HYDROGEN FACT SHEET

Hydrogen Production – Steam Methane Reforming (SMR)

Introduction

In today's energy supply system, electricity, gasoline, diesel fuel, and natural gas serve as energy carriers. These carriers are made by the conversion of primary energy sources, such as coal, petroleum, underground methane, and nuclear energy, into an energy form that is easily transported and delivered in a usable form to industrial, commercial, residential, and transportation end-users. The sustainable energy supply system of the future features electricity and hydrogen as the dominant energy carriers. Hydrogen would be produced from a very diverse base of primary energy feedstocks using the resources and processes that are most economical or consciously preferred. Methods to produce hydrogen from natural gas are well developed and account for over 95% of all hydrogen produced in the U.S. and 48% globally. It is anticipated that hydrogen from natural gas can serve as a foundation to the U.S. transition to a hydrogen energy economy.

Today, almost all hydrogen is produced via steam reforming of natural gas at oil refineries. The great majority of that hydrogen is used by oil refineries and petrochemical plants to refine fuel and to make industrial commodities.

Production Process

The steam methane reforming (SMR) process consists of the following two steps, as shown in Figure 1.

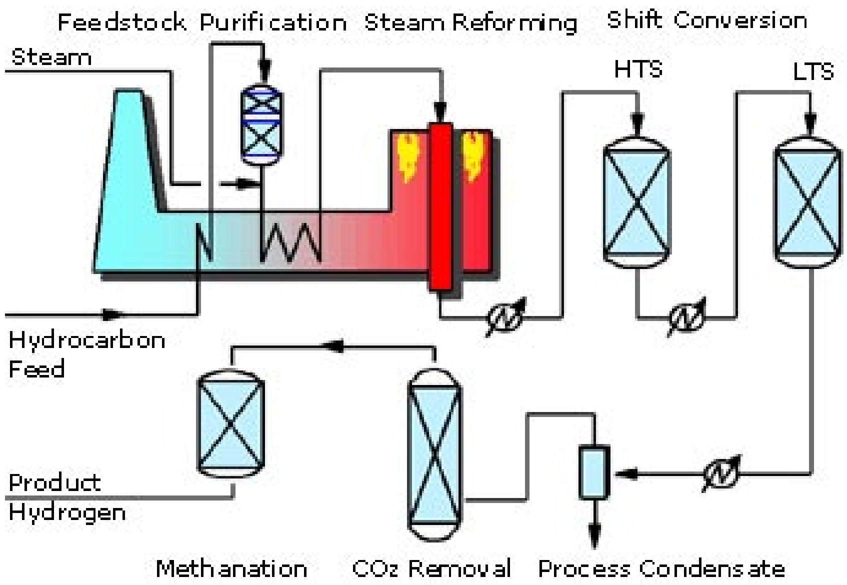
1. **Reformation of Natural Gas**
   The first step of the SMR process involves methane reacting with steam at 750-800°C (1380-1470ºF) to produce a synthesis gas (syngas), a mixture primarily made up of hydrogen (H_2) and carbon monoxide (CO).

2. **Shift Reaction**
   In the second step, known as a water gas shift (WGS) reaction, the carbon monoxide produced in the first reaction is reacted with steam over a catalyst to form hydrogen and carbon dioxide (CO_2). This process occurs in two stages, consisting of a high temperature shift (HTS) at 350ºC (662ºF) and a low temperature shift (LTS) at 190-210ºC (374-410ºF).

Table 1. Production Technology Scorecard

	Steam Reforming
Description	Steam reforming converts methane (and other hydrocarbons in natural gas) into hydrogen and carbon monoxide by reaction with steam over a nickel catalyst.
Feedstock	Natural gas
Energy	Natural gas. May be driven by heat from nuclear power plants.
Other	70% efficient. Will require carbon sequestration.
Challenge	Improve reforming efficiencies, identify more durable reforming catalysts, and reduce carbon sequestration costs. Develop advanced reforming and shift technologies.
Status	Near- to mid-term

Figure 1: Steam Methane Reforming Process



Natural gas consists mainly of methane (CH_4), mixed with some heavier hydrocarbons and CO_2. By applying high temperature steam to the CH_4, hydrogen, and carbon oxides are created.

Hydrogen produced from the SMR process includes small quantities of carbon monoxide, carbon dioxide, and hydrogen sulfide as impurities and, depending on use, may require further purification. The primary steps for purification include:

- **Feedstock purification** – This process removes poisons, including sulfur (S) and chloride (Cl), to increase the life of the downstream steam reforming and other catalysts.
- **Product purification** – In a liquid absorption system, CO_2 is removed. The product gas undergoes a methanation step to remove residual traces of carbon oxides. Newer SMR plants utilize a pressure swing absorption (PSA) unit instead, producing 99.99% pure product hydrogen.

High to ultra-high purity hydrogen may be needed for the durable and efficient operation of fuel cells. Impurities are believed to cause various problems in the current state-of-the-art fuel cell designs, including catalyst poisoning and membrane failure. As such, additional process steps may be required to purify the hydrogen to meet industry quality standards. Additional steps could also be needed if carbon capture and sequestration technologies are developed and utilized as part of this method of hydrogen production.

Current Status

Steam reforming of natural gas is widely used in industry today. Hydrogen is produced by the SMR process in large centralized industrial plants for use in numerous applications, including chemical manufacturing and petroleum refining. Research and development (R&D) programs are currently investigating the development of small-scale SMR technologies to enable the development of small-scale, distributed hydrogen production and delivery infrastructure.

The Advantages

Steam reforming of natural gas offers an efficient, economical, and widely used process for hydrogen production, and provides near- and mid-term energy security and environmental benefits. The efficiency of the steam reforming process is about 65% to 75%, among the highest of current commercially available production methods. Natural gas is a convenient, easy to handle, hydrogen feedstock with a high hydrogen-to-carbon ratio. It is also widely available from sources in the U.S. and Canada.

The cost of hydrogen produced by SMR is acutely dependant on natural gas prices and is currently the least expensive among all bulk hydrogen production technologies. A well-developed natural gas infrastructure already exists in the U.S., a key factor that makes hydrogen production from natural gas attractive.

Challenges

During the production of hydrogen, CO_2 is also produced. The SMR process in centralized plants emits more than twice the CO_2 than hydrogen produced.[1] To avoid emission of CO_2 into the atmosphere, CO_2 can be concentrated, captured, and sequestered; sequestration concepts and technologies are relatively new and there is no long-term test evidence to prove that these technologies will be successful. Sequestration in oceans is controversial because of the possible adverse impact on the aquatic environment by the reduction of ocean water pH.

SMR is a mature technology, which makes it especially important to beginning the transition to a hydrogen energy economy. Yet, the problem with SMR is that it is operating at or near its theoretical limits; the hydrogen produced is still expensive compared to the U.S. Department of Energy's (DOE) cost targets for producing hydrogen for future automobiles and other applications.

[1] In central station hydrogen production from natural gas reforming, the mass of CO_2 emitted is 2.51 times greater than the mass of hydrogen produced.

Interested in Learning More?

U.S. Department of Energy
www.eere.energy.gov/hydrogenandfuelcells

National Hydrogen Association
www.hydrogenassociation.org

U.S. Fuel Cell Council
www.usfcc.com

International Partnership for the Hydrogen Economy (IPHE)
www.iphe.net

Additional research and development is needed to identify more durable reforming catalysts; improve reforming efficiencies; develop advanced shift, separation, and purification technologies; and reduce the cost of carbon capture and sequestration.

Finally, natural gas is used in many other sectors of the U.S. economy, including the commercial, residential, and electric generation sectors. If natural gas is used for hydrogen production, and the demand of natural gas in other market sectors continues to grow, the natural gas reserves would decrease and the supply will be put under greater pressure. This could result in increased natural gas prices. Strong efficiency improvements in existing natural gas markets are therefore critical to keeping methane gas affordable for hydrogen production.

Implications for the Transition to a Hydrogen Economy

Natural gas represents one of the most viable pathways for introducing hydrogen as an energy carrier for the future U.S. hydrogen energy economy because it is among the least expensive feedstocks for producing hydrogen. However, carbon capture and sequestration is needed to eliminate the high level of greenhouse gas emissions associated with using natural gas. DOE's goal is to reduce the cost of distributed hydrogen production from natural gas to \$3.00/kg H_2 by 2005 and \$1.50/kg H_2 by 2010 as well as improve efficiencies to 68% by 2005 and 75% by 2010.[2] Significant R&D is needed to bring the cost of hydrogen using SMR to DOE targets as well as making the SMR process more efficient.

[2] Cost and efficiency targets do not include carbon capture and storage.

Sources:

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