capable of converting glucose to electricity at high rate and efficiency,” *Biotechnology letters*, vol. 25, pp. 1531-1535, 2003.
[9] A. Demirbas, “Biodiesel, A realistic fuel alternative for diesel engines,” *Sila Science and Energy*, Trabzon, Turkey, pp. i-viii, 1-208, 2008.
[10] N. Nguyen and S.H. Chan, “Micro machined polymer electrolyte membrane and direct methanol fuel cells,” *Journal of Micromechanics and Micro Engineering*, pp. R1-R12, 2006.
[11] J. H. Wee, “Applications of proton exchange membrane fuel cell systems,” Renewable and sustainable energy reviews, 2007, pp. 1720-1738.
[12] P. Thounthong, S. Rael, and B. Davat, “Analysis of super capacitor as second source based on fuel cell power generation,” *IEEE Transactions on Energy Conversion*, vol. 24, pp. 247-255, 2009.
[13] “Investigation on storage technologies for intermittent renewable energies: evaluation and recommended R&D strategy, Investire-Network, Storage Technology Report ST5: electrolyser, hydrogen storage and fuel cell” June 2003. Report produced for the European Commission under the 5th Framework Programme.
[14] Züttel, “Materials for hydrogen storage,” Materials Today, 2003.

Nidhi Badgotra, “Global clean energy revolution: a review”, *Journal of Scientific and Technical Advancements*, Volume 1, Issue 3, pp. 199-202, 2015.