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Modelling Electricity Generation in Malaysia using IMEM: Initial Results

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ABSTRACT

IMEM, which stands for Integrated Malaysian Energy Model was developed to model the Malaysian Energy system that compromises all energy resources, transformation and technologies involved. Factors such as economic, environment and demand sectors are also included in the IMEM. For this paper two main natural resources used to generate electricity namely crude oil and natural gas have been highlighted. Three types of crude oil and one type of natural gas are commonly used to generate electricity and distributed to the demand sector. A linear programming optimization has been used to maximize the projection of demand for reliable electricity supply for 5 and 10 years. Findings indicate that the electricity generated is sufficient and able to supply all the demands. The demand sectors for electricity in Malaysia are identified as residential, commercial, industrial, transportation and agricultural domains.

Keywords: IMEM, electricity, mathematical modelling, energy, supply, demand

INTRODUCTION

The requirement for electricity and its consumption in a country is directly linked to the nation's energy policy which enables the country to provide an efficient electricity generation and distribution. Other factors involved would be the availability of natural resources to generate electricity. This will also be linked to energy systems used by certain countries to maximize its energy and electricity usage and currently many countries all over the world are moving towards green energy and green technology. Among the usage for electricity system models include, as a tool for electricity analysis to manage and plan the electricity system as well as for trade and generation expansion planning purposes (Foley et. al., 2010). In Malaysia the demand for electricity has grown along with its economic growth where the demand for electricity in 2007 was 89,000 GWh compared to only 141.3GWh in 1949. In 1979 the National Energy Policy was implemented where long term energy objectives and strategies were introduced to ensure efficient, secure and environmentally sustainable supplies of energy. Electricity sector was also included into this National Energy Policy (Thahirah, 2009).

Figure 1 below shows the input involved in electricity generation in Malaysia for 2008 where 62.8% is from natural gas, followed by 27.3% for coal and only 0.1% for crude oil (Energy Commision, 2009). A similar case is evident in India where 35% of its natural gas consumption come from the electricity sector, causing it to become a high priority in government's policy making (Shukla et. al., 2009). In the more local context, Malaysia's supply of natural gas and crude oil are extracted from offshore wells and processed in refineries before distributed to electricity power plants for the generation of electricity.

There are a lot of electricity power stations in Malaysia which are used to generate the need of more than 3174 kWh (NEB, 2006). The focal point of this paper lies on electricity generation from natural gas and crude oil where among the biggest gas-fired power stations are the Sultan Salahuddin Abdul Azis Power Station in Selangor which generates 2420 MW, Lumut Power station in Perak which generates 1303 MW, Sultan Ismail Power station in Terengganu which generates 1139 MW and

Tuanku Jaafar Power station in Negeri Sembilan where it generates 1500 MW (souce;Wikipedia). One of the oil-fired power stations that generate electricity is the biggest station, named the Gelugor Power station in Penang which generates 398 MW. The objective of this paper is to present the projection using the IMEM for generation of electricity using two main natural resources that are the crude oil and natural gas in Malaysia.

THE INTEGRATED MALAYSIAN ENERGY MODEL (IMEM)

Structure of the IMEM

The IMEM consists of three main components: Energy Supply Module for all energy carriers; Energy Conversion and Technology Module; and Intermediate Module. For detailed explanation of these modules please refer to previous papers presented by the researches involved.

Equations Involved

Linear programming is used to build the IMEM where hundreds of mathematical equations have been tested to simulate the result.

The general form of linear programming model can be cast as:

$$\text{Max(min)} \quad c^t x_t$$

subjected to:

$$A_i\, x_t \leq b_t$$
$$x_t \geq 0$$

where x_t is the decision variables while $c^t x_t$ is the linear objective function and $A_i\, x_t \leq b_t$ are a set of inequalities constraints, where t and $i \in \{1,\ldots n\}$.

These equations involve all types of crude oil and natural gas used in the IMEM, as well as all the transformation processes and technologies involved. The demand sectors considered in the IMEM are divided into industrial, transportation, agricultural, residential, commercial and non-energy domains.

The constraints are: (i) the availability of natural resources, (ii) the capacity of crude oil and natural gas refineries to process these natural resources, (iii) the capacity of power generation plants, (iv) the price of crude oil, natural gas and electricity and (v) discount factor provided by the Malaysian government. Thus having considered all the constraints the objective function of this mathematical model for generating electricity is to maximize the difference in export and import and demand for natural gas, petroleum products and electricity. Mathematically the objective function is written such as:

$$\text{Max} \sum 1/3(\text{export-import}) + 2/3 \text{ demand}$$

Finding & Discussion

The result of the analysis is presented in the projection of 5 and 10 years for two types of natural gas and three types of crude oil in terms of electricity generation, extraction, import as well as export of petroleum products.

Extraction of Natural Gas and Crude Oil

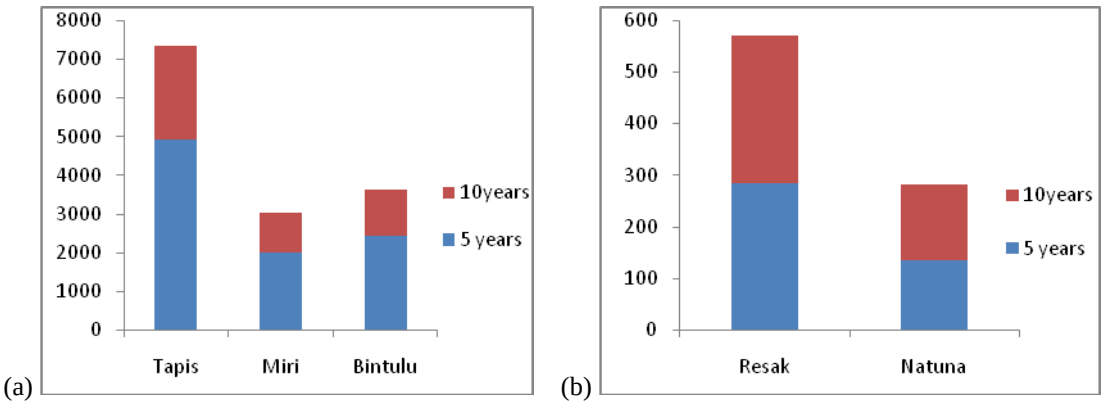

FIGURE 2: The Extraction of Crude Oil and Natural Gas

Figure 2(a) shows the extraction for Tapis Blend, Miri Light Crude and Bintulu Crude where the average extraction for 5 years projection for Tapis Blend is 4896.38 PetaJoule(PJ) while Miri Light Crude is 2006.71 PJ and Bintulu Crude is 2408.55 PJ. For 10 years of projection Tapis Blend is still the highest to have been extracted at 2448.19 PJ followed by Bintulu Crude at 1204.28 PJ and Miri Light Crude at 1003.36 PJ. Figure 2(b) illustrates the extraction of natural gas of Resak and Natuna where the extraction increases steadily for the period of 5 and 10 years with the average of extraction for 5 years 285 PJ for Resak and 134.83 PJ for Natuna. For the projection period of 10 years, the average extraction is the same for Resak while for Natuna is the average extraction is 146.57 PJ.

Import of Petroleum Products

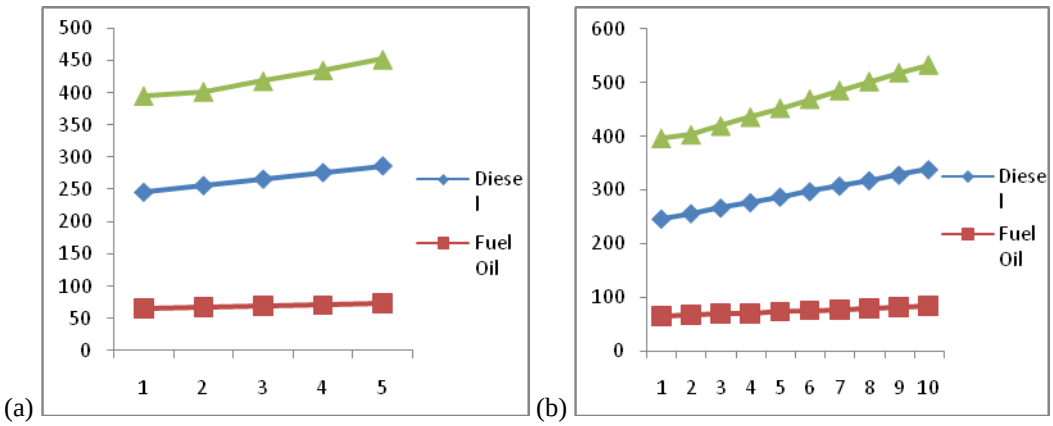

FIGURE 3: The Import of Petroleum Products

For petroleum products which are Motor gasoline (Mogas), diesel and fuel oil they are imported, while other products are exported since the local need for the products is sufficient. Figure 3 (a) shows the projection for 5 years while figure 3 (b) highlights the projection for 10 years. All three of these petroleum products show an increase in import while the imports of other products are at 0 level.

Export of Petroleum Products

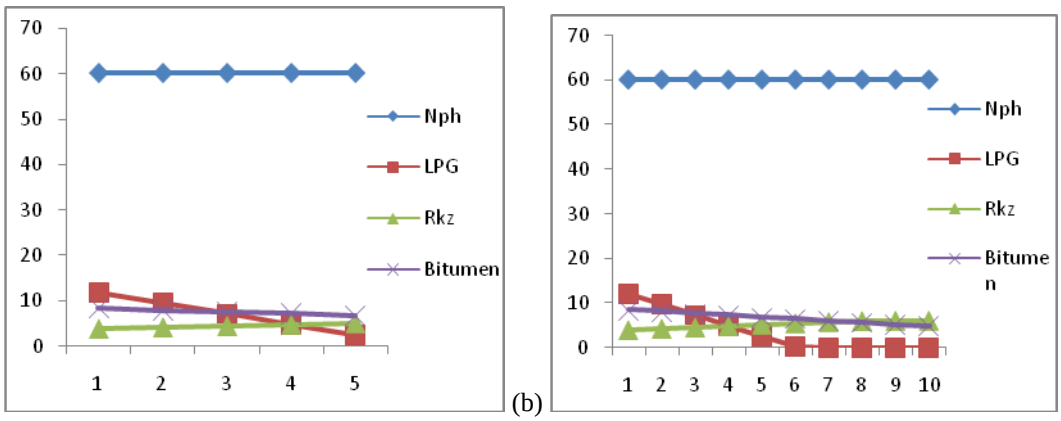

FIGURE 4: The Export of Petroleum Products

Figure 4 (a) and (b) illustrates the export of four petroleum products - naphtha, liquefied petroleum gas (LPG), raw kerosene and bitumen. The projection for Naphtha remains constant for 5 and 10 years at 60.12 PJ while the projection for LPG and bitumen has shown a decline. Export for LPG starts at 11.95 PJ and continues to decline slowly until it reaches 2.58 PJ at year 5 and remained at 0 for the last four years for 10-year projection. Bitumen also declined its export value starting from 3.96 PJ and ends up at 4.86 PJ for 10 years projection. Raw kerosene is exported at 3.96 PJ and increases steadily until it reaches 5.19 PJ at year 5 and continues up to 6.11 PJ at year 10.

ELECTRICITY GENERATION

In this model, the focus is on fossil fuel such as diesel and fuel oil, and natural gas as an input to the electricity generation. At this stage of research, the model seems to provide output only for diesel-powered electricity generation where the projection for 5 years time period is that it starts at 31.88 PJ, followed by 33.19 PJ and increases steadily until it reaches 37.13PJ for t=5. The same scenario is noted for the projection of time period of 10 years where the input for diesel-powered electricity generation starts at 31.88PJ for the first year with the same value as for 5-year projection, whereby the values continues to increase to 38.44PJ and 39.75PJ for year 6 and 7, respectively. Finally, it reaches 43.69PJ when t=10. This electricity is distributed to the demand sectors where the demand sectors embody residential, transportation, commercial, industrial and agriculture domains. This does not reflect the actual electricity scenario of Malaysia since this model is still undergoing a few corrections and is still unstable.

CONCLUSION AND FUTURE RECOMMENDATION

It could be concluded that the present electricity generation in Malaysia is sufficient to satisfy the needs and demand from the populace. Further work is being done on this model to include other inputs to electricity generation inputs such as coal and renewable resources, as exemplified by the hydro system.

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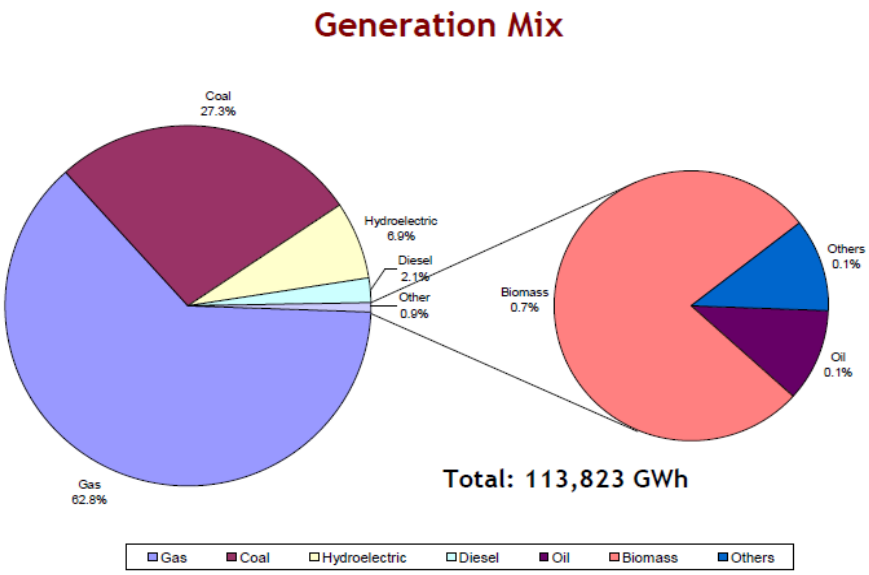
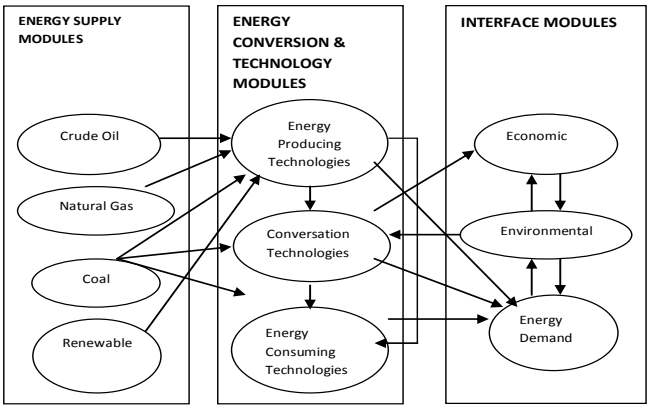


FIGURE 1: The generation Mix for Electricity Generation in Malaysia for 2008



FIGU**R**E 2: Framework of the IMEM