CHAPTER I

INTRODUCTION

In this chapter, a brief review of the global energy situation and an outline of the power sector in Thailand are presented to give an appreciation of the historical occurrence and the likely trend in the foreseeable future. The current energy scenario gives rise to the "statement of the problem" and at the same time, provides the "rationale" and "purpose" for this study to take place in helping to resolve the problem. The limitations and location of work are also stated in addition to the scope of the study.

1.1 Brief Review of Energy Situation

Crude oil, natural gas and coal are the three main fossil fuels that are widely used in the world and are available only in limited quantity. The finite supply of a particular fossil fuel is best indicated by its reserves-to-production (R/P) ratio. The R/P ratio is obtained by dividing the reserves remaining at the end of any year by the production in that year. The result is the length of time that those remaining reserves would last if production were to continue at that level. In the BP Statistical Review of World Energy (2005) [1], an estimate of the R/P ratio for crude oil, natural gas and coal for year ending 2004 is given (Figure 1).

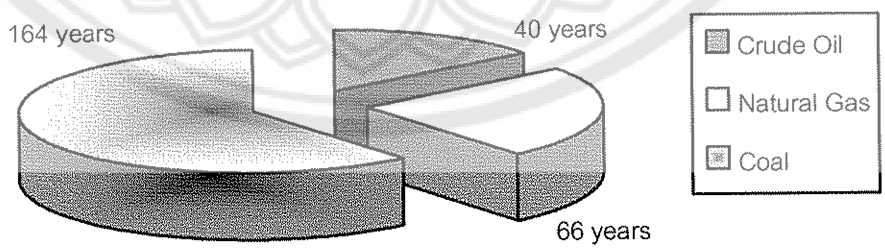

Figure 1 R/P ratios of global crude oil, natural gas and coal (at end of 2004)

Despite the scarcity of crude oil, natural gas and coal, the consumption of these fossil fuels remains high. Historical data from a 10-year period (1995 – 2004) indicated that world consumption has been on a rising trend [1] (Figure 2). This up trend is expected to continue over the next two decades. The International Energy Outlook (2005) [2] projects total world consumption of marketed energy (particularly fossil fuel) to expand from 412 quadrillion Btu in 2002 to 645 quadrillion Btu in 2025, a 57% increase over the 23-year time period (Figure 3). Much of the growth in energy demand is expected to occur mainly in the emerging economies. Demand in this region is projected to more than double over the forecast period (Figure 4)

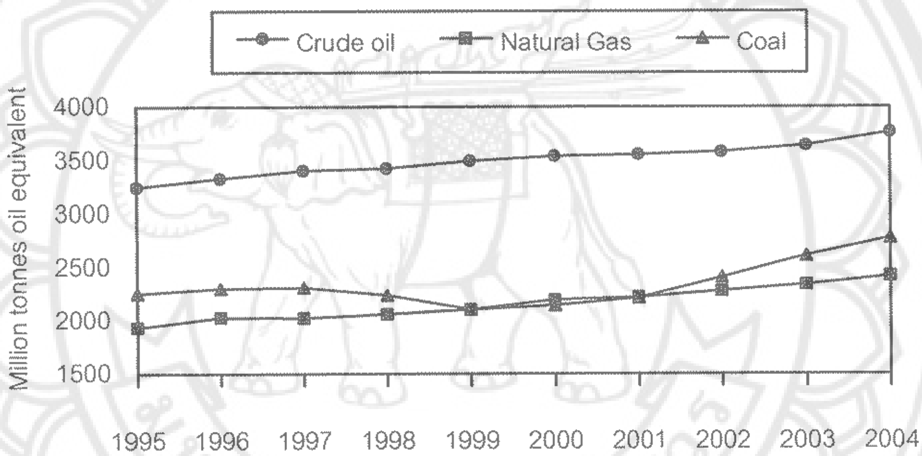

Figure 2 World consumption of fossil fuel, 1995 – 2004

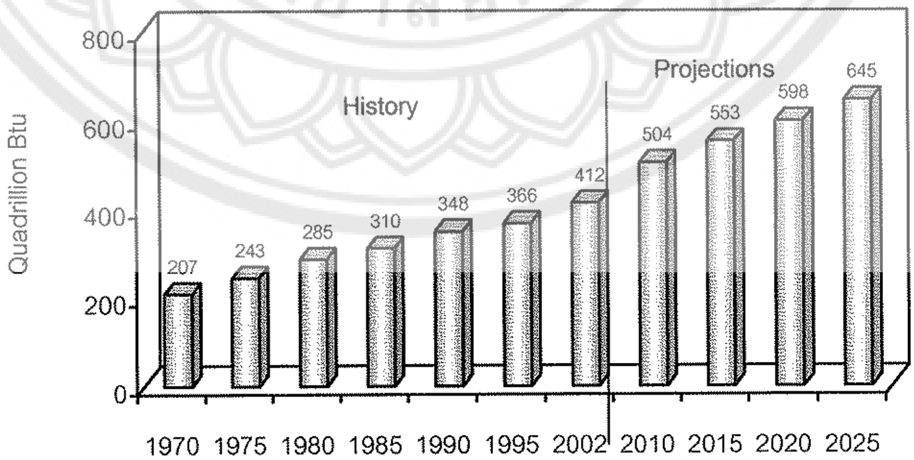

Figure 3 World energy consumption with projections to 2025

As one of the emerging economies in Asia, Thailand's energy consumption and peak power demand are also growing in tandem with its gross domestic product (GDP).

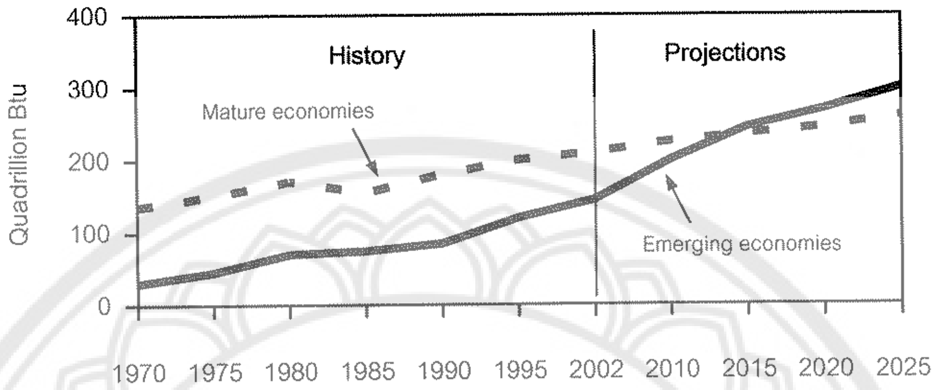

Figure 4 World energy consumption: mature vs emerging economies

Presently, Thailand has to import nearly half of its commercial energy needs. This amounts to about 300 billion Baht (USD 7.5 billion) annually. Up to a third of this energy is used for power generation. DEDE (2002) [3] projected peak power demand to increase from 19,000 MW in 2003 to 30,000 MW in 2011 and total electricity generation to rise from 118,000 GWh to 200,000 GWh during the same 9-year forecast period. The current growth rate of power demand is greater than 10%. This translates to an annual investment of about 50 billion Baht (USD 1.25 billion) for the construction of power plants, transmission and distribution systems to cope with the additional demand of more than 1,000 MW per year [4].

1.2 Outline of Thailand's Power Sector

Currently, Thailand's main power producer and supplier is the state-owned Electricity Generating Authority of Thailand (EGAT). EGAT's share in the production of electricity amounts to about 66% while the balance 34% is contributed by Independent Power Producers (IPP) and Small Power Producers (SPP).

Although there is a plan for the eventual privatization of EGAT by the Thai government, this option was rejected by the union and some interest groups in 2005 and the plan is temporarily put on hold. At present, EGAT supplies electricity to almost all its consumers through two authorized distributors; Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA). The MEA delivers electricity solely to the Bangkok metropolitan areas while the PEA is responsible for distributing electricity to the rest of Thailand (Figure 5).

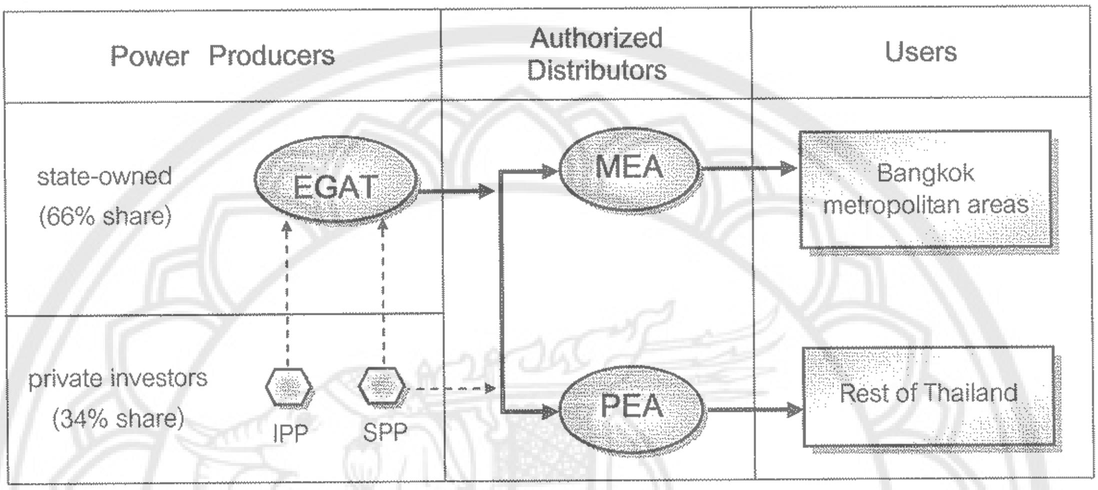

Figure 5 Power production and supply in Thailand

In general, the characteristics of the power sector in Thailand can be summarized as follow:

(a) State-owned and state-managed, with limited private entrepreneur involvement.

(b) Policy and decision-making are in the hands of a small group, with little grassroots participation.

(c) Consisting mainly of large multi-megawatt central power stations (CPS).

(d) Uses conventional delivery method, i.e. centralized generation with long distance transmission for meeting both base load and peak demands.

(e) Power generation uses mainly fossil fuel-dependent technology.

To-date, electricity produced by both state-owned and private power plants that are fossil fuel-fired account for more than 70% of the total generated capacity [5].

1.3 Statement of the Problem

A growing population and an expanding economy means that more electricity will be needed to satisfy increased demands. Although the status quo in the power sector has served the electricity needs of Thailand well, the situation will become severe in the years ahead due to higher price volatility and uncertainty in fossil fuel supply.

Thus, to contribute to the long term energy security of the nation, the government is encouraging the increased usage of renewable energy. On 28 August 2003, a workshop on "Energy Strategy for Competitiveness" organized by the Ministry of Energy established, among others, a strategic plan for renewable energy development. Some of the measures prescribed in the plan include: (a) for new power plants, at least 4% of their generation capacity must be generated by renewable energy, (b) provide incentives to encourage the purchase of power generated by renewable energy, (c) support research and development on renewable energy so that the outcome of R & D can be applied to actual implementation, and (d) encourage participation of the local communities in renewable energy-fueled power plants.

Of all the types of renewable energy available, solar and biomass have the highest exploitable potential in Thailand [6]. For example, the Department of Energy Development and Promotion had found that the total amount of agricultural residues was about 61 million ton a year, of which 41 million ton or the equivalence to about 426 million MJ of energy was unused [7],[8]. Hence, it is possible to operate biomass-hybrid parabolic trough solar power plants (BSPP) in suitable sites, given the vast abundance of biomass resource in the country [9],[10].

While there are some examples of solar PV power station [11] and rice husk-fueled steam engine power system [12] in the country, no working unit of the BSPP has been designed and installed in Thailand thus far. Just like other renewable energy systems such as solar PV generator, wind turbine, hydroelectric station and biomass power plant, the BSPP can function as an additional alternative to the existing conventional method of electricity production (Figure 6). However, there is still a lack of knowledge about BSPP currently and more research in this subject is needed.

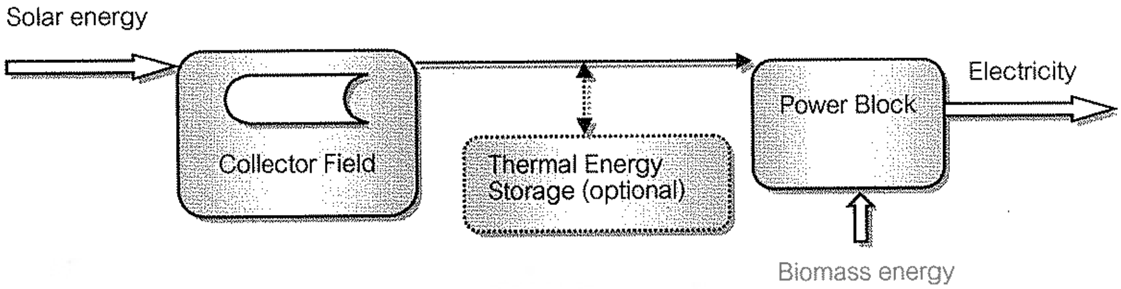

Figure 6 Block diagram of a basic BSPP system

1.4 Rationale of the Study

There are good reasons as to why a renewable energy system like the BSPP can be an alternative technology for power generation in Thailand. Some of its versatility and benefits are summarized as follow:

(a) A BSPP uses solar energy and agricultural residues (which are renewable, generally free and nonpolluting) as input energy to generate electricity. It does not require fossil fuel to operate.

(b) A BSPP operates using a combination of parabolic trough collector and biomass gasifier, both of which are proven technologies with low technical risk.

(c) The BSPP can function as a small-scale power plant of 1.0 MW or less, producing and dispatching electricity on-site. It can be integrated with a thermal energy storage system to extend generation capacity, and grid-connected to ensure reliability.

(d) Many units of BSPP can be installed in suitable sites on the basis of *"One Tambon One Power-plant"*. An aggregate installed capacity of several thousand MW could result in substantial energy cost saving and reduction in CO_2 emission in the long term.

(e) BSPP technology fits well with the government's strategic plan for renewable energy development. It can contribute to the nation's energy security and, at the same time, promote involvement of the local communities in renewable energy-fueled power plants.

Despite the above-mentioned advantages of the BSPP, more knowledge and local know-how must be acquired before the technology can be implemented. Although there are available information about parabolic trough solar power plant in other countries, those systems operated in conditions which were generally different from that of Thailand. Hence, there is still a need to carry out local studies in order to gain the experience that is specific to our conditions. It is because of this reason that the School of Renewable Energy Technology (SERT) installed a 50-m long industrial-scale parabolic trough collector at the Energy Park (known as EPC) for research purposes.

The parabolic trough collector (or solar trough) is the most important component in the design and operation of a solar thermal power plant. This is due to the fact that the energy input into other components of the power plant is dependent on the thermal output from the solar trough, which in turn is determined by the solar energy input it receives. Hence, by knowing the thermodynamic behavior and performance of the solar trough, the parameters for the rest of the power plant can be established. Since a solar thermal power plant is a relatively complex & costly system, it would be useful to have a mathematical model for preliminary analysis and parametric studies, prior to the design and construction of the actual power plant.

1.5 Purpose of the Study

The purpose of this study is to create a mathematical model for a proposed small-scale (20 kW_e) biomass-hybrid parabolic trough solar power plant (BSPP), which can be used as a simulation tool for performance analysis and parametric study.

1.6 Scope of the Study

A solar thermal power plant is a complex system and would require a multi-disciplinary approach, involving civil, structural, mechanical, electrical, safety and process control engineering expertise, for complete analysis. But in this study, only the thermodynamic aspect of the BSPP is considered and the scope of work is as follow:

(a) To develop a semi-analytical model for a proposed 20 kW_e BSPP based on the thermodynamic study of the flow and conversion of thermal energy in the power plant.

(b) To monitor and measure the fluid exit temperatures of the trough collector (EPC).

(c) To validate the collector system (CS) model by comparing the experimental fluid exit temperatures with the simulated values.

(d) To develop a solar radiation (SR) model for Phitsanulok province.

(e) To evaluate the thermal performance of the collector using the mathematical model.

(f) To demonstrate the usefulness of the mathematical model as a tool for analysis and parametric study using the fluid mass flux and collector area as case studies.

1.7 Limitations of the Study

The following limitations are set in order that the scope of study can be fulfilled:

(a) This study is done based on the climatic conditions of Phitsanulok province.

(b) The design point for the rated power of the proposed power plant is set at 20 kW_e.

(c) In the gasifier system of the mathematical model, rice husk is used as an example of an agricultural residue.

(d) In the proposed power plant, adiabatic condition between components is assumed. Parasitic losses in the piping, pumps and valves are not considered.

(e) This study does not consider the civil, structural and mechanical engineering aspects of the power plant. Only the mass & energy transfer balances and thermodynamic behavior are considered.

(f) This study does not consider the process control of the power plant. Every operation is assumed to occur automatically.

(g) This study does not consider the electrical engineering aspect of the power plant or how the power plant is to be coupled to the load or utility grid.

1.8 Location of the Study

This study takes place at the Energy Park of the School of Renewable Energy Technology (SERT) within the campus of Naresuan University in Phitsanulok province. Phitsanulok is situated 380 km north of Bangkok and about 400 km to the south of Chiangmai. The climate of Phitsanulok is generally hot & humid and can be broadly divided into two seasons; a mostly dry period from November to April and a relatively wet season from May to October, with annual rainfall slightly over 100 cm [13]. The annual average daily global insolation for the province is 5.14 kWh/m^2.d [14] which is slightly higher than the national average of 5.06 kWh/m^2.d for the entire country [15].

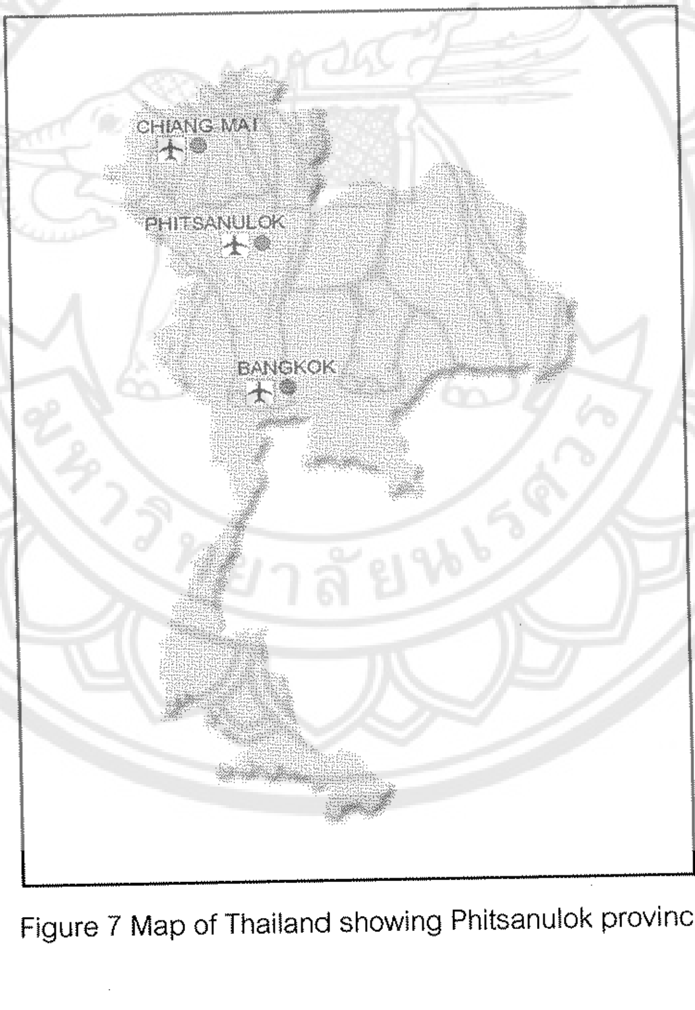

Figure 7 Map of Thailand showing Phitsanulok province

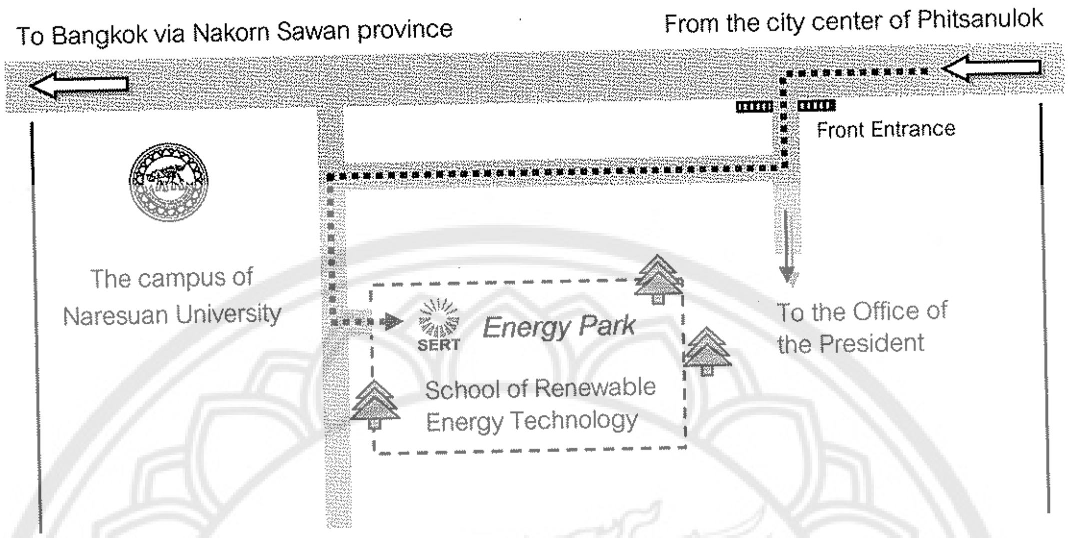

Figure 8 Location of the Energy Park at SERT in Naresuan University