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Introduction

South Africa, like most countries will face future limitations with its current energy systems. This is mainly due to the diminishing stocks of the world's fossil fuels, such as oil and coal, and the impact of their combustion on climate change. Scientists have been warning for decades about the impending disaster of global warming if urgent steps are not taken to find alternative or renewable sources of energy to reduce the carbon emissions which are polluting our environment. There has to be a move away from the use of fossil fuels and a move towards alternative energy sources. "Alternative energy" is a term used to refer to a broad range of energy sources intended to replace our existing energy sources that have undesirable consequences to the environment.

One of the solutions to the impending energy crisis is to move towards a global **hydrogen economy**. Hydrogen and fuel cell technologies (HFCTs) are seen as energy solutions for the 21st century, and will enable power and heat to be produced cleanly and efficiently from alternative sources of energy such as wind, solar or biofuel. Using hydrogen as an energy carrier and fuel is seen by many countries in the world as one potential way to address both the issues of energy security and climate change. Although uneconomical on a grand scale at present, HFCT will become more viable as the costs of current energy sources increase and their sustainability diminishes.

What is hydrogen and its sources?

Hydrogen is the most abundant gas in the universe. The sun is basically composed of a giant ball of hydrogen and helium gas. Hydrogen is the simplest element in the universe. One atom consists of only one proton and one electron. It is also colourless, odourless and tasteless. Hydrogen gas does not exist in a natural state on earth; it is always mixed with other elements such as oxygen and carbon.

Hydrogen is not an energy source itself, it used as **energy carrier** i.e. it stores energy from various energy sources and distributes that energy. The energy can be sourced from fossil fuels, nuclear energy and renewable energy sources such as wind, solar or biomass.

Since hydrogen can not be obtained in a natural state, it must be produced. The most common method to produce hydrogen is to employ steam to separate it from carbon found in petroleum and natural gas. This method uses fossil fuels. Hydrogen can also be produced by electrolysis, using electricity to separate it from oxygen in water. This process can be powered by sunlight, wind and nuclear energy sources.

The hydrogen that has been produced stores energy which can now be released and distributed through a device such as a hydrogen fuel cell to provide power for various applications.

What is a fuel cell?

A fuel cell is a device that uses electrochemical energy conversion to produce electricity from hydrogen or other fuels. This is one of the key enabling technologies for a future hydrogen economy. Fuel cells have the potential to replace the internal combustion engine in vehicles and to provide power in stationary and portable power applications. A fuel cell operates like a battery, but unlike a battery, it does not run down or require recharging, as long as the fuel is available.

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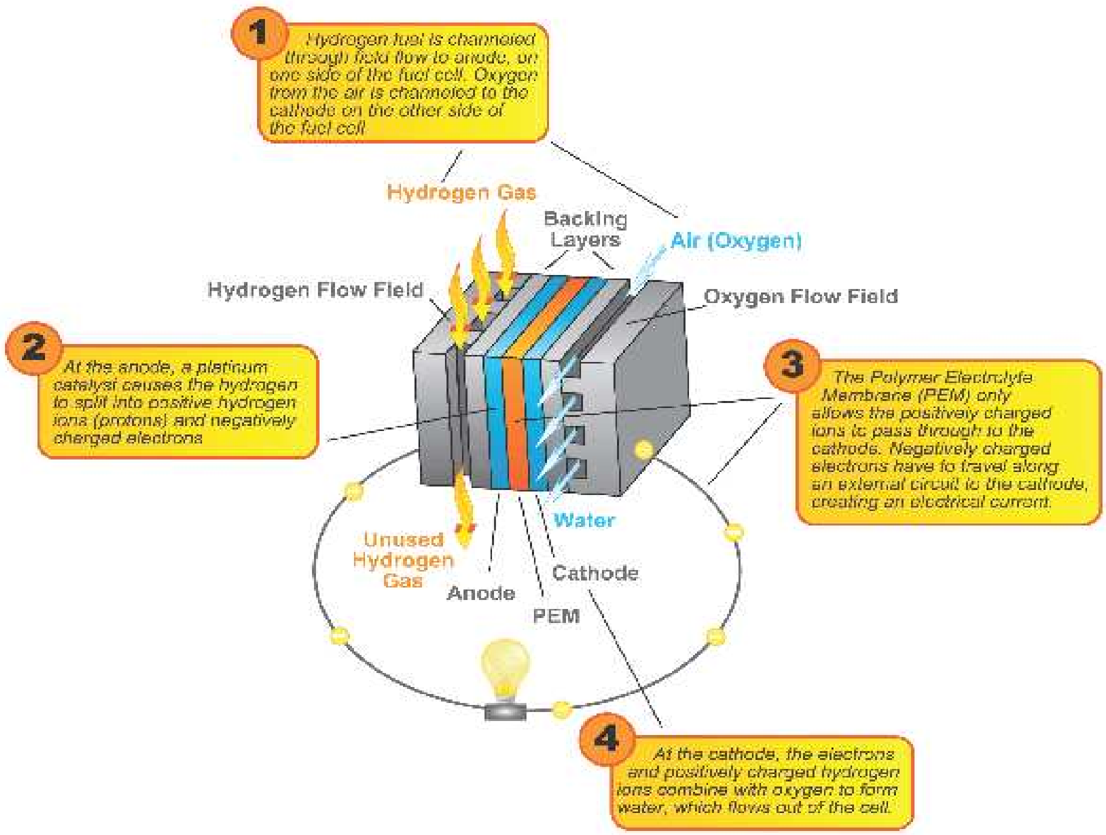
How the Fuel Cell Works

A fuel cell consists of an electrolyte and two catalyst-coated electrodes. Hydrogen is fed into the anode and oxygen is fed into the cathode. Made efficient by the use of a catalyst, electrons are stripped from the hydrogen atom and the protons pass through the electrolyte to the cathode. The electrons take a different path to the cathode, creating an electric current that can be utilized before they return to the cathode. At the cathode, another catalyst rejoins the hydrogen atom, which combines with oxygen to form a water molecule.



Applications of fuel cells

Fuel cells can be potentially employed wherever power is required, their applications range from powering hearing-aids to cell-phones to buildings and automobiles. They are very useful as power sources especially in remote locations, such as spacecraft, remote weather stations, nature reserves, rural areas and certain military operations. A recent application is in micro-combined heat and power (CHP) generation for homes, office buildings and factories. A CHP system produces electricity and hot water. The excess electric power could be sold back to the national grid

Benefits of Fuel Cells

Fuel cells have a number of advantages over competing technologies used in power plants and passenger vehicles. Some of the advantages that fuel cells offer are as follows:

Low to zero emissions- Fuel cells running on pure hydrogen produced from clean technologies does not emit any pollution. The only by-products emitted are heat and water. Even when using hydrocarbon or natural gas fuels, fuel cells emit smaller quantities of greenhouse gases than conventional power plants.

Reliable - Fuel cell systems are highly reliable, which is very desirable for stationary applications that require a high-quality uninterrupted power supply. Fuel cells are also very quiet which result in their silent operation. When compared to internal combustion engines, fuel cells have less moving parts, therefore these require less maintenance and have low operating costs.

Efficient - Fuel cells are highly efficient at converting fuel to electrical energy as compared to any other electrical generating technology. They are also expected to produce higher efficiencies when they are used as combined heat and power (CHP) for stationary applications. Combined heat and power are mostly used to power office buildings, industries and households.

Flexible – Fuel cells can operate on a wide load range and scale from micro production to megawatt production.

The disadvantages of fuel cells

Fuel cells, like any other source of power, have their own disadvantages. Fuel cells are still a young technology. Many technical and engineering challenges remain; scientists and developers are working hard to solve these challenges.

Cost - Fuel cells are currently produced in small quantities, therefore they are more expensive as compared to other sources of power. The price of fuel cells varies from one company to the other. Some companies sell fuel cells for about $3,000 per kilowatt. Mass production of fuel cells will make their costs more affordable and also compete with other sources of power. One of the main costs in a fuel cell is the platinum catalyst employed, and many researchers throughout the world are working on ways to reduce the amount of platinum used, or to even remove it altogether.

Safety - Like any other fuel, hydrogen is potentially dangerous and is flammable if not handled properly. Hydrogen vehicles can be safer than internal combustion engine vehicles. Unlike gasoline or natural gas vehicle that burns during collision, the hydrogen gas in a hydrogen vehicle quickly evaporates to the air, resulting in less potential hazard should it ignite.

Availability - Another challenge with fuel cells technology is that petrol stations don't sell hydrogen. The HySa Infrastructure Centre of Competence (North West University and the CSIR) is currently involved in R&D on hydrogen storage and distribution.

Size - Hydrogen storage is also a challenge at present due to the large volume of hydrogen gas (as 1 m^3 = 90 grams). The petrol tank in the internal combustion engine cars uses a small portion of a car, but the hydrogen storage tank for a hydrogen fuel cell vehicle, even at very high pressures, will be three times bigger than a petrol tank. Therefore the size and weight of fuel cells must be reduced in order to meet the packaging requirements for automobiles.

Durability– Fuel cell vehicles can travel fewer kilometres compared to internal combustion engines. For transportation applications, fuel cell power systems will be required to achieve the same level of durability of current automotive engines. The low operating temperature of Polymer Electrolyte Membrane (PEM) fuel cells limits the amount of heat that can be effectively utilized in combined heat and power (CHP) applications. Technologies need to be developed that will allow higher operating temperatures or more effective heat recovery systems.

South Africa's status with regards to hydrogen and fuel cell technology (HFCT).

The Department of Science and Technology's (DST's) National Hydrogen and Fuel Cell Technologies Research, Development and Innovation (RDI) Strategy (HySA) was launched in September 2008. The vision of the Strategy is to use local resources and existing knowledge to create knowledge and human resource capacity to enable the development of high-value commercial activities in hydrogen and fuel cell technologies.

The main driver for SA to accelerate RDI initiatives on hydrogen and fuel cell technology is that SA is a resource-based country with more than 75% of the world's known platinum reserves, the key catalytic material used in hydrogen fuel cell technology. HySA's main goal is to supply at least 25% of the future global fuel cell market with locally developed and fabricated PGM catalysts by 2020. So, while we acknowledge the need to reduce the amount of platinum employed in HFCT, we are striving to find ways to continue to employ platinum on an economically viable basis.

In order to develop capabilities and add value to this technology, the DST established three Centres of Competence (COC's) to conduct research in this field, i.e. HySA Catalysis, HySA Infrastructure, and HySA Systems.

The HySA Catalysis Competence Centre, co-hosted by the University of Cape Town and the South Africa's Mineral Research Technology Organisation (MINTEK) is involved in R&D on fuel-processor catalysts, fuel cell catalysts, portable power units and low temperature MEAs and stacks mainly used for hydrogen production.

The HySA Infrastructure Competence Centre, co-hosted by North West University and the Council for Scientific and Industrial Research (CSIR) main focus is to develop technologies for hydrogen production, storage and distribution. These technologies include investigation of small storage tanks and infrastructure for hydrogen filling stations.

The HySA Systems Competence Centre, hosted by University of the Western Cape (UWC) is focusing on technology validation and system integration in three key areas relevant to HFCT, i.e. combined heat and power, portable power and fuel cell vehicles. The centre's main focus is on high temperature PEM fuel cells, solid state hydrogen storage systems and lithium-ion batteries.

The three COC's have collaborative agreements with several universities in South Africa involved in HFCT R&D programmes. An example is the collaboration between HySA Systems, Tshwane University of Technology (TUT) and DST on the design and construction of the prototype hydrogen tricycle. HySA Systems developed the hydrogen storage technology that is currently used to power the tricycle.

How has big business and industry responded to the opportunities to become involved in hydrogen fuel cell technology?

Anglo Platinum, the world's largest miner of platinum group metals (which include platinum, palladium, rhodium, ruthenium, iridium and osmium), a US-based company Altergy Systems and DST has entered into agreement to establish a new company called Clean Energy Incorporated. Clean Energy Incorporated will be responsible to market and distribute fuel cells in South Africa, followed by the local manufacture of fuel cells for the sub-Saharan African market by 2013 and to supply the global market with at least 25% of fuel cell catalysts demand by 2020. With over 75% of the world's platinum reserves (the key catalytic component of PEM fuel cells), Anglo Platinum accounts for about 40% of the world's newly mined platinum, our country is therefore positioned with both the raw materials and the scientific expertise to drive a developing hydrogen economy.

Fuel cells to be manufactured in South Africa by Clean Energy will be for stationary power generation. The telecommunications companies such as Telkom and iBurst are also using fuel cells for power generation and as back-up power for some of their towers. Anglo Platinum demonstrated the use of large scale stationary fuel cell systems for power generation using coal-bed methane as the fuel source in their Lephalale plant.

Is the wider public aware of its potential for human capital development and wealth creation in RSA?

HFCT is still at its early stage in SA and therefore the general public is not yet aware of this emerging technology and its benefits. As a result the Public Awareness, Demonstration and Education Platform is being developed under the National Research Foundation through South African Agency for Science and Technology Advancement (SAASTA) to support public understanding of this technology.

Four fuel cells were also installed in four science centres around the country to support and engage the public towards understanding SA's benefits of using this technology. The main objective of HySA is to create wealth for SA through high value-added manufacturing and development of PGM catalysts and also to supply up to 25% of the world fuel cell catalysts demand by 2020. The local benefits include job creation and the development of appropriate skills for South Africans.

The Department of Science and Technology's Hydrogen South Africa (HySA) Public Awareness Platform is hosted by the South African Agency for Science and Technology Advancement (SAASTA).

For more information visit www.hydrogen.org.za or www.saasta.ac.za or contact SAASTA on (012) 392 9300.