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A Review on Concept of Hydrogen Fuel in Transportation

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ABSTRACT:The lightest and most abundant element in the universe is hydrogen, and it is an energy carrier. It can be produced using different methods from multiple sources and shipped to the fuelling station, or it can even be produced at the fuelling station.Water electrolysis or reforming of hydrocarbons such as natural gas will produce hydrogen in a large plant or even at the fuelling station. But when generated using renewable energy, such as wind, solar, geothermal, or hydroelectric, it has zero emissions.Hydrogen-powered vehicles either burn hydrogen in an internal combustion engine, or in a fuel cell react with oxygen.The idea of hydrogen highway is essentially to build a chain of hydrogen-equipped fuelling stations and other facilities along the city road or highway that will enable hydrogen powered cars to drive.More extensive hydrogen delivery facilities would include the use of high-pressure compressors for gaseous hydrogen and cryogenic hydrogen liquefaction systems.Hydrogen can be generated on site, transported by road via cylinders, cryogenic tankers, tube trailers, and in pipeline. Each of these modes of delivery and production requires a considerably different design of the fuelling station.Proton exchange membrane fuel cells (PEMFCs) can be considered as they are electrochemical devices that can produce electricity directly from hydrogen and oxygen without combustion, making the process clean and non-polluting.

KEYWORDS:Consumption, Fuelling Station, Hydrogen, Hydrogen Dispensing, PEMFCS, Storage.

INTRODUCTION

The increasing exposure to climate change and air pollution associated with emissions from the extraction of fossil fuels, combined with their depletion, and driven both academia and industry to look for alternative energies and renewable energy sources to mitigate the effects of harmful emissions.Proton exchange membrane fuel cells (PEMFCs) can be considered as they are electrochemical devices that can produce electricity directly from hydrogen and oxygen without combustion, making the process clean and non-polluting[1].PEMFCs have many advantages, such as compactness, low operating temperatures, continuous operation at high current density, quick start-up and sporadic operation suitability.Due to their ability to transform the chemical energy of a fuel (hydrogen) directly into electrical energy with relatively high performance, their adaptable size and low operating temperature, PEMFCs have been particularly attractive for power production in both automotive and stationary application.PEMFCs are a viable solution for electricity, as they have zero greenhouse gas emissions. Nevertheless, the main drawbacks negatively affecting their complete marketing are represented by fuel crossover, high membrane costs, and anodic catalyst poisoning caused mainly by Cox[2].PEMFC supply implements hydrogen purification currently taking place in second-stage processes, including water gas shift (WGS) reactions conducted in two series reactors at high and low temperatures, partial oxidation (PROX), and pressure swing adsorption (PSA) reactions.In addition to further stages of hydrogen purification devices, membrane reactor (MR) technology plays an important role as an alternative solution to conventional reactors (CRs) in terms of the combination in a single stage of the

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hydrogen generation reforming reaction and its purification without the need for further processing[3].

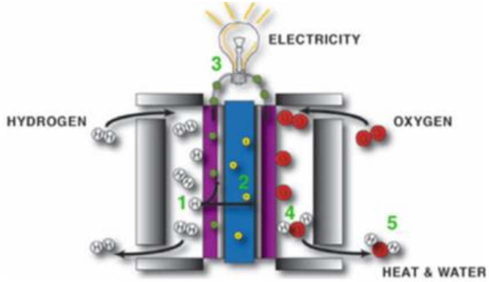

Figure 1: Schematic of a Proton Exchange Membrane Fuel Cell

SYSTEM DESCRIPTION

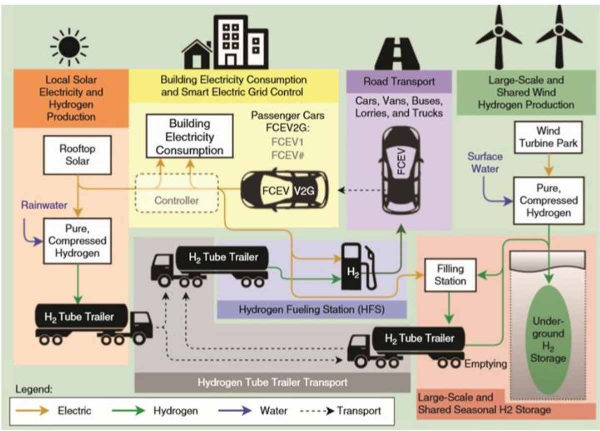

Figure 2: Hydrogen-Based Integrated Energy and Transport System

Figure 2 illustrates the smart city energy system and key components. Hydrogen is produced from local solar surplus energy and shared, large-scale wind energy within urban areas.Hydrogen is transported from urban areas via tube trailers to hydrogen fuelling stations, to other hydrogen hubs/consumers, or to seasonal hydrogen storage reservoirs on a large and shared underground[4]. The whole system consists of seven major elements:

1. *Local Solar and Hydrogen Generation:*local rooftop solar and rainwater capture, purification and storage systems produce solar and pure water for both building use and hydrogen production.
2. *Building Electricity Consumption and Smart Electric Grid Control:*the smart electric grid is controlled by a controller linking all buildings, hydrogen fuelling stations, solar and hydrogen output, grid-connected FCEVs, and the seasonal hydrogen storage tube trailer filling station. Any electricity shortfall is addressed by the hydrogen-generated electricity (FCEV2 G) through the fuel cell EVS parked and linked by vehicle to grid (V2 G).
3. *Hydrogen Tube Trailers:*tube trailers pulled by tube trailers carry hydrogen either from the local solar hydrogen production site or from the seasonal hydrogen storage to the hydrogen fuel station or from the local solar hydrogen production site to the seasonal hydrogen storage.
4. *Hydrogen Fuelling Stations*
5. *Road Transport:*Road transport fleet FCEVs including passenger cars, vans, buses or trucks.
6. *Large-Scale and Shared Wind Hydrogen Production:*Broad-scale off-site wind turbine parks are shared with other smart city areas and renewable hydrogen centres or centres. Both wind energy is used for the manufacture of hydrogen with purified water, which is held in broad seasonal hydrogen storage.
7. *Large-Scale and Shared Seasonal Hydrogen Storage*[5].

Modelling the Hydrogen-Based Integrated Energy and Transport System

Figure 3 displays the system's condensed simulation scheme and is composed of an hourly and annual energy balance. Next, the hourly equilibrium between electricity and hydrogen must be achieved; either by converting excess electricity into hydrogen or by converting stored hydrogen into electricity.The net hydrogen consumed from the seasonal storage of hydrogen in underground salt caverns needs to be nil on an annual basis. The hourly simulation is done for the whole year 2014 to size the components of the system in such a way that there is no electricity curtailment[5].

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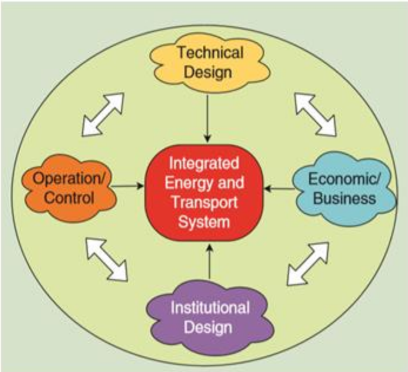

Figure 3: Analysis Framework for the design of the Future Smart City Area

HYDROGEN STORAGE

Hydrogen has very low density and hydrogen liquefaction energy requirements are high, so effective hydrogen storage is generally regarded as the most difficult hydrogen technology issues.Storage issues are not so important for current chemical applications, because the large hydrogen producers both generate and consume the gas on site simultaneously, thereby reducing storage requirements.But it is one of the significant issues of concern in the hydrogen technology[6].

1. Compressed Storage System:

The hydrogen storage challenges relate to transport applications in which restrictions on the size, weight, capacity, and performance of hydrogen vehicles limit the amount of gas that can be stored on-board. Approximately 4 to 10 kilograms of hydrogen are needed to power a 300-mile light duty vehicle, which is within consumersdriving range.Hydrogen refuelling stations may also include storage systems of small to medium size consistent with the footprint of existing gasoline or CNG stations.Many small-scale storage options are currently under development in the United States and some EU countries, and even in China, but there are many drawbacks to each.Compressed gas is currently the most preferred method for on-board storage system, but very high storage pressures of between 5,000 and 10,000 psi or 350 to 700 bars are required to contain sufficient fuel driving range.It is relatively expensive, and in the event of an accident, the high operational costs raise safety concerns. In addition to this, the energy used to compress the gas is important[7].

2. Liquid Hydrogen Storage:

Liquid hydrogen has the highest energy storage density and the lowest vehicle weight but it also requires an expensive, insulated storage container and a process of energy-intensive liquefaction.Several concept vehicles with liquid hydrogen storage are developed and put in service in the USA and Europe.The cost of this storage system is very high, and if there is no active refrigeration device in the storage system, approximately 2% of the hydrogen has to be vented daily.Depending on whether the fuel is used in a hydrogen internal combustion engine (HICE) or a fuel cell vehicle (FCV), the volume capacity required for the liquid hydrogen will vary considerably.Since liquid hydrogen has about 26 per cent the energy of a gallon of gasoline on a volume basis, the liquid hydrogen tank must have 3.8 times the capacity of a gasoline tank to carry the same amount of energy[8].

3. Other Storage Methods:

Other specialized methods for storage include metallic and chemical hydrides, amides, alanate storage systems and carbon nanotubes as well. Solid metal and chemical systems provide some innovative storage solutions for hydrogen but their weight and slow response times during refuelling are the main challenges now.Another concept with the potential for very lightweight hydrogen storage is the interstitial storage of hydrogen in carbon nanotubes but R&D is still in the early stages. Several other storage systems and mechanisms like sponge iron and glass microspheres can be promising[9].

4. Hydrogen Dispensing or Fuelling Station:

The key component of a hydrogen-based transport infrastructure is the hydrogen fuelling station. Several similarities in the design of stations, costs vary significantly depending on the type and size of station.Many stations need the following facilities, such as safety equipment, mechanical and electrical equipment, hydrogen purification system, storage and dispensing systems, compressor and hydrogen production equipment where hydrogen is manufactured on site.Fuelling station operating expenses include: installation and maintenance of equipment, station operator work, hydrogen costs, insurance, rent, etc. Including all of these capitals and operating costs is strategically important when determining cost of producing hydrogen.Total construction costs for the station also include design, permit, installation, commissioning, site preparation and security.Fuelling stations can be designed to produce on-site hydrogen, or to deliver hydrogen fuel through pipeline or truck from centralized production plants in gaseous or liquid form.The long experience of the present gas industry focused on truck or pipeline delivery system, where the cost of the feedstock for the production of hydrogen will be one of the dominant factors.Capital and operating costs are key variables once again for on-site manufacturing and dispensing. The benefit of small-scale electrolyser stations is that they are able to use renewable energy for the production of hydrogen.However, the main benefit to and from this development relies on the increased end users of hydrogen, irrespective of the specific hydrogen fuelling station, supply, and production systems[10].

CONCLUSION

Hydrogen has the ability to decrease our reliance on fossil fuel and the long-term impacts of energy and the atmosphere, but this technology now seems very costly to introduce.Hydrogen fuel and technology will help to reduce the dependence on petroleum in our transportation sector, improve the reliability of our electricity generation system and deliver very significant environmental benefits.The degree of benefits that can be achieved within a given timeframe ultimately depends on the market penetration of hydrogen-powered vehicles and energy technologies.Localized as well as regional impact assessments from end-use hydrogen production pathways are needed to ensure no negative external impacts to local communities.Production of proton-exchange membrane fuel cell grade hydrogen from renewable energy development processes such as ethanol and methanol using membrane reactor technology. Proton exchange membrane fuel cells (PEMFCs) can be considered as they are electrochemical devices that can produce electricity directly from hydrogen and oxygen without combustion, making the process clean and non-polluting.PEMFCs have many advantages, such as compactness, low operating temperatures, continuous operation at high current density, quick start-up and sporadic operation suitability.

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