Chapter 2
Literature Review*

2.1 Introduction and Overview

The majority of current energy needs is supplied by combustion of non-renewable energy sources, namely fossil fuels, and is associated with the release of large quantities of greenhouse gases (GHG), especially carbon dioxide (CO_2), and other harmful emissions to the atmosphere. The gradual depletion of these fossil fuel reserves, and efforts to combat pollution and greenhouse gas emissions, have generated considerable interest in using alternative sources of energy. Hydrogen gas may one day replace fossil fuels for various applications such as in automobiles and power stations [1]. However, hydrogen nowadays is mostly produced via fossil fuel reforming and fossil fuels are expected to remain a major hydrogen source in the long term [2]. Presently, hydrogen finds application as a chemical compound rather than a fuel in commercial operations, but if hydrogen is used to replace existing fuels, appropriate methods for large-scale production must be developed.

Hydrogen is the simplest element and the most plentiful gas in the universe. Yet, hydrogen never occurs by itself in nature; it is found combined with other elements such as oxygen and carbon, i.e. water or hydrocarbons, so these substances must be decomposed/reformed to get H_2 [3]. To release hydrogen, heat can be applied to hydrocarbons and water to break down the molecules (thermo-chemical), and electric charging (electrolysis) or a photolytic process can be used to decompose water. Some separation processes combine heat and electricity (steam electrolysis). Bacteria and algae can also be used to produce H_2 from biomass.

Currently, the main process for producing hydrogen is steam reforming of natural gas [1]. Steam reforming is a multiple stage process. The first stage is the highly endothermic catalytic reforming of methane ($\Delta H°_{298}$ = 206 kJ/mol CH_4) conducted at high temperature (800–900°C), while the second stage is the catalytic water gas shift (WGS) reaction, occurring in two steps: the first stage is conducted at (400–500°C) to reduce the carbon monoxide (CO) concentration to 2-5%, and the second stage is conducted at (177–257°C) to reduce CO to 1%. The third stage is the separation of the H_2–CO_2 mixture using pressure-swing adsorption (PSA) [4-6].