Hydrogen Economy Challenges And Opportunities: A Review

Abstract.

Hydrogen is the most abundant element in the universe. When used as a fuel hydrogen produces clean energy and water (H2O). The Hydrogen economy is considered as a sunrise industry which would help to achieve as many goals. Such as reducing energy consumption and emissions, also stimulating economic growth. Hydrogen economy is also the long term goal of many nations, which can potentially provide energy security, and environmental and economic benefits. However, the transition from a conventional petroleum-based energy system to a hydrogen economy involves many uncertainties.. The work done here is going to give a review about the challenges and opportunities of the hydrogen economy also it is going to give the recent trends and emerging application of hydrogen as a fuel. Since, Hydrogen holds out the promise of a genuinely sustainable global energy future. Also hydrogen is a clean energy carrier that can be produced from any primary energy source. By considering the wide range of applications and researches going on, Hydrogen could prove to be the answer to our growing concerns about energy security, urban pollution and climate change.

Introduction

The potential of hydrogen as an energy carrier has been known for approximately two centuries. One of the early internal combustion engines, developed by Isaac de Rivaz in 1805, was fueled by hydrogen. Approximately 90 years later the German inventor Rudolf Diesel invented and perfected the diesel engine that was fueled by pulverized coal (carbon and hydrogen). The futurist Jules Verne (1874) projected his vision of hydrogen as an energy carrier in the book “L’lle Mysterieuse” (Dixon, 2007). Approximately 80% of the present world energy demand comes from fossil fuels (Das, 2001). Unlike fossil fuels, hydrogen gas (H2) burns cleanly, without emitting any environmental pollutants (Field, 2003)

At present, a large portion (about 65%) of the world energy demand is met by the liquid and gaseous fossil fuels (i.e., petroleum and natural gas), the potential of hydrogen as an energy carrier has been known for approximately two centuries. A century after Jules Verne published his book a growing number of developed and developing countries have committed to accelerate the evaluation of hydrogen energy economy as a potential solution to energy, economic and environmental security (Ogden, 2004), cause of their widespread availability and convenience of use.

Hydrogen economy offers several advantages over traditional energy systems (Rifkin, 2003).Concerns regarding national security, emissions Of greenhouse gases, ?nite sources of fossil fuels, and environmental quality are partially or wholly resolved if hydrogen energy systems are employed. Hydrogen fuel is renewable and therefore potential production is theoretically limitless (Caldeira & Jain, 2003,). It can be derived from multiple feedstocks, which fosters fuel versatility, including fossil fuels, biomass, and water (Turner, 2004). Hydrogen is also a product of the nuclear energy industry (Grant, 2003). End-use technologies that employ

hydrogen, such as fuel cells and combustion engines, have a safety record that advances protection of the environment and public health. The use of hydrogen as an energy carrier has many implications and offers opportunities to solve traditional challenges in the conventional transport sector (Cho, 2004).

This review is focus about challenges and opportunities hydrogen economy and also it tells about the recent trends and emerging applications of hydrogen as a fuel.

Hydrogen the Energy Carrier: Current Status

Hydrogen was first observed and collected long before, it was identified as a unique gas by Robert Boyle in 1671. Hydrogen is the first element in the periodic table with one proton and one electron in its atomic structure. Hydrogen is the simplest element, an atom consisting of only one proton and one electron. It is also the most plentiful element in the universe (Magdalena Momirlana, 2005). In normal conditions it is a colourless, odourless, insipid gas formed by diatomic molecules H2. its atomic number is 1and its atomic weight is 1.00797 g/mol. It is one of the main compound of water and all inorganic matter on earth. And also, it's not only present in the earth but also its is one of the most abundant element in the entire universe. There are three isotopes for hydrogen, among these, protium which found about more than 99.985% of the natural element, deuterium found in nature about 0.015% approximately. Third one is tritium which appears in small quantities in nature. Unlike conventional petroleum and natural gas derivatives it has very small and light molecular structure. hydrogen is an excellent fuel because of many reasons, which is exceptionally clean, lighter than air, can easily produced from many different sources and it is carbon free source. That is Hydrogen is high in energy, an engine which burns pure hydrogen produces almost no pollution. Hydrogen is a colourless, odourless gas that accounts for 75% of the universe mass. And also Hydrogen is found on Earth only in combination with other elements such as oxygen, carbon and nitrogen. To use hydrogen as a fuel, it must be separated from these other elements. (Magdalena Momirlana, 2005)

Currently, the main source of hydrogen production is entirely based on the fossil fuels. It can be presented as a commercial mature technology which it can be applied at low costs and get high efficiencies (Sema, 2018,) Hydrogen can be produced using a number of different processes. Thermochemical processes use heat and chemical reactions to release hydrogen from organic materials such as fossil fuels and biomass. Water (H2O) can be split into hydrogen (H2) and oxygen (O2) using electrolysis or solar energy. Microorganisms such as bacteria and algae can produce hydrogen through biological processes (Department of energy, US).There are several production methods available because of versatile hydrogen sources available in nature. Renewable feed stocks such as wind, solar, biomass, hydro and geothermal, are likewise environmentally friendly hydrogen sources, whose use has greatly increased. Fortunately, renewable hydrogen feed stocks are abound. They are found in most parts of the world, ensuring domestic sources of hydrogen production (Oystein Ulleberg, 2016). Today hydrogen is primarily produced from natural gas (48%), liquid hydrocarbon(30%), coal(18%) and electrolysis of water(4%),(Sperling D., 2004). It can also be produced through the conversion of fuel gas produced by biological or thermal processes, but this option is under development and is not economic (Vogel, 2004). In the future, hydrogen could be produced from water and sunlight via direct photobiological, photochemical, or photoelectrochemical means (Turner, 2004)

Today, hydrogen is used in the refining industry as a petrochemical for hydro-cracking and desulphurization. Almost all the hydrogen produced in the world today is from steam reforming of fossil fuels using a nickel catalyst. At present, this is a commercially accepted and proven technology and is by far the cheapest way of making hydrogen on a large scale. That may remain the same in future also. In the chemical industry, it is used for ammonia production and fertilizer for agriculture. It is also used for applications in the metal production & fabrication, methanol production, food processing and electronics sectors (Global Hydrogen Generation Market, 2011-2016). Recent report by IEA G20 report in 2019 says that, Demand for hydrogen, which has grown more than threefold since 1975. Demand for hydrogen in its pure form is around 70 million tonnes per year (MtH2/yr). This hydrogen is almost entirely supplied from fossil fuels, with 6% of global natural gas and 2% of global coal going to hydrogen production. This hydrogen is currently produced from fossil fuels, with significant associated CO2 emissions. The economic growth of modern industrialized society has been based on the utilization of energy based on fossil fuels. At the present time, about 80 per cent of the world energy demand is met by fossil fuels coal, petroleum and natural gas (T. Nejat Veziroglu, 1998) The main constituents of fossil fuels are carbon and hydrogen, and also other ingredients, which are originally in the fuel such as sulphur, or which are added during refining that is lead or alcohols. Combustion of the fossil fuels produces various gases such as oxides of carbon, oxides of nitrogen, oxides of sulphur and hydrocarbons, soot and ash, droplets of tar, and other organic compounds, which are all released into the atmosphere and cause pollution. The amount of these pollutants to the atmosphere increases with the increased uses of fuels which are of fossil origin. Here emerges need for the transition from convenient but ultimately scarce energy resources to less convenient but more abundant energy source.

Hydrogen Economy and Its Opportunities

Hydrogen Energy System or Hydrogen Economy is a global energy system in which hydrogen is produced from available energy sources and used in every application where fossil fuels are being played a large role in transportation, residential, commercial and industrial sectors, and for electricity generation (T. Nejat Veziroglu, 1998).The first vision of the energy system based on hydrogen was mentioned by science fiction writer and visionary Jules Verne in his novel The Mysterious Island. In 1923 Haldane predicted that hydrogen -derived from wind power via electrolysis, liquefied and stored - would be the fuel of the future. This view was repeated in more technical detail, some 15 years later, by Sikorski, who realized hydrogen's potential as aviation fuel. He predicted that the introduction of hydrogen would bring about a profound transformation of aeronautics. Lawaczek in the early 1920s outlined the concepts for hydrogen-powered cars, trains and engines, collaborated in developing an efficient pressurized electrolyser, and was probably the first to suggest that energy could be transported via hydrogen-carrying pipelines, similar to natural gas. After that several findings and researches where occurred which include several suggestions and modifications and finally reached to the modern world technologies.

George W Crabtree and his colleges define hydrogen economy as a network of primary energy sources linked to multiple end uses through hydrogen as an energy carrier. Hydrogen adds flexibility to energy production and use by linking naturally with fossil, nuclear, renewable and electrical energy forms, any of these sources can be used to make hydrogen. Or simply we can say that, Hydrogen holds the potential to provide energy services to all sectors of the economy such as transportation, buildings and industry. Hydrogen can replace major energy carriers such

as electricity and many others. It would also helps to provide attractive energy options into several remote sensitive areas, where conventional electricity can’t be reached. The fundamental attraction of hydrogen is its potential environmental advantages over fossil fuels. At the point of use, hydrogen can be burned in such a way as to produce no harmful emissions. If hydrogen is produced without emitting any carbon dioxide or other climate destabilizing greenhouse gases, it could form the basis of a truly sustainable energy system the hydrogen economy, says recent studies United Nations Environment Programs. The opportunities of hydrogen economy is versatile, these fundamental attraction towards hydrogen is mainly relaid on its environmental advantages over fossil fuels. An analysis by Demirdoven and its colleges suggests that fuel cell vehicles using hydrogen derived from fossil fuels offer no signi?cant efficiencies over hybrid vehicles. In the long-term hydrogen produced renewable energy sources may signi?cantly change this equation. If we replace fossil fuels using hydrogen it would bring several environmental benefits. But the production methods of hydrogen could be emission-free if the feedstock or the energy is from renewable or nuclear sources.

The major advantage of a hydrogen economy would be in the transportation and energy section. Because of growing pollutions from road traffic and vehicles. Replacing internal combustion engines fuelled by gasoline or diesel with hydrogen-powered fuel cells would eliminate pollution from road vehicles. The key feature behind is the electrolysis process with hydrogen and oxygen as the only products. Fuel cells are the key enabling technology for a future hydrogen economy and have the potential to revolutionize the way we power our nations, offering cleaner, more efficient alternatives to today's technology. Additionally, fuel cells are significantly more energy efficient than combustion-based power generation technologies (Steven G. Chalk, 2006). Hydrogen-powered vehicles are zero emission devices at the point of use, with consequential local air quality benefits. Hydrogen-powered fuel cells could contribute to reducing or eliminating emissions of CO2 and other greenhouse gases from road transportation vehicles (Sonal Singh, 2015), The potential of hydrogen to be used in the transport sector is vast provided the right methods and pathways are taken to make it safe, trustworthy and clean.

Hydrogen Economy Challenges

When we focus on hydrogen economy and its future, there are several other factors need to be addressed, those are summarized in this title challenges. As we said, hydrogen is the most abundant and cleanest source of energy. But it is the most difficult source of energy to store and transport in the form of pure hydrogen fuel. The two most important challenges for hydrogen fuel cells are cost and durability. When we use it in automotive fuel cell systems. It will also be required to be as durable and reliable as current automotive engines (Steven G. Chalk, 2006).A critical obstacle to the hydrogen economy is the efficient and clean production of hydrogen. As an energy carrier, hydrogen has to be manufactured from a primary energy source. There are many industrial methods currently available for the production of hydrogen, but all of them are expensive compared with the cost of conventional forms of energy or we can say that it is several times more expensive compared with fossil fuels. The distribution and storage systems that would be needed to supply hydrogen on a large scale are also much more expensive because of the low volumetric energy density of the fuel. Bringing production, distribution and storage costs down sufficiently to make hydrogen a viable competitor to existing fuels will require important technological advances. According to IEA G20 report 2019, if hydrogen is produced, its widespread use will require large scale infrastructure to transport, distribute, store

and dispense it as a fuel for vehicles or for stationary uses. Because of its low volumetric energy density, since hydrogen is the most dangerous gas when it is taken its pure form, it must be compressed and stored in a pressurized container or chilled and stored in a cryogenic liquid hydrogen tank. Both techniques are in commercial use today, but they use significant amounts of energy and the tanks are expensive to manufacture and maintain. Hydrogen storage as other forms of states such as solid needs further studies. Because there also comes uncertainties in storage and transportation methods.

Conclusions

Formidable technical and cost challenges will need to be overcome for hydrogen to be able to compete with, and eventually replace, existing energy technologies. The biggest advances are needed in transportation and storage of the fuel, as well as in fuel cells vehicles. But recent advances in technology and a surge in public and private spending on research, development and demonstration suggest that the requisite technical and cost breakthroughs might be achievable within a generation. So that we can say that under proper method for implementation and supports for the research and development would help to bring energy-efficient and clean world in the future.

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