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THE DEVELOPMENT OF INTEGRATED MALAYSIA ENERGY MODEL: A REFERENCE ENERGY SYSTEM (RES) APPROACH

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ABSTRACT

Energy models developed by international institutions specifically address national and international issues surrounding the current energy environment. In particular, the first world oil crisis of 1973-1974 had prompted many countries to review the existing models and develop new models in an attempt to study the impact of high oil prices to the economy. Various types of models were developed with varying structures and objectives that range from single fuel to multi-fuel models linking to the economic sectors either through exogenously specifying the energy demand or endogenously computing from economic models. Malaysia's involvement in adopting world energy models dated as early as 1980's. Models such as WASP, ENPEP, LEAP, MARKAL and MAED were used, but with the exception of WASP (used by the power sector), the other models suffer serious limitations and weaknesses in analysing Malaysia energy scenarios. This is due primarily to data insufficiency and mismatch between model structure and local energy system. Thus the model gave unreasonable energy projections that Malaysia can not tolerate. Besides that, the local human expertise, to handle such models is lacking. In view of the current dynamic and fragile world energy environment, Malaysia has to develop its own energy model and this paper will discuss some methodological approach toward that development.

Keywords: energy resources, energy policy, energy models, reference energy system, linear programming.

INTRODUCTION

The need to develop comprehensive energy models and its related infrastructure requires no further justification as the energy scenarios in Malaysia are dynamically changing according to national as well as international aspiration and awareness. The energy sectors was once regarded as an intermediate sector is now considered as a major economic sector. The introduction of competition in the power supply sector (IPP and TNB generation Sdn. Bhd.) coupled with the restructuring of electricity sector marked a shift in paradigm in the electricity market. In years to come, a consumer is allowed to select its own electricity company for power supply. In the international scene, the singing of Kyoto Protocol in December 1997 obliged certain developed countries reduced the emissions of greenhouse gases by 5% below their 1990 levels. Malaysia in one of the signatories to the Kyoto Protocol.

Malaysia's involvement in serious energy planning is at an infancy stage. In the 80's a Switz energy consultant company (MOTOR COLUMBUS) was engaged in cooperation with local counterpart to study the long term energy plans for Malaysia, but the recommendations cannot be out rightly implemented due to massive investment requirement. In addition, an extra of RM2 million is needed to purchase the system for further use and analysis of the model. Thus the model was then abandoned. Another attempt was made in early 1990 when a national team comprising members from PETRONAS. Ministry of Energy, Telecommunication and Post, Ministry of Transport, Nuclear Energy Unit, local universities and Tenaga Nasional Berhad (coordinator) was formed to study energy plans using Energy and Power Evaluation Program model (ENPEP). Developed by Argonne National Laboratory USA, ENPEP is a micro-computer based energy planning model. It provides the user with comprehensive evaluation of energy system development strategies using several other sub modules such as model for analysis of energy demand (MAED) and Wien Automatic System Planning Package (WASP). Several energy scenarios were used for energy projections until year 2010. However, based on Malaysia case study, the team concluded that ENPEP suffers serious limitation and weaknesses in analyzing Malaysia's unique energy situations {6}.

Market Allocation Model (MARKAL) developed jointly by FKA a German energy institute and Brookhaven National Laboratory New York (BNL) is yet another model being adopted by Pusat Tenaga Malaysia (PTM) to study the long term energy planning. Under the ASEAN-AUSTRALIA Economic cooperation programme, the local participants comprising of officers from PETRONAS, TNB, Ministry of Telecommunication, Post and Multimedia, local universities, PTM were given 2 one week intensive course on model descriptions, simulation and data bases. Efforts were made to input Malaysia energy data but the model detailed description prevented the running of the model due to the lack of data. The basic trust of the model is on cost minimization which is an LP based and this is not in accordance with the objectives of our national energy policy. Furthermore (at least in the US), MARKAL was never used in government policy development simply because clear-cut policy objectives have not been previously identified and defined. The modeling of energy system should evolve from policy questions being raised by government and not the converse.

Another model used by the government is the long range Energy Alternatives Planning System (LEAP) developed by the Stockholm Environment Institute. Adopted by more than 150 countries worldwide, LEAP is an integrated modelling tool that can be used to track energy consumption, production and resources extraction and at the same time account for both energy sector and non-energy greenhouse gas (GHG). It is intended as a medium to long term modeling tool (20 to 50 years) designed around the concept of long-range scenario analysis. The results of the scenario study the long term energy analysis for Malaysia revealed that the recommendations cannot be implemented due to several policy reasons. However, the experience in using LEAP had given enough capacity building to young Malaysia energy planner.

Based on the experiences of using foreign models, it was concluded that several major "renovations" to the world models must be made before some meaningful and practical results could be obtained. Thus it was decided that instead of embarking on major renovation, a new model should be developed specifically to analyse the Malaysian energy system

ENERGY POLICY MODELING

Energy policy modelling should be viewed in the context of energy policy analysis which entails an option to meet energy needs of a particular society. The consequences of policy option, choices of particular energy resources, policy research analysis (decision making) are some of the pertinent issues raised in policy analysis which is not a straight forward task. However, energy models can provide effective tools in energy policy analysis. The use of a model can reflect complex system in an understandable form. Besides helping to organize large amount of data a model also provide a consistent framework for scenario analysis. In a "bird-eye" view, a model is a simplified representation or abstraction of some aspect of the real world. It describes the system in term of its components, variables, parameters, internal and external relationship. Thus a model should be able to provide a framework for organizing data and assessing the impact of changes in system variables and parameters. Since model building begins with addressing specific questions or hypothesis relating to the national and international issues, no single model can answer all questions related to energy without the use of other sub models embedded within the overall energy model. The development and use of several energy sub models could be viewed as complementing each other. Thus, model building is not an esoteric art, but it is a matter of clearity about the issues raised, knowledge of relevant concepts and methods, experience and plain common sense. Energy modeling is central to the energy planning and policy analysis and should perform the following fundamental tasks:

- Assisting in the evaluation and analysis of impact (economic, environment, society) of alternative energy policy option.
- Helping in answering "what if" types of questions relating to energy policy option.
- Realistically capturing features which emerge at the interface of energy and the economy and should provide coherent framework for resolving of those issues.

Thus in achieving those tasks, a modelling team should be well equipped with the following understanding and requirement.

- Policy context. In the Malaysian case it is National Energy Policy (NEP) and various strategies derived from the NEP.

- The interaction between energy, economy and the environment. Environment is an added dimension of the energy studies recently due to international as well as national awareness of environmental degradation due to energy consuming and production processes.
- Organization and working of the economy both at macro and micro levels.
- Methods of representing energy system in terms of their components and the underlying relationships.
- Special features of various types of energy as a unique economy commodity.
- Supporting energy modelling infrastructure such as data information system, software package for optimization and human capacity building.
- Optimization methodologies or techniques.

TYPES OF ENERGY MODELS

Energy models are traditionally classified according to its characteristic i.e the single fuel models and the multi –fuel models which can further classified into models that are formerly linked to an economic model and those that are not (pure multi-fuel models). The former classification deals with issues like resources exhaustion time, matching of resources supply and demand, generation and distribution of electrical energy and the short term effect on resources stock pilling in the case of supply interruption. Energy models developed by several world agencies are as follows:

1. Single Fuel Models such as World Energy Modelling, World Petroleum modelling, Simulation of Future Oil Flow.
2. Multi- Fuel Models such as Modelling New Zealand’s Energy Systems, ENERGETICOS (Mexican energy system), energy Flow Optimization Model (EFOM) and MARKet Allocation (MARKAL).
3. Multi- Fuel Model with linkage to Economic Model such as US Energy Policy and Economic Growth Model, Energy Technology Assessment-Macro Economic Growth (ETA-MACRO).
4. Multi-Fuel Models with linkage to Economic and Environmental Model such as Energy Environment Economy Model of Europe (E3ME), World Energy Model-ECOnomic (WEM-ECO) Model.

The basic modeling technique used are system dynamic and linear programming while the space and time dimension of these models extend from a nation to the multinational boundary of the non-communist world and from the short to the long term planning horizon respectively. Other single fuel model is the natural gas depletion model developed by The British Gas Corporation. Aimed at exploring alternative strategies for the depletion of the natural gas resources using an LP optimization technique, it offers flexibility in making formulation changes, and also allows further insights into the problems through the examination of the dual values.

Multi fuel models generally analyse the total effect of energy system on the sectors of the economy, the inter fuel substitutions and the impact of the external trade on energy consumption. The possibility of finding new energy sources, technological breakthrough in alternative energy, energy consuming and producing processes are some of the common features of the models. Of course, the structure of these models is increasingly complex as many types of fuels and processes enter the energy system. However, these models are classified as pure multi –fuel models solely based on the fact that the linking to the economic sectors is made through the exogenous specification of the useful energy demand. MARKAL (original version) and NZES are not linked to economic model, but ENERGETICOS is linked to DINAMICO (a multi sectoral planning model for Mexico). Specific features of these models are

- Energy – Economic Interaction: the prospect that rising energy cost and limited supplies will prevent the economy from achieving its full potential GDP growth.
- Cost-effective conservation: will be explicitly modelled for the possible realization of energy mix strategies.
- New supply technologies: taking into account the various environment issues and difficulties facing the introduction of alternatives such as nuclear fuel.

A FRAMEWORK OF THE MALAYSIAN ENERGY MODEL (MEM)

As indicated earlier and in other modeling strategies, the ultimate trust of the model development is based on the model users rather than model developers. One of the major impediment in implementing models as quantitative tools in decision making is the inability of the users to comprehend the mechanics as well as mismatching between the model purpose and user objectives. Experiences with MARKAL for instance tell us that the model is not used by the US government in energy planning studies simply because the policy objectives are not set by government. Thus policy objectives in developing MEM must be clearly identified and defined.

The primary objective of MEM is to fully develop the nation's own energy model by taking into consideration of our unique economic structure, demographic composition, technology assets that are consistent with socio-economic and environment objectives. In addition, MEM should be able to produce short, medium and long term energy forecasts and energy development plans and also to ensure energy investment decision can support the nation to achieve sustainable development. The gist of developing MEM is to enable the users to forecast short, medium, and long term energy mix as well as to plan for energy development activities. Surpassing these objectives, the development of MEM must be consistent with the National Energy Policy objectives. They are stated as:

- Supply objective: to provide the nation with adequate and secure energy supplies by reducing the dependence on oil by developing and utilizing alternative energy resources.
- Utilization objective: to promote and encourage efficient utilization of energy and discourage wasteful and non-productive pattern of energy consumption.
- Environment objective: to ensure that in achieving the two objectives, the environment is not neglected.
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Based on these policy objectives, various other strategies such as Four Fuel Policy, Petroleum Depletion Policy and Fifth Fuel Policy which put biomass as an energy component were derived.

Characteristics of MEM

In the course of developing MEM the model should possess the following characteristics.

1. Exhaustive account of all energy carriers: the model should be able to account all types of energy carriers available presently and also in the future at least during the planning horizon.
2. Flexibility: some degree of model flexibility should be maintained in the context of adding and deleting energy systems that are available. As such nuclear energy which may dominate Malaysia energy scenario by the year 2020 may be accounted for in this model.
3. Introduction of Competition: Long term energy plans, called for better vision of the future. Thus all types of energy carriers (present, future, imported domestic), energy conversion technologies, energy producing technologies are allowed to compete in order to achieve a global optimization.
4. Scenario Analysis: Central to any model building, scenario simulation studies are key elements in any energy policy analysis. The uncertain global energy situation may lead one to analyse the effect of such changes towards Malaysia energy plans in the short to long term planning.
5. Stepwise Development: The development of an energy model must be made dynamically. A stepwise development is proposed such that the introduction of several types of energy, and technologies should be made as the model optimization allows such an introduction.
6. Data Maintenance: Several supporting tools, computer packages, technological, economic, natural resources data base should be created and maintained to enable the model accessing new information.
7. Optimization Technique: The choices of any optimization technique should be able to cater the needs and purpose of the model and its users.

Based on these guiding principles, a reference energy system (RES) methodology is considered as an appropriate technique. It traces all primary energy flows from its sources to destination (demand), after undergoing several transformation and conversation processes.

RES METHODOLOGY

The Reference Energy System (RES) is a network representation of all of the technical activities required to supply various form of energy to end-use activities. Analytical techniques are described to examine all operation involving specific fuels including their extraction, refinement, conversion, transport, distribution and utilization. Each of these activities is represented by a link in the network for which efficiency, environment impact, and cost coefficients may be specified. The network is quantified for a given year with the level of energy demands and the energy flows through the supply activities that are required to serve those demands {1}. In the an area of energy planning a decision maker is always faced with many technical options and policy options which have specific and distinct effect on the efficiency, cost and environmental attributes on the energy systems. Comprehensive analysis on technical and policy option includes industrial process studies, economic analysis, transportation, conversion, and health impact of pollutants. In most cases of energy studies RES was developed for that purpose, may it be at the national, country and regional level policy analysis. Furthermore RES allows for insertion of specific policy option that may affect the energy system and the assessment of alternative energy technologies and energy strategies.

Framework of the Medium-long Term Malaysia Energy Model

The following pictorial representation gives us the framework of Malaysia medium-long term energy model using the RES methodology. It consists of three modules, namely energy supply, energy conversion and technologies and interface modules. Arrows linking several modules represent the flows of energy carriers from sources to demand modules and also the interaction between various energy economic and environmental activities. The model is cast as a network flow theory using the feedback loops as depcited in diagram 1.

Energy Supply Modules

The energy supply module consists of several energy resources. They are crude oil extracted from offshore wells (domestic crude) and imported crude. Another energy supply module consists of natural gas supply which can be classified as domestic non associated gases, domestic associated gases and non domestic gas (joint venture between Malaysia and Thailand). Coal supply module will utilised basically imported coal from Australia and Indonesia while domestic coal will not play important role in our energy system since its deposits is small and of a low quality. Renewal energy supply will be from biomass and hydro potential.

Energy Conversion AndTechnology Modules

Several energy conversion and technology modules are considered based on the current available technologies. They are energy producing technologies comprising of different types of refinery and hydro cracking facilities which caters local and imported crude. Gas processing plants are compact natural gas (CNG) facilities and gas processing facilities while coal processing plants will clean to coal before it is used in the power plants. Conversion technologies considered are all power plants types either by independent power producers as well as TNB. They are basically gas, diesel and hydro plants. Heavy consuming technologies are cement industry (heating and cooling technologies).

Interface Modules

The interface modules are economic, environment and energy demand modules. In the economics module various economic parameters are considered in order to forecast the energy demand for specific industry while the environmental modules will set permissible pollutants emission levels by the energy consuming technologies. Green house gases are also considered in this module. The energy demand will give the energy demand by energy products according to sectors. These sectors also link to the environmental and economic modules.

OPTIMIZATION TECHNIQUE (OT)

Even through several optimization techniques could be used in running of the model (general equilibrium, simulation), the appropriate optimization technique is the linear programming (LP). It fulfils the basic characteristics of RES methodology, besides being able to assess the dual/shadow price of any energy carriers. Optimization technique uses linear programming to identify energy system that provides the best alternative of providing energy services for specific demand. It is performed under various constraints generated by the linear programming routine. Least cost solution had been the basic optimization criterion use by MARKAL, EFOM, and WASP.

CONCLUSION

Energy system consists of integrated set of technical, economic and environment activities operating within our complex society. As energy environment is subject to uncertainty, as a result of regional political instability, research and analysis in energy system modelling and forecasting had grown rapidly. Energy system modeling uses theoretical and analytical method from several disciplines including engineering, economic, operation research and management science. Techniques of applied mathematics and statistics used by the model include mathematical programming in particular linear programming and integer programming, econometrics and network analysis. Studies on Malaysian energy systems and its linkages to the other sectors of the economy can be traced way back in the early 1980’s. The use of several foreign energy models proved to be of less relevance in developing Malaysia energy plans. Energy modelling is a complex, sophisticated and tedious assignment, but in the Malaysian national interest it has to be done.

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DIAGRAM 1 : Reference Energy System For Malaysia