CHAPTER 1

INTRODUCTION

1.1 Current Energy Demand

In the decades ahead, world's population is expected to increase continuously from 6.5 billion to 9 billion in 2050, shown in Figure 1.1. This will drive world energy demand in every sector such as residential, transport, services, agricultural and heavy industry sectors to continue growing, shown in Figure 1.2. The International Energy Agency (IEA) expected strong growth in energy demand on electricity supply, that such an investment of around $26 trillion, including $5 trillion in renewable energy is needed. Since 1950, the populations have doubled, but energy demands in crude oil, natural gas and coal have increased three times while hydroelectricity has increased twice.

After 2030, alternative energy such as solar, geothermal energy, hydroelectric and biofuels will play an important role, instead of fossil fuels (Figure 1.3), because of the depletion of fossil fuels and climate change.

A shortage of petroleum fuels (Figure 1.4) brings about increasing oil price. In the next 10 years, price of petroleum products will increase, causing activities such as transportation, agriculture to have high cost. Its demand will drop and use of renewable energy will increase. In 2012, energy demand in Thailand is expected to rise almost 5% to 1.94 million barrels of oil equivalent per day, following growth of 4.1% in 2011 which was driven by economic grow after flooding in 2011. Oil consumption rose from 411,000 to 808,000 barrels per day between 1990 and 1997, before the Asian financial crisis triggered a collapse and consumption decreased to 701,610 barrels per day in 2001. Demand has been on an upward trend and reaches 991,000 barrels per day in 2011. It is assumed around 2-3% average annual growth, and will reach 1.13million barrels per day in 2016. The production of oil and liquids was about 337,000 barrels per day in 2011. This will decline to 286,000 barrels per day in 2016. This means that the country has to import oil for 845,000 barrels per day.

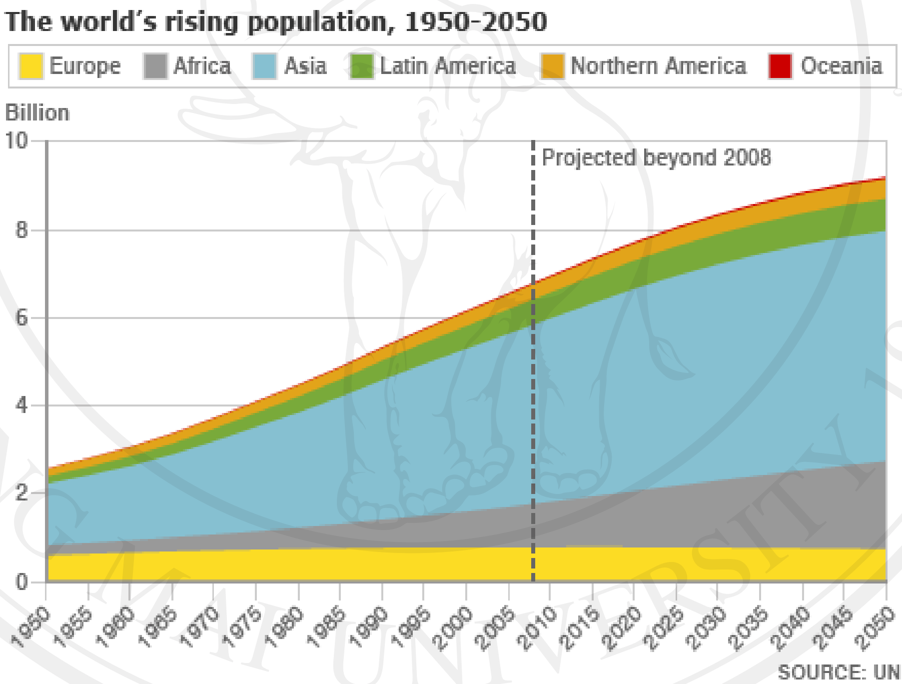

Figure 1.1 World's rising population (Energy & Capital, 2012b)

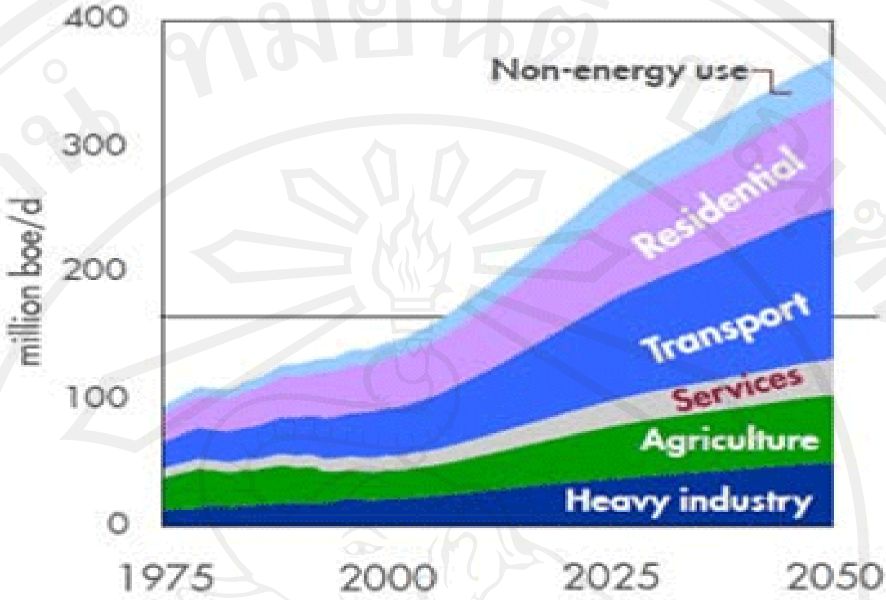

Figure 1.2 Rising global energy demand (Shell company, 2012)

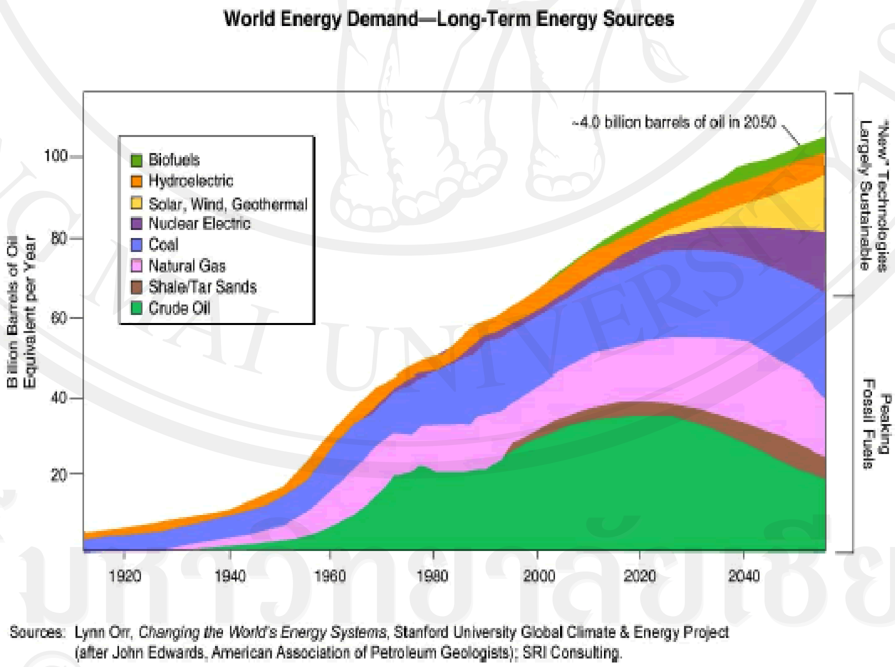

Figure 1.3 World's energy demand forecast (Energy & Capital, 2012a)

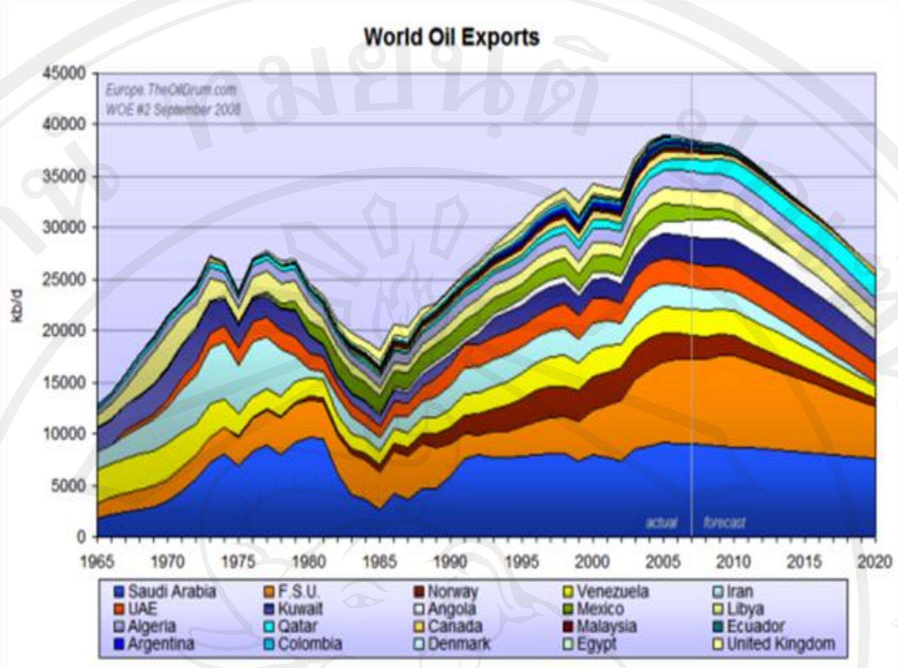

Figure 1.4 World oil exports (Stafford, 2012)

1.2 Renewable Energy Sources

Renewable energy is derived from natural resources such as biomass, heat (solar and geothermal), moving water (hydro, tidal, and wave power), and wind energy. Most renewable forms of energy, other than geothermal and tidal power, are ultimately derived from solar energy. Biomass is from plant material produced by photosynthesis using energy from the sun. Renewable energy resources may be used directly, or used to create other more convenient forms of energy.

There are growing interests in renewable energy utilization because they are not depleted. The main advantage of using renewable resources is not leading to any environmental pollution problems. It is distributed over a wide geographical area, and they are quickly renewed through the natural process. This energy has potential for supporting the world's energy demand.

From Figure 1.3, there are many sources of the power that are renewable such as solar, hydro, geothermal, wind and biomass. The use of solar, wind and geothermal energy will increase dramatically in the next ten years. Hydropower has been used for over hundred years. Utilization of biofuels has been increasing since 2000. The energy prices of fossil fuel, renewable energy and environmental costs are heading in opposite directions. The sustainable energy markets are widespread and supported by the economic and policy mechanisms. The growth in the energy sector is mainly in the new renewable energy technologies, not in conventional oil and coal sources.

1.3 Importance of Biomass

Biomass is among the first energy sources harnessed by mankind. It remains the primary source of energy for more than half of the world's population, and accounts for about 14% of the total energy consumption in the world (Kaygusuz and Türker, 2002). Biomass is a low-carbon fuel, absorbs CO_2 in its production, and becomes a sink for greenhouse gases. Utilization of biomass is an attractive, clean development mechanism option for reducing greenhouse gas emission (Junfeng and Runqing, 2003).

Biomass is the term used to name materials derived from plants (grass, trees and crops) and animals. Plant biomass is mainly composed of carbon, oxygen, hydrogen and traces of mineral elements such as nitrogen, potassium, phosphorus, sulphur and some others. Biomass energy is a form of solar energy because it depends on photosynthesis. Green plants transform energy of sunlight into chemical energy into chemical bonds of structural components of biomass, converting carbon dioxide from the air and water from the ground into energy rich organic compounds, mostly sugar cellulose, starch, lignin and also proteins and oils. When burning biomass (extracting the energy stored in the chemical bonds) efficiently, oxygen from the atmosphere combines with the carbon from biomass to produce carbon dioxide and water. Both water and carbon dioxide are the basic compounds that, together with inorganic nutrients from the lithosphere, driven by the solar energy, build up new biomass "organism" through the process known as photosynthesis. Thus, biomass is a renewable resource.

The externalities of bio-energy, which are not accounted for its cost, are important to be considered as well and can offer benefits, compared to fossil fuels. Its carbon neutral character is one of those externalities. Furthermore, biomass has very low sulphur content. It is available to most countries in the world, while fossil fuels need to be imported from a limited number of suppliers. Although there are environmental impacts related to bioenergy, it is usually more beneficial in terms of external costs than coal, gas or oil. It is stressed that biomass is by far more environmentally friendly fuel than fossil fuels.

1.4 Biomass Utilization Pathways

Biomass can be converted into liquid, solid and gaseous fuels with the help of some physical, chemical and biological conversion processes. The conversion of biomass materials has a precise objective to transform a carbonaceous solid material which is originally difficult to handle, bulky and of low energy concentration, into the fuels having physico–chemical characteristics which permit economic storage and transferability through pumping systems. Biomass ranks fourth worldwide, as an energy resource. It is the most important source of energy in developing nations. The use of biomass fuels provides substantial benefits as far as the environment is concerned. Biomass offers important advantages as a combustion feedstock due to the high volatility of the fuel and the high reactivity of both the fuel and the resulting char. However, it should be noticed that in comparison with solid fossil fuels, biomass contains less carbon and more oxygen and has a low heating value. Direct combustion is the old way of using biomass. Combustion is responsible for over 97% of the world's bio-energy production. Some processes such as pyrolysis, gasification, anaerobic digestion and alcohol production have widely been applied to biomass in order to obtain its energy content (Demirbas, 2004).

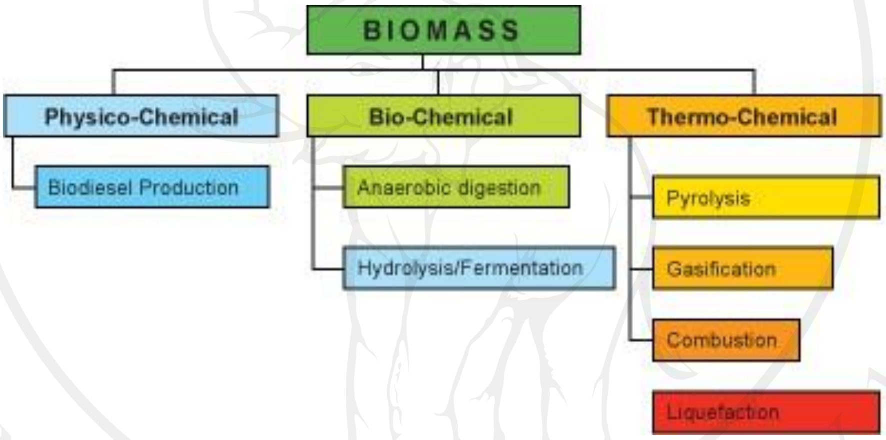

Figure 1.5 Biomass resource conversion processes

1.5 Gasification Technology

The "primitive" biomass conversion technology is the direct combustion, which is still widely used in scales ranging from small scale (household uses for cooking or heating) to industrial scale, for heat and/or electricity generation in different scales, up to hundreds of MW. Presently, biomass energy technologies consist of many conversion technologies used to extract biomass energy and convert it into a more useful form. There are several technologies that can be used to convert solid materials to energy rich useful products. Thermo-chemical process is one of them. There are three products that produced from solid biomass to useful fuel. First, carbonization is a process that changes solid feedstock to carbon rich fuel. Second, pyrolysis is a process that converts solid or liquid feed stock to liquid fuel under inert environmental atmosphere. The last one is gasification. This process converts solid feedstock to gas fuels under oxidation atmosphere.

The most dominant way of extracting biomass energy is the direct combustion. Nevertheless, direct combustion gives low energy transfer efficiency since it depends on many factors including the reaction conversion rate. Intensive R&D is still underway to improve direct combustion energy efficiency. Gasification is another thermochemical conversion process, which converts dry biomass into a mixture of fuel gases that can be burnt in internal combustion engines and gas turbines. Actually, air gasification is a thermal process that takes place in a special sealed container in a poor oxygen environment. Pyrolysis is the process that converts biomass into liquid fuel (bio-crude), solid and some gaseous fractions, in the total absence of air at relatively high temperature (about 500ºC).

Gasification is a form of pyrolysis, carried out at high temperatures in order to optimize the gas production. The resulting gas, known as producer gas, is a mixture of carbon monoxide, hydrogen and methane, together with carbon dioxide and nitrogen. Biomass gasification is the latest generation of biomass energy conversion processes, and is being used to improve the efficiency, and to reduce the investment costs of biomass electricity generation through the use of gas turbine technology. High efficiencies (up to about 50%) are achievable using combined-cycle gas turbine systems, where waste gases from the gas turbine are recovered to produce steam for use in a steam turbine.

Gasification for power production involves the devolatilization and conversion of biomass in an atmosphere of steam and/or air to produce a medium or low calorific value gas. If air is present, the ratio of oxygen to biomass is typically around 0.3. A large number of variables affect gasification based process design. Gasification medium is an important variable. Air blown or directly heated gasifiers, use the exothermic reaction between oxygen and organics to provide the heat necessary to devolatilize biomass and to convert residual carbon-rich chars.

Biomass gasification process is similar to processes used for many years by chemical and petrochemical manufacturers, including methanol, ammonia and ethylene producers. In these chemical processes, natural gas or another hydrocarbon is 'reformed' into a more desirable gaseous chemical feedstock by reacting it with steam at elevated temperatures. The hydrogen and oxygen molecules in the steam are liberated and a series of reactions result in a reorganization of the compounds to form synthesis gas (primarily H_2, CO and CO_2). This synthesis gas is then catalytically converted into methanol, ammonia or another product.

1.6 Problem Statement

There are many researchers investigating gasification process, for many kinds of biomass and agricultural residues. A number of researches focused on biomass available locally in Europe, America, Africa, with a small number of published works reported on local biomass materials available in Thailand.

There are many kinds of agricultural residues which are unique considering composition, texture and other physical properties, and available in large amount. In addition, residues from major economics crops, such as, longan seed, bamboo and weeds may be important. It is of great interest to study them. Their components are different from those available in literature. It is interesting to compare results, obtained from these agricultural residues with those prediction models based on common composition such as lignin, cellulose, hemicellulose or C, H, O or fixed carbon, volatile matter and ash contents. Up to date, there have rarely been any studies on these biomass sources, in carefully controlled condition of gasification process. Different biomass sources lead to difference in product yields and compositions. Information to define specific conditions that appropriate for particular biomass will be crucial in the future utilization of these agricultural residues.

There are a number of studies of dolomite with different types of biomass. But, there is limited research in Thailand with local biomass. It is interesting to use dolomite as catalyst in gasification process with specific biomass to define an appropriate condition for syngas and tar reduction.

In this research, therefore, experimental study to find the conditions that appropriate for agricultural biomass in gasification process such as: reaction temperature, gasifier medium, biomass types and catalyst that resulted in yield and composition of producer gas is carried out.

1.7 Research Objectives

1.7.1 To design, construct and test laboratory scaled gasification system.

1.7.2 To experimentally investigate the effects of temperature, biomass type, gasifier medium on yield and compositions of producer gas.

1.7.3 To experimentally compare the effect of the presence of catalyst on yield and compositions of producer gas.

1.8 Potential Benefits

1.8.1 A useful laboratory scaled system obtained can be used for further research into thermochemical reaction.

1.8.2 Explanation on effect of temperature, biomass type, gasifier medium and catalyst on yield and compositions of bio-syngas are obtained

1.8.3 Further knowledge in control parameters that affect gasification process.

1.9 Scope of the Study

1.9.1 Experiments are conducted in two lab scale reactors; fixed bed and fluidized bed.

1.9.2 Operating pressure is at atmosphere

1.9.3 A medium type (from air or steam) was used.

1.9.4 Two biomass types such as bamboo and mimosa pigra L were tested.

1.9.5 At least four temperatures between 400 - 1,200 °C were chosen.

1.9.6 Fixed equivalent ratio used was employed at 0.25.

1.9.7 Catalyst bed at a temperature between 500-900 °C was chosen

1.10 Outlines of Thesis

This thesis has six chapters. Chapter 1 is an introduction that contains the statement and significance of problem, objective, benefit and scope of this study. Chapter 2 contains the principle and theories of gasification that used in this research. Chapter 3 reviews the previous studies about thermogravimetric analysis, gasification, thermodynamic equilibrium modeling. Chapter 4 is the methodology of this research, about experimental set up two series of gasification experiments and data collection and modeling of the experiment. Chapter 5 is the discussion of the experimental results of fixed bed and fluidized bed and experimental modeling. Chapter 6 presents conclusion and suggestion of this research.