Green Hydrogen Generation - Upcoming Technologies

Introduction

Apart from Electrolysis, researchers and various industry players are working tirelessly to develop and produce Green Hydrogen using multiple methods, including decomposition of natural gas, solar hydrogen production, biological hydrogen production, and thermochemical splitting. Each of these green hydrogen production methods has some advantages and also faces specific technical challenges. Industry players and researchers are trying various research activities to overcome these challenges.

Current Landscape of Hydrogen Production

Hydrogen generation is associated with different colors like grey, blue, or green. These different colors represent distinctions in the emissions profiles for the different hydrogen production pathways.

- **Grey hydrogen** – Use of fossil fuels for hydrogen production – Natural gas reforming is the widely used process for the production of hydrogen, but this results in a considerable amount of CO$_2$. Various industries are dependent on this process for the generation of cost-effective hydrogen.

- **Blue hydrogen** – Hydrogen produced from fossil fuels and use of carbon-capture technology to reduce CO$_2$ emissions

- **Green hydrogen** – Hydrogen produced via electrolysis – using electricity generated by renewables and other technologies. Several plants with more than 100MW plant size have been announced for green hydrogen production using electrolyzers. Alkaline and PEM electrolyzer technologies are widely used technologies. Developments are also taking place in high-temperature electrolyzer processes.

Apart from water electrolysis following are some of the technologies for the production of hydrogen (Green and Blue) that are in different development stages:
Methane Pyrolysis

Thermal decomposition and plasma decomposition of natural gas produces hydrogen and carbon. Carbon can be stored in a solid form and used for various processes. Hydrogen produced from the process is free from CO$_2$ emissions and is a clean source of energy. Some of the market developments for the technology are as follows:

BASF is currently developing a process to produce hydrogen using methane pyrolysis. BASF’s technology splits natural gas directly into its components hydrogen and solid carbon at high temperatures.

In Dec 2019, Karlsruhe Institute of Technology (KIT) and Wintershall Dea (In which BASF has minority stake) partnered for a joint study project which is expected to run for three years to develop methane pyrolysis process for use on an industrial scale.

HiiROC has developed a step-change methane pyrolysis technology for low-cost, zero-emission Hydrogen production using a plasma process. In Jan 2020, AFC Energy and HiiROC have agreed to enter into a commercialization agreement that will allow AFC Energy to integrate HiiROC’s plasma-based technology.

Key challenges for the methane pyrolysis include optimizing various processes for both hydrogen and solid carbon product. Removal of solid carbon from the molten media is also one of the challenges for the process researchers are trying to address.

Solar Hydrogen Production

These are photolytic processes that use light energy to split water into hydrogen and oxygen. Several types of researches are happening across two major processes, including photocatalytic water splitting and photoelectrochemical water splitting. These processes are currently in the very early stages of research; these processes offer the potential for green hydrogen production with low environmental impact.

Photoelectrochemical water splitting (PEC) – In the PEC process, hydrogen is generated from water. It uses sunlight and specialized semiconductors that are called photoelectrochemical materials. These materials use light to directly dissociate water molecules.

In Jan 2020, researchers in Israel have developed a design of a separate-cell
PEC water-splitting system with decoupled hydrogen and oxygen cell.

According to DOE, PEC water splitting is a promising future pathway for hydrogen production.

**Photocatalytic water Splitting** – It’s an artificial photosynthesis process with photocatalysis used for the dissociation of water into oxygen and hydrogen. The majority of the research activities in the Photocatalytic Water Splitting is concentrated in developing a high-performance photocatalyst. Researchers are looking to develop photocatalysts with high light absorption properties, high rate of charge transfer, and suitable surface reaction properties.

Continued improvements in efficiency, durability, and cost of both processes are still required for the market viability of these processes. The overall system’s efficiency for the solar hydrogen production process is one of the key challenges for the process. Some of the other challenges include the development of durable, effective photocatalysts and electron transfer catalysts. The process also requires the development of multifunctional materials available in large quantities at a very low cost.

**Biological hydrogen production**

Hydrogen production of using the photolytic biological pathway uses sunlight and specialized microorganisms, such as green algae and cyanobacteria. Microbes use a natural metabolic process to consume water and produce hydrogen as a byproduct. According to US DOE, this pathway is still in the nascent stage of its development and is expected to evolve and have an estimated production capacity of less than 1,500 kg/day in the long term future.

**Biomass Gasification**

It is a technology that uses a process involving heat, steam, and oxygen to convert biomass to hydrogen and other products, without using combustion. It converts organic or fossil-based carbonaceous materials at temperatures higher than 700°C. In this process growing biomass removes carbon dioxide from the atmosphere and results in low net carbon emissions, especially if coupled with carbon capture in the long term.

Biomass sources include forestry crops & residues, agricultural crops and residue, sewage, industrial residues, animal residues, and municipal solid waste. Production of hydrogen via gasification helps in solving the important
environmental problem of mounting waste stocks.

Some of the challenges which have resulted in major roadblocks in widespread commercialization of this process include high reactor cost, low system efficiency, feedstock impurities, and cost of carbon capture technologies.

**Future Outlook**

The current hydrogen generation market is dominated by Steam methane reformation that accounts for over 95% of all hydrogen production due to well-established processes and low cost. Green hydrogen generated using electrolyzers and blue hydrogen using carbon capture technologies constitutes of other 5% of the market. Technological advancement and reduction in the cost of the electrolyzers have resulted in a significant increase in green hydrogen production in recent years. There have been several announcements related to more than 100MW of electrolyzer plants as well. Solutions and incremental developments for challenges like system efficiency and cost of the hydrogen generation related to green hydrogen production methods including methane pyrolysis and solar hydrogen production will present a great opportunity and help these technologies to become viable in years to come.