7.3. Technologies for Hydrogen Production

Technologies for hydrogen (H_2) production fall into three main categories:

1. ***Thermal Processes:*** Some thermal processes use the energy in various feedstocks (natural gas, coal, biomass, etc.) to release the H_2 that is part of their molecular structure. Other thermal processes known as thermo-chemical processes use heat in combination with a closed chemical cycle to produce H_2 from feedstocks such as water.

   In addition to gasification, the main thermal process technology which is available for production of H_2 is steam reformation of natural gas. It is a well established technology that produces about 95% of the H_2 produced in the United States. Steam reforming involves the reaction of natural gas and steam over a nickel based catalyst. This breaks the methane component of the natural gas into carbon monoxide (CO) and H_2 gas, similar to synthesis gas (syngas) produced via gasification. Then water-gas shift (WGS) is performed to increase the amount of H_2 in the product gas as much as possible.
2. ***Electrolytic Processes:*** These processes use electricity to split water into its two chemical constituents, oxygen (O_2) and H_2, using an electrolyzer. The cost and efficiency of producing H_2via electrolytic processes is directly dependent on the cost and efficiency of the electricity used in the process.
3. ***Photolytic Processes:*** These processes use light energy to also split water into H_2 and O_2. These processes are currently in the early stages of development and currently are not viable for large scale production.

Efficiency/Cost Comparison to Competing Technologies

Table 1 presents the cost and performance characteristics of various H_2 production pathways, as of 2004. Many of the technologies that are in the research and development (R&D) stage will require years of improvements before becoming a commercial reality.

Table 1: Efficiency/Cost Comparison to Competing Technologies [1]

Process	Energy Required (kWh/Nm^3)		Status of Tech.	Efficiency [%]	Costs Relative to SMR
	Ideal	Practical			
Steam methane reforming (SMR)	0.78	2-2.5	mature	70-80	1
Coal gasification (GE Energy)	**1.01**	**8.6**	**mature**	**60**	**1.4-2.6**
Partial oxidation of coal			mature	55	
H_2S methane reforming	1.5		R&D	50	<1
Landfill gas dry reformation			R&D	47-58	~1
Partial oxidation of heavy oil	0.94	4.9	mature	70	1.8
Naphtha reforming			mature		
Steam reforming of waste oil			R&D	75	<1
Steam-iron process			R&D	46	1.9
Chloralkali electrolysis			mature		by-product
Grid electrolysis of water	3.54	4.9	R&D	27	3-10
Solar & PV-electrolysis of water			R&D to mature	10	>3
High-temp. electrolysis of water			R&D	48	2.2
Thermochemical water splitting			early R&D	35-45	6
Biomass gasification			**R&D**	**45-50**	**2.0-2.4**
Photobiological			early R&D	<1	
Photolysis of water			early R&D	<10	

Photoelectrochemical decomp. of water			early R&D		
Photocatalytic decomp. of water			early R&D		

The cost of H_2 production depends heavily on the cost of fuel or electricity from which it is produced. As the market price for these inputs to the H_2 production system fluctuate, one given technology may become more attractive economically compared to others.

Coal-to-Hydrogen Process Description

The U.S. Department of Energy (DOE) has sponsored many design studies on the production of H_2 from coal, with or without the co-production of power.

Recent DOE studies presented the following four process design schemes as possible options for centralized-large-scale H_2 production from coal, and discussed their performance and efficiency:[2]

- Co-producing H_2 and power in today's coal-based integrated gasification combined cycle (IGCC) plants
- Co-producing H_2 and power in coal-based IGCC with carbon capture
- H_2 production from coal without power export
- Co-producing H_2 and power in future IGCC based on advanced warm gas clean-up and advanced membrane (combined shift and H_2 separation) technologies

1.	Hydrogen: Automotive Fuel of the Future, by FSEC's Ali T-Raissi and David Block, IEEE Power & Energy, Vol. 2, No. 6, page 43, Nov-Dec 2004.
2.	Hydrogen from Coal, *D. Gray & G. Tomlinson, Mitretek Technical Paper* (Nov 2001)

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- Why Hydrogen
- Hydrogen & Synthetic Natural Gas from Coal
- **Technologies for Hydrogen Production**
  - Co-producing H_2 with Current IGCC Technology
  - Co-producing H_2 in IGCC with Carbon Sequestration
  - Hydrogen Production from Coal without Power Export
  - IGCC/H_2 Co-production with WGCU and Advanced WGS Membrane
- Technology for SNG Production
- SNG from Coal: Process & Commercialization
- DOE Supported R&D for Production of Hydrogen