# INDONESIAN ENERGY POLICY PATHWAYS: FROM PAST TRENDS TO FUTURE ALTERNATIVES

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Resource and Environmental Planning

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# Abstract

The main achievement of this thesis has been the development of an operational system dynamics model of the Indonesian energy system. This model attempts to *integrate* a wide range of data so that policy-makers can understand the connections between economic, environmental and energy policy objectives. This is the first such model to be developed for Indonesia, building on previous modelling efforts that have been restricted to regression-based forecasting and optimisation modelling.

The first part of the thesis provides a systematic analysis of background data, information and the context for the model development. These chapters review the historical and political context of energy developments in Indonesia; review past energy policies as well as emerging energy policy objectives; analyse the determinants of energy demand (by regression and divisia decomposition methods) and review energy supply options. The regression analysis concluded that GDP and household income had the most significant effect on energy demand. The effect of fuel price rises, on the other hand, did not exert a significant effect on energy demand. The divisia decomposition method found that, over the entire Indonesian economy, technical change was found to give a greater contribution to energy efficiency improvements (as measured by the energy:GDP ratio) than structural changes.

The system dynamics model was developed and validated using the extensive data collected, refined and analysed in the first part of the thesis. The model consisted of an economic module (17 sector input-output model), energy demand module, electric power module, heat and transport fuel module, primary energy supply module and an environmental module.

Five scenarios were developed from this model in order to analyse possible energy development pathways for Indonesia, over the 1998-2020 period. These scenarios reflected five themes Business-as-Usual, Environmentally Beneficial, Economic Efficiency, Self-Sufficiency and Balancing Trade-Offs. These scenarios were assessed using a number of policy evaluation criteria to measure various energy, economic and environmental policy objectives. All of these scenarios indicated that Indonesia's energy demand and hence $CO_2$ emissions will grow significantly over the scenario period, even if Indonesia introduces some quite stringent polices to restrict these trends – eg, $C0_2$ emissions are expected to increase by 189% under the 'Business-as-Usual' scenario; and even though they can be reduced to a 85% increase under the 'Environmentally Beneficial' scenario, this is still a significant and

somewhat alarming increase in $CO_2$ emissions. The scenarios also highlighted the trade-offs between different sets of policy objectives as an aid to energy planning and policy-making.

Finally, further areas of research that could improve the model and its use were identified: improving the data on energy supply and demand (particularly the end-use characterisation), endogenise the economic growth dynamics into the model rather than depending on regression analysis, possibly converting the input-output structure into a computable general equilibrium model, including more sectoral detail, making the model at least partly spatially-specific, and investigating more participatory approaches for further developing the model so as to enhance its uptake.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Need for an Integrated Approach to Energy Policy Development

Indonesia, with a population of 210 million in the year 2000, is the fourth most populous country in the world after China, India, and the United States. A rapid increase in economic activity and population growth over the last two decades (especially before the Asian Economic Crisis in 1997) has brought about an escalating demand for energy for domestic purposes. Of particular concern is the rapid growth in oil consumption which has not been balanced by new oil reserve findings. The oil reserve is depleting while the need for oil exports for foreign exchange earnings has to be maintained to support economic development. As a consequence, in the not to a distant future, Indonesia is predicted to have to change its status from an oil exporting country to an oil importing country (BAKOREN, 1998). This change of status will undoubtedly have significant impacts on the economy given the important role oil has played in the economic development of Indonesia for more than 10 decades.

Rapid changes in the economic structure, from an agricultural based economy to industrial based economy, have further escalated the energy demand growth. The country is still heavily (more than 60 percent at present if biomass is excluded) dependent on oil to drive domestic economic activities. Government attempts to diversify the source of energy supply (shifting away from oil) as well as to conserve energy, have been largely unsuccessful. The oil share of the total domestic energy mix (biomass excluded) is still large - it was 64 percent (in 1984) and has only dropped to 60 percent (in 1998) despite the energy diversification efforts, which have been in place since the 1980s (DGEEU, 2003). The transport sector which is still heavily dependent on oil (more than 90 percent) is the main reason for the slow progress in energy diversification.

Many of the most pressing energy issues in Indonesia have been addressed, but this reaction is not based on robust analysis of energy policy options. It could be argued that many energy policy decisions have not sufficiently or appropriately addressed the energy problems and worse still have even been counterproductive as they have resulted in additional economic, social and economic costs for the government. The financial problems and heavy foreign debts amounting to Rp. 40.5 trillion (US $ 4.76 billion) in 2000 faced by PLN (The State

Owned Electricity Company) is an example of poor management and unwise investment decisions in electricity project. Most energy projects, like new refineries and power-plant installations in the country, were the results of government decisions that were made without a comprehensive and integrated plan involving related energy institutions. Lack of economic considerations in the project analysis and the heavy influence of political decisions have characterised the decisions on project installations leading to further ineffectiveness in Indonesia's energy supply performance (Asia Times, 2004). There have also been serious questions linking the impact of increasing economic activities, technology development, energy prices and population growth to energy demand and supply that need to be addressed and analysed.

Experience in the past showed that any change in energy policy direction (e.g. adjustments to energy prices, shifts to alternatives like nuclear, or policies directed at the environmental aspects of energy utilisation) had unexpected and unpredictable effects. Energy price increases had profound flow on effects, not only to the Indonesian economy, but also influenced the social and political situations.

Hill (1996) argued that the process of policy making in Indonesia is inefficient and lengthy. With respect to energy policy Prawiro (1998) contended that the policies often look 'spectacular' on the surface but are void of substance and do not serve any real purpose.

Given the complexities and connectiveness of different aspects of Indonesian energy policy, there is need for an integrated approach. A continuation of past ad hoc and piecemeal approaches to energy policy formulation and implementation will lead to outcomes that don't best serve Indonesia. An integrated approach requires that the whole range of economic, social and environmental values be considered and evaluated. Further this integrated approach requires that the connections and trade-offs between these values need to be understood so that informed policy decisions can be made. It is important however to distinguish between an integrated and comprehensive approach to policy and planning. By definition, comprehensive means all-inclusive. In contrast, the integrated approach while similar to the comprehensive approach, does not seek to analyse all components and interconnections, but concentrates on those that are critical to the policy issue or set of issues being analysed.

The rational--comprehensive approach in planning has been widely criticised for ignoring the political dimension of policy making (Alexander, 1992). In Indonesia as in other countries, politics has played an important role in shaping energy developments and energy policies. Examples include the cancellation of the removal of energy subsidies by President Megawati only several weeks after it first was issued in the first week of January 2003. The cancellation was aimed at maintaining political stability due to the many protest rallies by university students in Java. Secondly, the postponement of gradual (every quarter year) electricity tariff adjustments which were to take effect in 2004 and 2005 for the reason of maintaining political stability especially during the parliamentary and presidential election. This will further increase the government financial burden as electricity subsidies amounting to 4.4 trillion rupiahs in 2003 (DPR, 2003). Another example is the cancellation of the proposed nuclear installation which was planned to be built in Mount Muria (Central Java) in 1998, due to harsh public opinion and protest by environmentalists.

Given these political realities, the integrated approach being pursued in this thesis will initially focus on the the political history of energy policy in Indonesia, to provide the context to inform the selection of the modelling approach and the type of policy issues that need to be considered.

There are a number of specific energy policy issues that need to be addressed within an integrated framework - eg: (i) Can domestic oil utilisation (especially in the industrial sector) add more value to the economy? (ii) Can domestic energy demand be met sufficiently with available national resources? (iii) With emerging environmental concerns, can economically 'friendly' environment policies be formulated for the energy sector?

## 1.2 Need for a Modelling Approach to Aid an Integrated Approach to Energy Policy

Energy planning and policy formulation in Indonesia is the responsibility of the Ministry of Energy and Natural Resources. Energy policies, and the planning and decision making process in the energy sector by this Ministry, has so far been based on:

1. simple energy modelling techniques such as regression analysis - eg, the sectoral energy studies described by BAKOREN (1992).
2. optimisation approaches (such as MARKAL)

These approaches have several weaknesses. The regression approach assumes that past trends will continue into the future which is not always true in real life. In general, this approach fails to explain the structural changes which might happen in the future. This approach cannot explain the determinants for energy demand. Because the approach can not accommodate the feed-back interactions between energy and the economy, it is not suitable for energy policy analysis (Yusgiantoro, 1999).

The MARKAL approach also has weaknesses. MARKAL is a supply-side planning model. Thus, it relies on the exogenous input of the results of the 'demand forecast' of other models. The difficulties occur when the forecasting demand of other models are inaccurate. MARKAL is also considered to be a model which poorly represents the 'rest of the economy'. In addition MARKAL neglects the feed-back effects of emission reduction policies on the rest of the economy, and does not capture demand – price interactions (LPEUI, 2003).

Almost all of the pressing energy policy issues in Indonesia, have not been addressed using a reliable integrated energy policy model that clearly explains the impacts of various policies on economic factors (such as prices), technologies, environment, lifestyle, GDP, population and so forth. As a result, many energy problems have not been sufficiently or appropriately addressed and have even caused unintended economic and social consequences. Issues associated with the increasing population, greater economic activities and rapid technological changes in almost all sectors make the challenges of the energy problems more complex and provide the impetus for a better modelling approach that can integrate the changes and provide alternative policy solutions.

This thesis develops a system dynamics energy simulation model, as an alternative to past modelling approaches, specifically so that the different elements of energy policy (economic, environmental and social) can be evaluated in an integrated fashion. A system dynamics energy simulation model can address a wide range of relevant policy issues in a constantly changing environment, and estimate the relative impact of policies in a consistent and widely accepted manner. Specifically, the advantages of the system dynamics approach are :

1. Unlike other approaches it is capable of simulating *future scenarios*. An energy policy decision made today will have future impacts on the economy and on such factors as the long-term level of energy reserves. System dynamics models are specifically designed to simulate such impacts, so that the policy maker can foresee future problems and issues. Importantly, the system dynamics approach does not seek to define 'optimal' future policies (as in the MARKAL approach) but provides a tool whereby policy makers can explore future policy options and decide for themselves what is the preferred course of action.

2. System dynamics models are based on a *systems approach* that emphases the interconnectivenees of real world issues – this is in contrast to the regression-based approach which is more reductionistic. Systems concepts such as interdependence, feedback, hierarchy, and uncertainty are recognised and accommodated in this approach.

3. System dynamics models (that use packages such as STELLA or Vensim) are *highly transparent*. They use graphical and iconic interfaces that can easily be understood by the non-expert. This is unlike many other modelling approaches (such as MARKAL), which are highly technical, and difficult for non-expert to understand. The transparent and user-friendly nature of such models enables end-user to explore policy options in a truly interactive fashion.

## 1.3 Research Aims and Objectives

### 1.3.1 Overall Aim

The main aim of this thesis is to develop a system dynamics modelling tool for evaluating future energy policy options for Indonesia in an integrated fashion. The modelling tool will be used to generate a range of indicative energy policy scenarios for Indonesia. *Chapters 2 to 7* provide the background data, information and context for the model. These chapters: review the historical and political context of energy developments in Indonesia; review past energy policies as well as emerging energy policy objectives; analyse the economic, social and technological determinants of energy demand; and finally analyse the energy supply dynamics. *Chapters 8 and 9* draw all of these analyses together in the development and application of a system dynamics model of the Indonesian energy sector and economy. Five indicative policy scenarios are developed from this model: 1) business as usual, 2) environmentally beneficial future; 3) economic efficiency; 4) self sufficiency; and 5) balancing the trade-offs.

### 1.3.2 Specific Objectives

The specific research objectives for this thesis are to:

1 Review the history of Indonesian energy developments and associated policy responses. This review will mainly cover the post World War Two period.

2 Review the current Indonesian energy policy framework. This will cover the current institutional and legal framework; the process of energy policy-making and planning; and the emergent policy objectives in Indonesia.

3 Review the Indonesian energy supply and demand patterns over the last 20 years. This will cover primary energy supply patterns, consumer (delivered) energy use and the end-use of energy.

4 Analyse market and social determinants of energy demand. This will include the impacts of GDP growth, energy prices and lifestyle.

5 Analyse technological determinants of energy demand. This involves an analysis of the penetration rates of new demand-side technologies as well as analysing improvements in technical energy efficiency in the Indonesian economy.

6 Analyse energy supply dynamics and determinants. This involves an analysis of the penetration rates of new supply-side technologies and their economics.

7 Build a system dynamics model of the Indonesian energy system. The model will be built by linking a number of modules (sub-models): Economic module (I-O matrix of the Indonesian economy), Energy Demand Module, Electric Power Module, Heat and Transport Fuel Module, Primary Energy Supply Module and Environment Module.

8 Develop energy policy scenarios for Indonesia using the above model. This will involve developing five indicative scenarios for Indonesia that emphasise different sets of policy objectives.

## 1.4 Structure of the Thesis and Methodological Approach

In order to achieve the research objectives the structure of the thesis will be as follows:

*Chapter Two* critically reviews the history of Indonesian energy developments and policy. This involves understanding the influences of economic and political factors on past energy policies. The aim of this chapter is to learn from the past failures and successes of the management of the energy sector in Indonesia.

*Chapter Three* provides reviews of the energy policy framework of Indonesia. This review initially focuses on the country's institutional and legal frameworks for energy policy formulation. Emerging energy policy objectives (and their operational measurements) are then critically discussed, with the aim of providing direct input into the policy modelling process in Chapter 8. This review of policy objectives will also be very important in helping the author to design the policy scenarios in Chapter 9.

*Chapter Four* presents an overview of the historical Indonesian energy supply and demand patterns. This includes analysing its historical trends/patterns, so as to understand the main energy issues facing the country in the past and present and project likely issues in the future. The chapter also provides information about the country's energy resources, how they have been utilised in the past and what may remain in the future.

*Chapter Five* provides an analysis of past patterns of energy demand in Indonesia. Regression-based methods are used to quantify the main economic and social determinants of energy demand in Indonesia. The results of this analysis will be used to build a correlation between demand and other significant variables/determinants in the system dynamics model developed in Chapter 8.

*Chapter Six* provides an analysis on the current and future status of demand-side energy technologies, including a review of their market penetration rates. Improvements in technical energy efficiency at the aggregative level are also measured using the Divisia decomposition method.

*Chapter Seven* provides an analysis of the country's current and future status energy supply-side energy technologies, based on current international and domestic developments. This includes a brief review of the economic feasibility of primary energy and renewable energy technologies and their penetration rates.

*Chapter Eight* describes the system dynamics model of the Indonesian energy system. The overall modelling framework is outlined along with the equations that make up the model. This model draws together and integrates data and information from chapters 2 to 7. It also discusses the advantages and limitations of the model and further (future) works needed in the model development.

*Chapter Nine* provides a discussion on the philosophy of the scenario approach and an analysis of the results. It also presents a series of indicator variables that can be used in modelling the policy scenarios. The chapter compares the results of one scenario to another as well as suggesting what would be the policy implications and decisions required to deal with the problems that emerge from each scenario.

Finally, *Chapter Ten* summarises the thesis discussion, and draws possible conclusions from the whole 9 chapters. This chapter will also discuss the future work required for the advancement or improvement of the model.

The methodological approaches to addressing each of the research objectives, and the consequent of the research structure are given in the following table 1.1;

**Table 1.1 Research Objectives and Methodological Approaches**

| No. | Research Objective | Methodology | Chapter |
|---|---|---|---|
| 1. | To review the history of Indonesian energy developments and associated energy policy responses. | Critical literature review with the objective of understanding the causal links between the Indonesian economic/political trends and their impacts on the energy policy and management. | **2** |
| 2. | To review the state of the Indonesian energy policy framework. | Critical literature review to examine the Indonesian current institutional and legal framework, planning strategies, the process of policy-making in the energy sector and the emergent energy policy objectives in Indonesia. | **3** |
| 3. | To review the Indonesian energy supply and demand patterns over the last 20 years. | Data analysis of the historical primary energy supply patterns including resource potentials, import and export, consumer/delivered energy and end-use energy. The review will include new and renewable sources of energy (NRSE). | **4** |
| 4. | To analyse market and social determinants of energy demand. | Multiple regression models will be used to analyse the determinants of energy demand by primary energy types and sector demands. The correlation between the energy demand and GDP growth, energy prices, populations, electrification ratio, lifestyle and income will be researched | **5** |

continued ......

| | | | |
|---|---|---|---|
| 5. | To analyse technological determinants of energy demand. | Approaches: (1) data analysis of penetration trends and technology-specific energy efficiency trends (2) extension of the divisia decomposition method developed by Ang and Choi ( 1997), to quantify improvements and aggregate-level technical energy efficiency. | 6 |
| 6. | To analyse energy supply dynamics and determinants | Data analysis of penetration trends of supply-side technologies and the impact of new technologies. Economic analysis (current and projected) of primary energy supply options including NRSE. | 7 |
| 7. | To build a system dynamics model of the Indonesian energy system. | Building a system dynamics simulation model using STELLA software.<br>Input-output matrix to describe flows in the Indonesian economy. | 8 |
| 8. | To develop energy policy scenarios for Indonesia using the model | Analysing the results of the model runs in accordance to various policy scenarios. Scenario methodology as promoted by Schnaars (1987) and Fowles (1978) | 9 |
| 9. | To summarise the whole thesis discussion | Drawing together the conclusion of the whole 9 chapters and to discuss the future work required for the improvement of the model | 10 |

## 1.5 Scope, Assumptions and Limitations of the Study

Some of the data used in the system dynamics energy model is drawn from regression/econometric models. Future projections were done based on the coefficients and correlations obtained from these regression models – this has to be approached with caution as these *correlations and coefficients may change in the future.* Although these correlations and coefficients accurately describe past trends, it is axiomatic to the scenario approach used in this thesis to not automatically assume that past trends will continue into the future. Nevertheless, the regression coefficients provide a good point of departure for many of the scenarios developed in this thesis.

*Data limitations* is one of the crucial issues to be resolved in using this system dynamics energy model. As in many other developing countries, the availability of appropriate data for the Indonesian economy is the most difficult problem facing the modeller. While data does exist, mostly it is not relevant to the specific modelling needs. For example, a lot of data on electricity generation costs and investments is available, but most has little relevance to the modelling needs and modelling problems at hand.

*The Level of aggregation required to build the model reduces its accuracy* To build the model, the author aggregated economic sector or processes, and the energy demand as well as the energy type in accordance to the data availability. It is difficult to produce a model with more micro aggregation better suited for the Indonesian-energy system, again for the reason of data shortages.

The model has to some extent been built to include major economic-energy-environment elements. However, due to data limitations, it has not considered a geographical or regional approach. The model assumes there is only *one national energy system*, which is not divided into island economies, like Sumatra, Java, Kalimantan, Sulawesi etc. This is despite the fact that Indonesia is an archipelagic country comprising of thousands of islands. Further refinements to the model need to include the regional approach, which will have to be taken into account when future work is done.

In building this model, due to the time-constraint, the *objectives of the study were not sufficiently defined.* Not all energy related decision-makers (from coal, natural gas, oil divisions etc.) were consulted for defining the objectives. For future works, refinements on the model are needed, based on well-defined objectives, involving the views of the related decision-makers of the system or sub-systems under study. The modellers should be aware of the decision-makers' goals and objectives, in order to ensure maximum utility of the model output.

*The Model validation* or the matching of the model with the real world system, is particularly difficult for this economy-energy-environmental study. In structuring this model, all the best possible understanding of the economy-energy-environmental phenomena is incorporated and then validation is done in the following steps. First, the validation of the model structures which consist of economic, energy demand, energy supply and environment modules, then followed by the validation of model behaviour which involves various parameters and indicator variables in each module. Because of the difficult nature of validation of this complex energy-economic system under study, the model was only partially validated, or it was validated only within some prescribed limits of uncertainty. This may limit the accuracy with which decisions based on the model may be made. There is clearly an urgent need for more theoretical work on the estimation and validation of this relatively complex model system and the involvement of all related experts, with an understanding of and sympathy for, energy system developments.

*The Choice of time horizon of the model* has been made based on inadequate information available to guide this preference. The model chose 20 years of time horizon for the projection of energy demand and supply. It is possible that if this choice of time horizon is inappropriate (the time horizon is too long or too short), it may lead to important points being missed in terms of the requirements for policy-making analysis, because the selection of the time-horizon is also dependent on the nature of the simulation modelling objectives. It is acknowledged that when building this model, the objectives of the study were not sufficiently defined, as not all energy decision-makers (from coal, natural gas, oil divisions etc.) were consulted. For future works, refinements on the time-horizon need to be done based on clearly defined objectives, involving the views of related decision-makers of the system or sub-systems under study.

Although the model is relatively comprehensive there are *two particular areas in need of priority attention*: 1) the assumption of fixed coefficients in the input-output matrix of the economy, and 2) the model has a demand-side orientation in which the supply-side and energy investments are inadequately considered. The future revisions of the model should pay particular attention to these limitations.

*There is a need for a more participative approach.* Modifications to the model may have to be made to better reflect the needs or to better accommodate the aspirations of decision-makers. In future work, it is anticipated that the model developers will work closely with the decision-makers and regularly present the results of the model, its interpretations and analysis. The modelling software (Stella, Vensim) is ideally suited to a participative approach. This type of approach was however not achieved because the model was developed for a PhD thesis in a country other than Indonesia.

Because of all these limitations the model must be considered ‘a preliminary model’. Most importantly the data needs to be refined and improved, and the model needs to be developed and applied in closer collaboration with policy end-users. Notwithstanding this comment the author contends that the model is already providing a useful and robust tool for analysing future energy scenarios for Indonesia. Furthermore, it is unlikely that the model in its current state of development will give false results given the effort put into preparing the data in chapters 2 –7. Also the transparent nature of the model makes any errors and assumptions very obvious to the user.

# CHAPTER TWO

# HISTORY OF INDONESIAN ENERGY DEVELOPMENTS AND POLICY

## 2.1 Analytical Framework

The history of energy supply, its use and the policy responses described in this chapter are of importance for several reasons. *Firstly,* by understanding the history, past mistakes in policy implementation can be minimised or avoided. *Secondly,* we can learn what challenges, barriers, failures and successes, the past management of the energy sectors faced so that in the future we can be more prepared and be more effective in dealing with energy problems. In this way, a more appropriate and pertinent energy policy to solve similar energy problems in the future can be formulated. *Thirdly,* history will deepen our understanding about the causal link between various policy objectives and what impacts they may bring to the total management of the energy system. Experience shows that past changes in energy policy direction (e.g. energy prices, shift to an energy alternative like nuclear, environmental aspects) had unexpected and unpredictable effects, and sometimes had (unintended) adverse political and economic outcomes.

It is argued in this thesis that there are four main phases in Indonesia's energy policy development. *The first phase is the Dutch Colonial Era (1602 – 1942).* The energy policy during the Dutch era was characterised by the excessive exploitation of the country's wealth of natural resources (including oil and coal) for the industrial development of the Netherlands (Barnes, 1995). This view is also confirmed by Lindblad (1989) and Schouten (1995). Schouten (1995) as cited in Booth (1996, p. 3) states:

> *".... Oil, and to a lesser extent coal, were certainly major reasons for Dutch intervention in Central Sumatra and South Kalimantan at the close of the nineteenth century."*

*The second phase is the Japanese Era (1942 – 1945).* The acquisition of natural resources, mainly oil and gas to support the Greater East Asia War was the major reason for Japanese occupation. The severity of impact was lessened by the relatively short (3.5 years) occupation (Sato, 1996).

*The third phase is the Sukarno's Era (1945 – 1966).* During the Sukarno era, the energy policy was very much influenced by his centrally controlled government and strong nationalistic foreign policy. Foreign investments including those into energy industries were restricted in this era.

*The fourth phase is the Soeharto's Era (1966 – 1997).* Contrary to the Sukarno era, the Soeharto era was characterised by decisive efforts to attract foreign investments and foreign aid. During this era, a series of measures were implemented to help the country embark on a new and increasingly successful path of economic development. Measures included permitting the return of foreign investment through joint schemes and affirmation on repatriation of profits (Barnes, 1995).

The influences of economic and political policies during these four eras are discussed in this chapter, to get a better understanding of their impact on the energy policies enacted during those eras.

## 2.2 Dutch Colonial Era (1602 – 1942)

### 2.2.1 Government and Economic Influences

The colonial policy of the Dutch era was largely influenced by the Dutch wish to exploit natural resources. Furnival (1939) argued that the original objective of the Dutch coming to the Indies was for trading and later for the trade monopolies and not for the acquisition of wealth. However, it is evident that the original objective was diverted into the exploitation of the country's wealth. This was the consequence of the long period of colonization which took place over almost three and half centuries. The Dutch supremacy exploited the country's wealth with little regard to the social and economic wellbeing of the natives as Barnes (1995) puts it:

> *"Dutch colonial rule was harsh, even by comparison with other colonial powers of the day, and always had the basic aim of extracting as much as possible of the natural resources of the islands for the sole benefit of the Netherlands"* (Barnes, 1995, p. 3)

**The Dutch Supremacy and Accumulation of Wealth**

How was 'Dutch supremacy' built? Furnival (1939) describes how the establishment of the Dutch supremacy happened through a long process and the gradual expansion of occupied territories. Firstly, the Dutch established the East India Company (VOC) in 1602, which was not a purely private endeavour as it was sponsored by the State and the Civic Corporations. In order to secure trade with the Spice Islands around the Indies, it established a base in Java. Then the VOC had to secure this base by annexing and ruling the adjacent area. This annexation naturally led to the building up of protected states and a process by which independent states gradually reduced to a position of dependent states.

The accumulation of wealth developed naturally as a consequence of Dutch interest in maintaining their trade monopoly in the region. Furnival (1939) described the process of wealth accumulation as follows. Originally the Company was just an association of commercial ventures, dependent on the favour of native rulers for their trade. It then, gradually became a trade prince, the chief political power in the region, and dependent for its revenue mainly on forced deliveries and tribute from local people. As a trading Company, revenue was initially generated from trading profits, but later trade profits were transferred into tribute as the main source of revenue, as the Company gradually built its trade supremacy. The Company forced the natives to provide free of charge a certain percentage of their total produce, e.g. 5%, and pay other contributions in kind on the same scale. Natives were also required to give compulsory services, which may be considered as a form of taxation. Thus revenue was for the most part collected in kind. The Company's policy remained the same throughout its history, though practice varied from time to time and place to place.

**The Dissolution of the VOC and Establishment of the Batavian Republic**

The East India Company (VOC) was dissolved at the beginning of nineteenth century, the 1st of January 1800. Corruption was argued as the main reason for the fall of the company. According to Furnival (1939) although outwardly the Company's wealth accumulation respectably progressed, inwardly the company was 'corrupt'. The Company was living on its reputation, and suddenly it crashed. The possessions of the Company, together with its debts, amounting to f. (Gulden) 134.7 millions, was taken over by the Batavian Republic which was the name given to the Netherlands when it was under French occupation. The Batavian Republic became the Kingdom of Holland in 1806 under the domain of Napoleon Bonaparte's brother Louis and Dutch administration then continued until the Dutch were forced to leave Indonesia in 1942.

**Liberal Economic Policy and Ethical Policy Introduced**

The liberal economic policy aimed at improving the agrarian welfare of the native people was introduced in 1870. In line with international development of liberal economic policy, administrative and political reforms were carried out in the early 1900s, with the purpose of establishing a more constructive policy for improving the welfare of the people throughout the archipelago. Administrative reform through the reconstruction of Ministries was conducted to accommodate the tremendous expansion of state activity and more away from laissez-faire policy. Political reform was also carried out through the so-called 'ethical policy' with the objectives of improving the material welfare of the indigenous people, strengthening the native social order, and encouraging unification of society (Furnivall, 1939). According to Wertheim (1956), the effort was not only based upon humanitarian considerations alone but also industrial interests. It was argued that, the ethical policy was a fruitless effort as the actual goal was making the Dutch administration more efficient and enhancing trade and export for the benefit of the Netherlands. The ethical policy was intended to expand the education system turning more bright young indigenous people into physicians, engineers, clerks, lawyers and economists. However, this open door policy for education was not balanced with opportunities for careers and jobs. As a result, the ethical policy provoked racial discrimination, which caused the greatest source of resentment in the colony (Cribb & Brown, 1995).

**Poor Social Wellbeing Provoked Native's Resentment and Antipathy Toward the Dutch**

The profits accumulated by the Dutch were not balanced by any corresponding move to improve the social wellbeing of the native people. Imports and exports during the Dutch era developed rapidly, however, this material accumulation did not improve the standard of living of the native Indonesian (Palmier, 1962). Booth (1996) confirmed that the native Indonesians remained poor despite the very obvious signs of economic development in Java by the early twentieth century. Palmer (1962) also argued that income discrimination was also the main source of antipathy toward the colonial government. Booth (1996) stated that the per capita Indonesian GDP was 20 percent of that in the Netherlands in 1920 and this gap grew even higher by 1950. This gap was caused by the very organized exploitation of the wealth of the Dutch Indies for the advantage of the Netherlands' economic development.

**The World's Industrialization Accelerated Mineral Exploitation**

Another important development was the industrialisation of the world, which brought about the acceleration of mining mineral deposits in the outer islands of Indonesia. Most Western countries during the first quarter of the twentieth century were transformed into industrial states. Due to this transformation, the world felt an increasing need for raw materials. Accordingly, the colonial and imperial policy of the great powers was fundamentally affected by the desire to acquire the sources of those raw materials, especially mineral deposits. The colonial policy at that time was to intensify the exploration of mineral deposits all over the colony and the exploitation for all those which guaranteed profits. The most important raw materials from the Outer Islands were for a long-time oil (mainly Sumatra and Borneo) and rubber

### 2.2.2 Energy Policies

Economic and political influences, which occurred during the Dutch colonisation Period greatly shaped the energy policy of Indonesia. This is particularly applicable to the Sukarno era, which adopted a closed-door policy toward the West. The energy policy during the Dutch era was influenced by the need to exploit the country's mineral wealth as much as possible, to support the economic development of the Netherlands. Barnes (1995) confirms that the oil policy during the Dutch era was very much driven by the Dutch interest to make Indonesian oil an instrument to support industrialisation and economic development in the Netherlands.

**The Beginning of the Oil Era**

The beginning of the oil era in Indonesia started about 118 years ago, when the first oil trace was found in Langkat, North Sumatra in 1883, by A.J. Zijker, a Dutch farm administrator. However, it was not until the year 1885, that the first economically exploitable well was found in the Telaga Tunggal by A.J. Zijker. The field was known later as Telaga Said field, and marked the beginnings of Indonesian crude oil production. In 1890 A.J. Zijker's concession was transferred to De Koninklijke Nederlandsche Maatschappij tot Exploitatie van Petroleumbronnen, an oil company in the Dutch Indies known as De Koninklijke. After the success of this the Dutch oil company, other foreign companies including US, Canadian and Japan oil ventures were quickly paying attention to Indonesian oil deposits.

**The Dutch Oil Monopoly**

Realising that the Dutch Indies possessed huge mineral deposits notably oil, the Dutch were attracted to use oil as a vital source of funding to support industrialisation and economic prosperity in the Netherlands. The Dutch government started thinking about extracting oil for the exclusive benefit of the Netherlands and began putting limits on other foreign companies' seeking oil in Indonesia. In order to implement this idea, the Dutch Colonial Government established a new mining regulation, the IMW (Indische Mijnwet) in 1899, to narrow other foreign companies' opportunities to obtain new concessions. Under this regulation, Royal Dutch Shell with De Bataafsche Petroleum Maatschappij (BPM) as its operator, had the monopoly on oil and gas mining ventures in the Dutch Indies (MME, 1995).

**Reappearances of Other Foreign Oil Ventures**

The Dutch monopoly in oil ventures in the Indies did not last very long. The Dutch were criticised by many foreign countries for discriminating against foreign oil ventures. As a response to the Dutch policy, in 1922, the United States issued a *'General Leasing Act'*, which banned the leasing of land in the United States, to foreign companies coming from the foreign countries that applied discrimination toward American companies. As a result of this policy, Royal Dutch Shell faced difficulties conducting its business in the United States. The Dutch Indies Government began to give some exemptions to American companies so they could obtain concessions in Indonesia. Standard Oil of New Jersey founded a subsidiary in the Netherlands called the American Petroleum Company in 1912, later named NKPM. By means of this new subsidiary body (NKPM), Standard Oil of New Jersey was then entitled to have oil and gas mining venture in Indonesia under the New IMW (Indische Mijnwet). The Dutch colonial government then allowed American companies to obtain their first concessions in Java, Madura, and areas near Talang Akar, South Sumatra. Stimulated by the NKPM's success, the Dutch Colonial Government founded a joint venture enterprise with BPM in 1921, named NV Nederlands Indische Aard-Olie Maatschpij (NV NIAM), having the first concession area in Jambi. From the beginning of the Dutch oil era until 1938, there were 437 mining concession rights and exploitation permits granted covering various minerals including crude oil, most of which were in the hands of Dutch companies (MME, 1995).

### Coal and Gas Era

The coal era in Indonesia began in 1849, when NV Oost Borneo Maatschapij (Dutch company) carried out the first coal mining in Pengaron, East Borneo. Over a period of 36 years, it produced some 300,000 tons. In 1850, geologists convened and founded Dienst van het Mijnwezen, to seek for minerals – especially coal. More surveys and explorations of coal were carried in the Indonesian outer islands (Sumatra and Kalimantan) with the help of Dienst van het Mijnwezen. Survey and exploration along the Durian river, West Sumatra, conducted between 1868 and 1873 revealed a potential Ombilin coal mining field. Motivated by the success of the Ombilin coal mining, between 1915 to 1918, the Dutch colonial government, surveyed and explored for coal in the Bukit Asam area, South Sumatra and had another success. In 1940, the Netherlands East Indies produced over 2 million tons of coal and exported 690,000 tons to nearby countries in Asia (MME, 1995).

Unlike oil and coal, the development of natural gas was not significant during the Dutch era. Gas was utilised, when some town gas systems were built. However, this was based solely on coal conversion (Barnes, 1995).

### The Development of the Electric Power Sector

Electric power development in Indonesia began during the Dutch era at the end of $19^{th}$ century, when several Dutch Colonial industries, processing sugar, tea, and agriculture industries, for example installed power-generating units for their own use. Not until 1890, was there any intention of generating electricity for public use with the establishment of the Dutch Private Company, NV NIGM (Nederlands Indische Gas Maatschappij) in Jakarta. The company ran a gas business and then expanded to supply electricity for the public. The company was granted a permit in the form of a "Electriciteits Vergunning" or a Concession, which could be for either a local concession (Plaatselijke concessie) or regional concession (regionale concessie). Electricity generation for public consumption was very profitable at that time, so many Dutch private companies established electricity businesses in Indonesia. It was not until 1927 that hydroelectric generation began in Indonesia, when some hydro power plants were constructed. In this year, the Dutch Colonial government (Staatsblad 1927 No. 419) established "Lands Waterkracht Bedrijven (LWB)", a State Electricity Company, which ran Hydro Power Plants (PLTA) in Indonesia (MME, 1995).

### 2.2.3 Energy Indicators

In 1940, the total domestic oil production in Indonesia was 162 thousand barrels per day, which made it the fifth largest world oil producer after United States, Soviet Union, Venezuela, and Iran. Despite booming industrial output in 1930s, the electricity consumption per capita was very low. According to Booth (1996), annual per capita electricity consumption was only about 6 kWh (in 1939) or less than 2 percent of that of the industrialised countries. For this reason, the Dutch government established a commission to promote the use of electricity in 1939 and pushed ahead with new hydroelectric projects to enhance the supply.

## 2.3 Japanese Occupation (1942 – 1945)

### 2.3.1 Government and Economic Influences

By early 1942 Japan had conquered most of the Southern Regions. On 1 March 1942, General Imamura Hitoshi, leading the Sixteenth Army landed on Java. One week later the Dutch forces surrendered. According to Sato (1956), most Indonesians welcomed the Japanese army and regarded them as liberators from Dutch colonial domination. Only later did it become apparent that the Japanese did not plan to grant independence to the Indonesians. Wertheim (1956) stated that the abundance of natural resources had attracted the Japanese to transform Indonesia into its own colony.

**The History Behind the Occupation**

To gain a clear understanding of why the Japanese occupied the Indies, it is necessary to study the history of the Japanese coming to the Indies. In 1939, Japanese imports of raw material, including oil, from the Indies declined because of restraining measures by the Dutch. Its oil imports dropped from 927,000 tonnes in 1937 to 547,000 tonnes in 1939. As a result, the Japanese became more dependent on the United States to furnish domestic needs and war demands. The share of Japan's total oil imports from the United States grew from 67 per cent in 1935 to 80 percent in 1940. Political relations between the two countries was deteriorating, especially after the second Sino-Japanese war in 1937, which was then followed by the Japan-United States Commerce and Navigation Treaty in July 1939. On the 25th July, 1940, President Roosevelt announced a total termination of oil exports to Japan, but he soon withdrew this statement. From the 28th to the 30th July, the Japanese army moved forward into Southern French Indochina. The Netherlands Indies immediately prohibited all exports to Japan except under licence in protest against the Japanese action. Simultaneously, the United States declared the total cessation of oil exports to Japan (Sato, 1994). In response to this new development, on 25 October 1940 the Japanese cabinet decided the following policy, which read in part:

> *Confirming the inevitability of the emergence of economic blocks as a result of the development of the new world order, as well as the supremacy of the Empire in the Netherlands Indies based upon the Tripartite Treaty, Japan shall endeavour to strengthen her economic relations with the Netherlands Indies to exploit the rich resources, and to make the Netherlands Indies an integral part of the Greater East Asia economic sphere centring around the Empire, in order to achieve the broader objective of co-existence and co-prosperity* (Sato, 1994, p. 7).

Japan invaded the Indies in March 1942.

### The Administration of the Occupied Territories

Immediately after the Japanese army invaded Java, they promised that the administration format be determined separately. However, even after the Japanese surrender, there had never been any concrete guidelines for the administration. There were practically no existing administrative structures anywhere. What the occupation authorities did was remove high-ranking European officials and leave no clear form of government. According to Sato (1994), the untrained occupation forces had to formulate their own policies, based on local conditions and probably merely applied replicas of policies in Japan.

### The Political and Economic Impacts of the Occupation

Although Indonesia made economic sacrifices, politically it gained from the occupation. The Japanese occupation stirred up the political consciousness of Indonesians and built up their motivation to resist the Dutch colonialism and even provided them with the military means of resistance. As Palmier (1962, p.78) puts it,

> *They did what the Dutch colonial regime had never dared to do: they furnished the Indonesians with arms on a large scale and taught them how to use them.*

Barnes (1995) also said that the Japanese occupation, although it paid with a high-price in human terms and with destruction to the country's oil industries, it unexpectedly inspired and strengthened nationalistic movements. Wertheim (1956) argued that the stimulation of national consciousness and the military training during the Japanese occupation was fortunate, because it enabled Indonesia to attain independence.

The Japanese preoccupation with material acquisitions for the war resulted in a total neglect of economic policies for the occupied territories. According to Sato (1994), the military government's only defined economic objectives were for fulfilling the raw material demand for the execution of the war (short-term) and for establishing what was so called 'an autarkic Greater East Asia Co-Prosperity Sphere'. This is evidence that the Japanese were perhaps merely interested in material acquisition, especially oil, and not in improving the social and economic wellbeing of the Indonesians.

### 2.3.2 Energy Policies

During the Japanese occupation, which was relatively short (ending in 1945), the country's oil reserves were significantly depleted, not only by over exploitation, but also by negligence. The Japanese government, in an attempt to collect currency to support the Greater East Asian War, heavily exploited the country's oil and other mineral resources (Sato, 1994). Indonesian crude oil and refineries were looked upon as vital for the running of the Japanese war machine as well as for Japanese domestic needs.

**Oil Acquisition for the Japanese War and Domestic Needs**

After the Dutch left the country, the Japanese found out that the Dutch had inflicted considerable damage on petroleum installations. The Japanese planned to gradually increase the amounts of oil acquisition, taking into account the possible destruction of wells and refineries by the Dutch and the irregular availability of shipping space. According to Sato (1994), the Japanese intended to acquire from the Netherlands Indies 300,000 kilolitres in 1942, 2,000,000 kilolitres in 1943, and 4,500,000 kilolitres in 1944, by increasing crude oil production. However, the Japanese failed to rapidly increase crude oil production. According to Booth (1996), crude oil output in 1942 was less than half that produced in 1938. In 1943, production output was estimated at 6.5 million tons, which was nearly 90 percent of the 1938 level. However, this figure dropped again very rapidly, and in 1945, it was only 850,000 tons.

Many training schools for the oil industry were established, which were aimed at accelerating exploitation activity and boosting crude oil production. This eventually brought about beneficial effects and enabled many Indonesians to gain expertise in oil field and refinery operations which later helped set the foundations for the post-war national oil industry in Indonesia. Training helped to improve skills, and by chance, the nationalism of the oil workers. The Japanese era inspired the present motto of PERTAMINA, the State Oil and Gas Company): 'Learn while you work, work while you learn' (Barnes, 1995).

The exploitation of oil and other natural resources was for fulfilling domestic demand in Japan as well as for the war purpose. This was made clear by the statement of General Imamura in Bandung:

> *"...but oil is an exception. Oil is vital for the execution of the Greater East Asia War, so we must make the effort to meet the (Japanese) national needs even if it may cause inconvenience for the (indigenous) people's transport. Apart from this, the natives' happiness must be the core of our concern."* (Sato, 1994; p. 12).

**Development of Coal and Electricity**

Due to a relatively short period of occupation, not much has been observed regarding coal development during Japanese colonialism. According to MME (1995), one coal related activity that can be considered as important, was the formation of a geological body named Kogyoo Zimusho in 1942, which later changed to Chisitsu Chosajo .

In the electricity sector, a minor development was also recorded. The main event for this sector was the transfer of all electricity and gas companies from the Dutch Colonial government to the Japanese Military authorities at the end of Dutch Colonialism in 1942. For the Japanese colonial government, electricity played an important role in strengthening its occupation. Therefore, they instructed that all of the Presidents of electricity companies, during the Dutch era, be replaced with Japanese people. All of these companies were then merged into one company called Jawa Denki Jigyuo Kosha. Later, after the transfer of the electricity business from the Japanese military officials to civilians (Japanese), Jawa Denki Jigyuo was changed into Jawa Denki Jigyo Sha (MME, 1995).

## 2.4 Sukarno's Era (1945 – 1967)

### 2.4.1 Government and Economic Influences

Sukarno declared the independence of the Republic of Indonesia on 17 August, 1945. Soon after the declaration, he became the first President of Indonesia. The sovereignty of the nation, according to International Law, was formally transferred by the Netherlands four years later in 1949. This was obtained through negotiations at the Round Table Conference in the Hague, in 1949, which was sponsored by the Security Council (Wertheim, 1956). For the people of Indonesia, however, August 17, 1945 remains the important date.

**From Parliamentary Democracy to Guided Democracy**

Long before independence, Indonesian nationalism aspirations were based on the ideal of a liberal-democratic society rooted in Western models. According to Legge (1964), this was developed partly from the Western education enjoyed by many of the nationalist leaders, and also from the revolutionary struggle itself, where a commitment to a common goal made possible an easy cooperation between different elements. After the declaration of Indonesian independence in August 1945, a new government, which followed the pattern of *Parliamentary Democracy,* was established. This pattern, which President Sukarno described at the time as liberal politics and liberal economy, continued even after the four year independence war between 1945 - 1949 (Mody, 1987). According to Legge (1964), Parliamentary Democracy was not destined to survive in its original form for very long in Indonesia, because it does not fit the traditional indigeneous concepts. In February 1957, Sukarno declared to the nation that liberal democracy, Western-style democracy, had failed to meet the particular needs of Indonesia and he imposed *Guided Democracy* which he described as a specifically Indonesian style of democracy. According to Mody (1987), the Sukarno's Guided Democracy can be defined as follows:

> *"...the system of Guided Democracy was justified as one establishing a traditional pattern of authority based on indigenous concepts like mufakat and musjawarah based on gotong royong, rather than one based on the will of the majority. Under it, power came to be determined by Sukarno, justifying the traditional concept of authority in which the leader functioned as the Bapak or benevolent patriach. Pancasila formed the basis of the values on which the Sukarnoist revolution was based. The principles of Pancasila included nationalism, internationalism, democracy emerging from Indonesian conditions, social justice and belief in God – notions sufficiently vague to be extolled by any system of government"* (Mody, 1987, p. 193).

Legge (1964) stated that the principles of Guided Democracy is deliberation and consensus,

> *"In particular, Sukarno wanted political procedures to follow what he believed to be the model of the village, where questions were talked out until a general consensus was achieved. Deliberation and consensus – musyawarah and mufakat – were to be the essential principles of "guided democracy."* (Legge, 1964, p, 15).

**Presidential Decree for Parliament Dissolution**

In July 1959 Sukarno dissolved the constituent assembly and decreed a return to the 1945 constitution, which placed greater control in the hands of the President (Beers, 1970). The return to the 1945 Constitution created a more authoritarian government, as stated by Legge (1964, p. 16)

> *"By contrast with the provisional Constitution of 1950, the Constitution of 1945 was extraordinarily flexible and open in its prescriptions. It prescribed no formal checks on the exercise of presidential authority. It created no framework for the institutionalising of political behaviour. In externals it appeared to establish something approaching a personal dictatorship".*

**Export Oriented Economic Policy**

The economic condition of the new nation at the time was deteriorating due to the complex situation caused by the struggle for independence. The government was heavily dependent on mineral and agricultural products to build and improve the deteriorated economic condition. Foreign investments were also slow in coming and most of them were directed toward material and mineral extraction for export purposes rather than for economic industrialisation. The new state's debt was high, partly inherited from the colonial government in accordance to the Hague's agreement, which granted a formal sovereignty to Indonesia. To pay off the heavy burden of its debt to the Netherlands, the new government had to continue the colonial government policy that emphasized exports.

**Anti-Foreign Economic Interests**

After more than three centuries of Dutch colonial rule, which involved a long history of discrimination and disregard to social-well being, it is natural that many Indonesian nationalists hated everything to do with the foreign interests, especially that of the Dutch. Many foreign enterprises and investments during the era were subject to more restrictions than during the colonial period. According to Wertheim (1956) nationalists also opposed the Indonesian entrepreneurs, political leaders, feudal chiefs and landowners who cooperated closely with the foreign interests. Mody (1987) stated that Sukarno's regime took strong action against US and British interests, including the rejection of American aid. The anti-western attitude was further expressed through the withdrawal of Indonesian membership from the United Nations (UN). Two important events occurred that heightened the political tension at the end of November 1957. The first event was the failure of the UN to pass a resolution on the Irian' issue (West Papua). This prompted Sukarno to warn he would take steps which would startle the world. The second event was the attempt to assassinate Sukarno, supported by the West, further building Sukarno's hatred toward the West (Mody, 1987). The UN disaster triggered anti-Dutch extremism leading to the taking over of Dutch enterprises and business offices on 3 December, 1957. The first victim was the Dutch-owned Royal Mail Stream Packet Company (NKPM). Royal Dutch Shell, one of the Dutch stronghold companies was not nationalised, but on the 5th December, the Ministry of Justice ordered the removal of about 46,000 Dutch citizens from Indonesia.

**Military Involvement Into Political Arena.**

A very important development began when the army started to take control of the seizures of foreign enterprises. The event had given an opportunity for the army to build up its strength position relative to other services and the civilian government. The army focused not only on military functions, but also on taking care of other civilian and government matters, accelerating corruption in the officer ranks (Ricklefs, 1981). The military, during the Sukarno's era, was increasingly drawn into the political arena due to the political ambitions of army officers. The involvement of the army in the political arena and Sukarno only being interested in building popular support for his regime caused economic matters to be somewhat neglected.

### Economic Stagnancy

The political system and economic policies adopted during Sukarno's era aggravated the economic condition of the country. The buying power of the rupiah dropped by fifty per cent. Mody (1987) stated that lack of policy direction and planning, mismanagement and corruption led to economic stagnation. During 1964 and 1965, the rate of inflation was out of the ordinary even by Indonesian standards. The foreign debt position was worse. According to Mody (1987), on 31 December 1965, the total foreign debt reached US $2,358 million, of which the Soviet Union led with $990 million followed by Japan with $231 million and the United States with $179 million. Sultan Hamengkubuwono IX described the economic condition:

> *"As things look at the beginning of 1966, there seems to be little prospect of rapid economic growth in Indonesia. Any person who entertains the idea that Indonesian society is experiencing a favourable economic situation is guilty of lack of intensive study. If we fulfil all our (foreign debt) obligations, we have no foreign exchange left to spend for our routine needs ... In 1965 prices in general rose by more than 500 percent ... In the 1950s the state budget sustained deficits of 10 to 30 percent of receipts and in the 1960s it soared to more than 100 per cent. In 1965 it even reached 300 per cent"* (as quoted in J. Panglaykim and H.W. Arndt, 1966, and Hill, 1996, p. 3).

Under these deteriorating conditions, it is strange Sukarno did not make any tough economic decisions. Instead, according to Hill (1996) he preferred to indulge in uncontrolled government spending, leading to the severe inflation of the mid-1960s. He was financed in his extravagant spending by loans, both from the Communists and the Western capitalist world.

### 'Go to Hell Policy' with Foreign Aid and Investment

Realising he would have to pay a very high political price to secure future economic aid, Sukarno refused the American-backed I.M.F. plan to rehabilitate the Indonesian economy in 1963. He was famous for his 'go to hell with your aid' speech. The escalation of antipathy toward foreign investment accumulated in 1965 when for example, on the 27$^{th}$ May, the law on foreign investments was abolished. The government nationalised more foreign companies followed by the controversial action of its withdrawal from the capitalist world, I.M.F. and World Bank in August 1965 (Mody, 1987).

**The Ill-Planned Coup d'etat.**

The social, political, and economic conditions of Indonesia were deteriorating and near collapse. Inflation was severe, with prices escalating to something like 500 per cent for the year (Ricklefts, 1981). Lev (1996) stated that this provoked demand for reform and reaction against the Guided Democracy's abuses in 1965. Due to dissatisfaction with the regime, many efforts had been made by Sukarno's opponents to topple it. An ill-planned coup attempt was made on the night of 30 September – 1 October 1965. Who masterminded the events and what manoeuvres were arranged behind them was surprisingly unclear and is still debated up to the present time. Ricklefs (1981, pp. 280, 281) commented on the coup:

> *"It seems improbable that there was a single mastermind controlling all the events, and interpretations which attempt to explain events solely in terms of a PKI, army, Sukarno or Soeharto plot must be treated with caution. The attempted coup was typified by extraordinary incompetence and confusion".*

### 2.4.2 Energy Policies

**Anti Colonial and Anti-Western Oil Policy**

As a result of the economic and political influences during the Sukarno's regime, the oil policy was characterised by an anti colonial and anti-imperialist position throughout Sukarno's presidency (Barnes, 1995). Around 1948, before the transfer of full sovereignty of the country from the Dutch, the hatred toward the Dutch Colonial Government and sentiments against Dutch investments in the oil business gradually came to the surface. Many influential elite and politicians did not want the continuation of Dutch assets in Indonesia, including those in the oil business. After the admittance of sovereignty in 1949, all Dutch colonial government shares in NV NIAM were transferred to the Indonesian government. In this year Caltex (a US Oil Company, a joint venture between Chevron and Texaco) re-opened its concession and mobilized its drilling activities in Central Sumatra. A decade later, with the accumulation of sentiments against foreign investment, The House of Representatives cancelled all the concessions and mining rights of oil and gas private companies, including oil and gas concessions which were no longer actively operating, stating that mining rights were only given to State enterprises (Staats Bedrijl).

**The Introduction of a New Oil and Gas Mining Law**

The end of the concession system in Indonesia occurred in 1960 following the enactment of new policy by the House of Representatives. In this year, the government issued the Oil and Gas Mining Law No. 44/1961, which cancelled the concession system and signalled the end of the old oil era in Indonesia. The Law stipulated that oil and gas mining could only be carried out by the state as the holder of mining rights. The Law reformed the foundation and principles of the oil and gas venture which was previously regulated in Indische Mijn Wet (IMW) 1899. With the enactment of this law, the government declared that IMW was no longer in effect (MME, 1995). Following the Oil and Gas Law No. 44/1961, in 1961 the government formed three State Enterprises, which were given the tasks of conducting oil and gas mining ventures. There were PN Pertambangan Minyak Indonesia (PN PERTAMIN), PN Pertambangan Minyak Nasional (PN PERMINA), and PN Pertambangan Minyak and Gas Nasional (PN PERMIGAN). Also in line with the enforcement of the new law, BPM/Shell was liquidated and replaced with PT Shell Indonesia (PT Shell). Shortly after that, the Indonesian government ended the concession of ex-NIAM and purchased the shares of BPM/Shell in PT PERTAMIN (MME, 1995).

**Tokyo Heads of Agreement and the Beginning of Full Execution of Law No. 44/61**

In practise, the government faced a very difficult situation to enact the new oil and gas mining law. Many foreign companies opposed the Law and blamed the government for applying discriminatory policies toward foreign interests. The government was very concerned about the slow progress enacting Law No. 44/1961 and issued a State decree, setting the end of the transition period for foreign oil companies as 15 June 1963. The affected companies had to adapt their operations to the current mining laws. The companies faced two choices, either continue their operations, or leave Indonesia. As a follow up to this act, the government and oil companies came to an agreement called 'Tokyo Heads of Agreement' in 1963. This agreement set up new terms to be integrated into the contracts of work with the three companies involved (PT Shell, PT Stanvac and PT Caltex). Each of the three foreign oil companies gave away their old concession rights and, as a substitute, they were awarded 20 year contracts and accepted to act as contractors to one of the active three-State Oil Companies (PN Permina, PN Pertamin and PN Permigan), or the right to go on developing in the old concession areas. More significantly, they were allowed to apply for 30 year contracts to explore and develop new areas near their existing operating areas (Barnes, 1995). The Tokyo Heads Agreement stated that the profit shares between the government and foreign companies were to be set at 60% : 40%. The oil companies were obliged to provide free to the government a minimum of 20% of annual production. In addition, the oil companies were required to supply oil to domestic consumption in a certain ratio, which is less than 25% of its total oil production. For this contribution, the oil company receive compensation costs and an additional service charge of US$ 0.20 per barrel. Three foreign oil companies, PT Caltex, PT Stanvac, and PT Shell agreed to sign the operating agreement (Law No. 14/1963). Later in 1964, in accordance with Law No. 44/1960, NV Caltex Pacific Petroleum Maatschappij (Caltex) changed its legal status to PT Caltex Pacific Indonesia (PT

Caltex). This event ended all oil mining operations, based on concession contracts under the IMW 1899 and began the full execution of the Law No. 44/1961 policy.

**Introduction of A New Joint Venture Type of Production Sharing Contracts (PSC)**

The attempt to follow up the new oil law No. 44/1961, was not finished with the signing of the operating contracts with foreign oil companies. According to some oil specialists, the principle of the nation's possession of an oil resource (in relation to the 1945 Constitution) was not fully reflected in Law No. 44/1961. In view of the fact that the management of an oil resource had to be in the hands of Indonesia, in 1964 the government introduced a joint venture type of production sharing contract (PSC) that guaranteed the oil ventures by the state. With the PSC, profit sharing was no longer based on sales but on production. Profit sharing in PSC was 65% : 35% to the government and companies respectively. The operational cost was limited to 40% of gross crude oil production. With this type of contract, the minimum guarantee of 20% of the gross crude oil production to the government in previous operating agreements, was changed to a minimum of 39% (ARCO, 1998). In certain areas, the development of oil industries during Sukarno's era progressed well. For example, the establishment of the PSC scheme was so successful, that it was later copied by many oil exporting countries.

**Coal and Natural Gas Development**

No significant development in the coal industries was observed during the period 1945 to 1970. The relatively low price of oil, and the more efficient and user-friendly diesel engine, compared to the steam engine, made coal utilisation less attractive than oil (MME, 1995).

In the early days, natural gas was mainly used to produce fertilizer, not as an energy source. The Sriwijaya Fertilising Plant (PUSRI) in Palembang, South Sumatra started to use of natural gas to produce fertilizer in 1964. Since then, the infrastructure for the gas sector has expanded and natural gas is used by fertilizer industries, petrochemicals, steel plants, for city gas, and power generating plants. . The need for liquefied petroleum gas (LPG) for the domestic market (small and medium industries), though not significant, prompted the government to start building LPG plants in Indonesia. LPG started to be produced in 1965 with the installation of a new LPG plant in Rantau, North Sumatra.

**Nationalisation of the Electricity Sector**

Strong discontent and sentiment toward the Dutch Colonial Government initiated the nationalisation all of the Dutch Electricity Companies. On the 3rd October 1953, the government enacted a Presidential Decree on the nationalisation of foreign electricity companies in Indonesia when the in active concession expired. The Dutch owned State Electricity Company was then dissolved and re-established with a new name "The State Power Company (PLN)" on 23 September 1958 and under the coordination of the Ministry of Public Works and Power. After that, on 25 August 1959, the government established a Board of Directors of PLN, and placed the gas and electricity sectors in a single organization. In 1965, BPU-PLN was dissolved and two new institutions, the State Electricity Company (PLN) and the State Gas Company, were established, both of which are still in operation.

### 2.4.3 Energy Indicators

*Domestic Production.* The oil production level at the end of the Dutch era was around 162,000 barrels per day. It decreased during 1942 – 1948 period falling below 100,000 barrels per day, because of the war. In 1946, domestic oil production was at its lowest level at 6000 barrels per day or 2.2 million barrels per year. By 1966, domestic oil production had escalated, reaching almost 500,000 barrels per day.

*Crude Oil Export.* PN PERTAMIN successfully conducted the exporting of crude oil in 1962. The first shipment of 103,000 barrels of crude oil took place on the 10th September 1962. Other shipments followed from January 1963, onwards when a shipment took place, on average, every 18 days (MME, 1995).

*Domestic Oil and Electricity Demand.* Domestic oil demand increased at an alarming rate in the early 1960s, possibly triggered by relatively cheap oil prices due to government control of the domestic oil price. Domestic oil fuel consumption increased reaching 3.3 million litres that year. The electricity production per capita averaged at 17.7 kWh per annum during the 1960s.

## 2.5 Soeharto's Era (1967 – 1997)

### 2.5.1 Government and Economic Influences

#### Soeharto Came Into Power

The attempted *coup d'etat* of October 1, 1965 had thrust Soeharto into as the position of the second President of Indonesia. Right after he successfully countered the ill-attempted coup, which was argued by Prawiro (1998) as quoted from Ricklefs (1981) as being characterized by extraordinary incompetence and confusion, General Soeharto took control of the army, the police and the navy. What happened on the night of 30 September 1965 was unclear. What ordinary people heard from radios and newspapers, was that seven Generals, or the so-called 'Council of Generals' were brutally murdered by Sukarno's left wing supporters, and only one General, A.H. Nasution, the Minister of Defence, managed to escape. According to the communist leaders, the 'Council of Generals', who were anti-communists were sponsored by the Central Intelligence Agency (CIA) of the United States, and planning a coup against the government of Indonesia. Communist leaders and other signatories, therefore, claimed that the purge of 'the Council of Generals' was necessary to pre-empt the anticipated coup. What Sukarno's left wing supporters had not anticipated was that Maj. Gen. Soeharto, then a commander of the Army Strategic Command would quickly assembles the forces to counter the attempted coup and quickly restore relative order to the capital, Jakarta and take over control of the country. An authorization Letter of 11 March 1966 (Supersemar) issued by Sukarno empowered Soeharto to take all steps considered necessary to guarantee the security, tranquillity and stability for the smooth functioning of the government and the course of revolution, and to safeguard the personal safety and the authority of the leadership of the President (Prawira, 1998). Soeharto began to consolidate his political and economic efforts, with the elimination of Sukarno and his 'left' wing supporters from the political arena. Thousands of communist or 'left' wing party members and leaders were reported killed and jailed by Soeharto's supporters during the elimination time.

### The Administration Model : Repelita

As soon as he assumed power, Soeharto established the administration model which was used for the next 30 years in Indonesia. It was similar to the colonial model of the Dutch era. Soeharto defined the task of the government as 'development' or 'pembangunan'. According to him, 'development' meant pursuing the twin objectives of prosperity and modernity by utilising technology and sound management. The core element of his development policy was a series of five-year development plans (Repelita) aimed at putting an organized and permanent structure into what was anticipated to be 'twenty-five years of accelerated modernisation' (Cribb & Brown, 1995). The first Repelita commenced at the beginning of 1969. Ricklefs (1993) argued that Repelita was a more rational programme than the eight year plan designed by Sukarno with his Guided Democracy. Based on the first five year development plan, the first priority was for the areas where government investment was expected to produce the highest returns, like agriculture, economic infrastructure, expansion of exports and import-substitution industries. The plan also included upgrading and extending the system of roads and dams, establishing an efficient communications network, building more houses and providing more employment (Dahm, 1971)

### The Introduction of Pancasila Democracy

Soeharto established the system that was inspired by Pancasila, based on belief in God, nationalism, democracy, social justice and humanitarianism. He established the government system, which was called *Pancasila Democracy.* According to Pancasila, democratic decision making should not be based merely on the formal power of the majority or voting, but should be based on 'consensus' or 'musyawarah' through control. Soeharto's main objective was to achieve peace and stability for smoothing the process of economic improvement. To materialise this objective, he adopted the policy of integrating the armed forces and centralising the command and expansion of the military role. Mody (1987) stated that since the New Order regime relied politically on a platform of economic performance, it determined to achieve it through political repression and controlled political participation. These elements of his style continued until after 1974, when, according to Cribb & Brown (1995), he added one more important element, which was ideological control.

**The Militarisation of the Bureaucracy**

According to Mody (1987) the first crucial move that Soeharto made was the militarisation of the bureaucracy, then the gradual removal and centralisation of authority within the army. This was followed by the integration of the armed services and finally taking control over economic activity and governmental structure. Some argued that Soeharto posted military personnel throughout the administrative structure, the aim being to strengthen and oversee the performance of the civilian hierarchy. Cribb and Brown (1995) stated that strategic government posts from the cabinet minister and provincial governor down to the village head, were given to military personnel. During his first term of presidency, almost all positions of Secretary General, and the highest administrative posts in each ministry, were filled by army generals. In vital ministries, new positions of Inspector General were established, and mainly given to Generals. According to Mody (1987) Soeharto was very smart. Although the percentage of military officers was dropped in the Cabinet, the number and percentage of Secretary Generals and Inspector Generals, which are is less observable (but crucial levels for implementing policy as linked with the financial matters) have substantially increased. To illustrate this, ten out of eleven of the Secretary Generals in 1967, or ninety-one-per cent, – were previously Army Generals.

**Open Door Policy Toward Foreign Investment**

Soeharto's economic policy on foreign investment was the opposite of that of Sukarno. Soon after he took control in March 1966, Soeharto announced that the foundation of his economic policy was to pursue foreign aid for development. He invited an I.M.F. mission to come to Indonesia to construct a stabilisation programme and employed familiar western-type solutions to control inflation. Several months after that in December 1966, in an attempt to attract foreign creditors, Soeharto returned the foreign companies, nationalized by Sukarno, to their former owners. Soeharto promised that he would not nationalise companies and would protect foreign investment for a 20 year period and promised reasonable compensation in case of nationalisation. He also guaranteed the freedom to remit profits and repatriate capital. Tax holidays, a protected tariff rate and subsidized infrastructure were also provided for. Foreign creditors of Indonesia formed IGGI (the Inter-Governmental Group on Indonesia) in early 1967. They were very generous allowing vast credits, which saved the countries from economic collapse and provided a moratorium on debt repayments till 1971. Funding for aid programmes and projects escalated from 1965 to 1973-74;

**Tabel 2.1 Funding for Aid Programmes and Projects From IGGI**

| Year | $ Million (US) |
|---|---|
| 1968 | 371.8 |
| 1969 - 1970 | 522.5 |
| 1970 - 1971 | 604.5 |
| 1971 - 1972 | 627.0 |
| 1972 - 1973 | 723.6 |
| 1973 - 1974 | 876.6 |

*Source: Mody (1987)*

Many people believed that the regime's dependence on foreign support was needed for its survival. In 1981, the government signed multi-million dollar contracts for new capital-intensive industries, which were the largest ever signed by the government in the history of the New Order regime. About 60% of foreign investment was spent in the oil and gas sectors. From 1979 to 1981, oil investment tripled from US$ 500 million in 1979 to US $ 1.6 billion in 1981. According to Mody (1987), foreign aid continued to escalate although Frost and Sullivan, Inc., one of America's leading business research firms, rated Indonesia as the least stable nation in the Asia Pacific Region. Mody (1987, p. 342) further added :

> *"... despite having one of the highest debts of US $ 16 billion and a debt service ratio of 15 per cent, foreign investment continues, no doubt lured by the super profits, which emerge. The total figure for foreign investment in 1980 was US $ 900.8 million".*

**Achievements and Failures of the New Order Achievements**

*Achievements.* The achievements of the New Order have been quite remarkable in many respects. In agreement with nearly every indicator, the developments between the mid-1960s and the early 1990s have been impressive. The foundation behind these changes has been macroeconomic stability, as signalled in reduced inflation. Real GDP per capita, increased from 0% (1965) to 5% (1991); per capita electricity production grew from 17.7 kWh (1960s) to 218 kWh (1990s), the poverty level (very poor category) dropped from 61% (1960s) to 10% (1990s) in Java and from 52% (1960s) to 7% (1990s) outside Java. According to Booth

(1996, p. 9) between 1969 and 1993 the Indonesian economy grew by 7 per cent annually. She further stated:

> *"Not only was this economic growth remarkable in comparison with what had gone before, but it was also much better than that of most other developing countries".*

With these achievements, according to Mody (1987), Soeharto's government and its cliques brought Indonesia out of the Sukarnoist gloomy ages. Some point to the regime's achievement in increasing Indonesian annual per capita income to nearly US$ 600, which led the World Bank to reclassify Indonesia as a middle-income country in 1982.

*Failures.* Ironically, some adversities emerged under this regime. *Firstly*, according to Cribb & Brown (1995) there was suppression of democracy in the decision making process. They argued that the New Order failed to give people a sense of controlling their own destinies. It was common knowledge that the New Order maintained control with a heavy force on dissenters, and jailed students and political activists with inadequate evidence. *Secondly,* many people argued that under the New Order the economic benefits were unevenly distributed, creating a gap between the upper levels of society and the rest of society. Mody (1987) stated that despite the 'obvious' wealth of the elite segments of Jakarta, the general population continued to struggle for life and suffered the cost of providing affluence to the elite military bureaucratic regime which kept exploiting the nation. Cribb & Brown (1995, p. 149) further stated about the disparity,

> *"The New Order's achievements in economic growth and development contrast sharply with its conservative, even static, approach to political development. The New Order has delivered increased prosperity to many, perhaps most, levels of society, but disparity in income and living standards between rich and poor has reached a point many Indonesians feel is unsustainable, both morally and practically".*

*Thirdly*, many people argue that mismanagement and corruption were widespread during this military bureaucracy New Order. The New Order was accused of abusing its power for commercial purposes and accumulating personal gains. Some suspected that the army had access to large funds out of the regular government budget, to use to increase power. Mody (1987, p. 137) stated,

> *"The New Order increased the 'commercial orientation' of the officer corps. The leadership did not seem to disapprove that officers were exploiting official positions for their personal gain. On the contrary, the families of the most powerful figures involved in the ownership of private entrepreneurs is devoted to raising funds directly for political purposes".*

The regime had been charged with spreading a 'culture of corruption'. Many foreign analysts believe that under Soeharto's regime, corruption had been widespread and has escalated to an undisclosed scale. Hill (1996) predicted that approximately 30 per cent of IGGI aid and GNP had gone secretly into private pockets. Hill (1996) also stated that corruption is there, at practically all levels of society. This condition, according to Hill (1996), has occurred in Indonesia, due to the existing dictatorial political system, a restricted press, an inadequately paid civil service, and a complicated commercial regulatory regime.

> *"In summary, corruption in Indonesia is serious, widespread, and inherently non quantifiable in its incidence and consequences. But at least there have been some notable achievements in the struggle to contain it"* (Hill, 1996, p. 119).

*Fourthly*, the regime which had won a reputation for its credible economic management was threatened by increasing inflation in 1974, which soared to 41 percent. This was caused by the substantial oil windfalls as a result of the first oil shock. There was immense political pressure on the government to use the windfall gains domestically, but deflationary measures were urgently required. Hill (1996, p. 33) quoted Arndt (1974),

> *"Indonesia in 1974 is like a man who has won first prize in a lottery. The opportunities are immense, almost unimaginable. But so are the pressures and temptations to spend too much fast, and the difficulties in making wise and effective use of the windfall".*

*Fifthly,* the country's dependency on foreign aid had caused the accumulation of huge debt under Soeharto's regime. Mody (1987, p. 197) argued that the achievements claimed by the New Order were an empty ones because they were built mainly from foreign loans. He stated:

> *"... the achievements if any, are possible only because of the IGGI loans which support the budget and the balance of payments position. The IGGI enables the financing of millions of dollars worth of imports each year, for which Indonesia could not pay from its foreign exchange earnings. These annual doses of substantial aid produced the 'Economic miracle', which had nothing to do with real development to promote the country's economic independence. These policies on the contrary, make Indonesia far more dependent on continued injections of aid''.*

Mody (1987) also stated that the much-criticized Sukarno's debts are nothing compared to those accrued by Soeharto's regime. According to him, Soeharto's regime left a legacy of over $4 billion (in 1974 alone), a much bigger amount than Sukarno's legacy, which was only $2 billion in total debts.

### 2.5.2 Energy Policies

It is argued in this thesis that under Soeharto's presidency, energy activities, especially oil, gas and coal mining ventures achieved substantial improvements, especially in the areas of regulation of exploration and production as well as the organization of mining institutions. As a consequence of his open door economic policy, Soeharto adopted a more receptive policy toward foreign private sector participation in the economic development of Indonesia.

Soeharto's reforms began with the issuance of the policy that signalled the new policy approach, and provided incentives for private investors to participate in energy venture activities in Indonesia.

#### 2.5.2.1 Oil Policies

**The Blooming of Foreign Investments in the Oil Sector**

A new approach to the management of the energy sector began in 1967, when the House of Representatives issued Law No.11/1967 giving opportunities to foreign private sectors to invest in mining and energy in the form of operating agreements, joint ventures, and production-sharing contracts. As a result of this policy, according to MME (1995), a total of 22 production-sharing contracts in oil ventures were signed in 1968. Foreign interest was triggered by the rise of oil prices in early January 1979. Forty three oil contracts were signed between 1979 to 1982, twelve contracts were signed in 1979, nine contracts in 1980, nine contracts in 1981 and thirteen contracts in 1982. All working contract companies had changed to production sharing contractors by November 1993.

**The New Production Sharing Contracts (PSCs)**

The rise of crude oil prices, which happened during the period of 1973 to 1975, inspired the government to renegotiate the PSC scheme. Due to the accelerated increase in crude oil prices, (US$ 2.18 a barrel in April 1971 to US$ 10.80 in January 1975), the government pursued negotiations known as New Deal 74/75 with PERTAMINA's contractors to surrender part of the profit. The government insisted that the consequent 'windfall' profit should be largely for the advantage of the state. As a result, early in 1974, companies with PSCs had their contracts 'corrected'. The contractor's equity share was valued on a base price of US$ 5 per barrel escalating proportionately with increasing oil prices (Barnes, 1995). At the price of up to US$ 5 a barrel, the profit shares remained 60% : 40% for operating agreement contractors and 65% : 35% for production sharing contractors. Above US$ 5 a barrel, the profit share ratio became 85% : 15% for both contractors.

**Incentives Packages for Enhancing Oil Foreign Investments**

The Indonesian government made an attempt to increase oil and gas investments through various forms of joint venture and incentive packages. Besides PSCs, PERTAMINA started to open joint ventures in the form of PSC-JOP (Joint Operating Production), PSC-JOA (Joint Operating Agreement), and PSC-JOB (Joint Operating Body) in 1977. From 1988 to 1994, the government issued 4 incentive packages in investment credit, commercials, DMO price, and export price, profit sharing, production sharing, etc (ARCO, 1998). The goal of these incentive packages was to provide a more conducive environment for oil investment so that foreign oil investors would be interested in enhancing their activities in Indonesia.

#### 2.5.2.2 Gas Policies

The rapidly growing domestic market prompted the government to enhance natural gas exploration in Indonesia. This led to the discovery of big gas fields in Arun (Aceh) and Badak (East Kalimantan), which made Indonesian natural gas a prospect for export. Indonesia successfully exported LNG and condensate in 1977 and virtually created the total world energy market for LNG in the 1970s. In 1994/95, it was considered the largest gas exporter in the world. It was not until 1987 that the government investigated alternative fuels for the transport sector. The path toward Compressed Natural Gas (CNG) then began during 1987 and 1988, in line with the government effort to diversify domestic energy usage, particularly in the transport sector. PERTAMINA in co-operation with the State Gas Company (PGN) introduced Compressed Natural Gas (CNG) for road vehicles. Up to 1994, there had been 8 CNG stations owned by PERTAMINA and 2 CNG stations owned by the private sectors in operation, all of them were located near the capital, in Jabotabek (Jakarta-Bogor-Tangerang-Bekasi). The mounting significance of gas to the Indonesian economy is not merely in the form of additional exports but increasingly from its role as a substitute for oil in the domestic market. Barnes (1995) stated that policy on the future management gas development is crucial to the economy and wealth of Indonesia.

#### 2.5.2.3 Coal Policies

A bleak coal market brought low investor interest in coal sector development during the early 1960s (MME, 1995). The first oil shock in 1973, opened up more opportunities for coal to become an alternative for domestic consumption. Soeharto instructed some cabinet ministers to carry out measures to boost domestic coal development and utilisation, particularly for industry and power generating, in line with government policy to improve energy efficiency and energy saving. An effective method of acceleration in the domestic market development began to open up with the initiation of interdepartmental cooperation. In 1977, two ministers, the Minister of Mines and Energy, and the Minister of Transport issued a Joint Ministerial Decree regarding the establishment of a Development Project on Bukit Asam Coal Mining and Transportation (P4BA) which aimed to increase domestic coal utilisation. This effort was furthered with the establishment of a Steering Committee made up of representatives from the two Ministries as well as related government institutions. The main tasks of the Steering Committee are managing, transporting, and utilising coal for domestic needs.

**The Introduction of PSCs for the Coal Sector**

Motivated by the success of the PSC system in the oil industry, the government made an attempt to begin the Production Sharing-Contract (PSC) system between PT Tambang Batubara and private companies (as the contractors) for the coal industry in Indonesia in 1981. Later, during 1981 to 1984, several coal production sharing contracts were signed between the government and foreign contractors. In the period of 1985 to 1987, four more Production Sharing Contracts were signed with three foreign investors and one local investor. Between the period of 1981 and 1987, there had been nine foreign and one local coal investors in Indonesia (MME, 1995). There were 24 candidates (20 local and 4 foreign investors) applying for PSCs. Twenty candidates passed and were allowed to enter the negotiation process (4 foreign and 16 local investors). In 1994, government and private sectors signed 19 PSCs for coal mining and production in Indonesia.

**Acceleration of Coal Utilisation for Power Generation**

The drive to accelerate the utilization of coal as a substitute for oil in the power generation sector emerged at the end of the 1980s. The aim was to speed up the coal diversification program in the domestic market. A Committee for Coordinating Large Electric Power Plant Installations in Java, Suralaya (Coal), Gresik (Natural Gas), and Paiton (Coal) was established, together with a Secretariat with three technical committees for the three areas. Quite ambitious targets were set for this program. PLN, the State Utility Company already generated some 25 percent of its electricity from coal, with 55 percent as the target for 1999 and 66 percent by 2004 (DGM, 1999). In 1989, Suralaya Steam Generation Power Plant – Units I, II, III, and IV started their operation with a coal supply from PT. Tambang Batubara Bukit Asam.

### 2.5.2.4 Electricity Policies

**Electricity Pricing Policies**

Realising that electricity pricing is a politically sensitive area and very much affects the development of economic sectors, the government started to regulate the electricity price in 1966. The electricity tariffs have been revised several times up to the present time. These tariff deregulations were aimed at regulating electricity demand, improving economic efficiency, encouraging the development of certain sectors, social purposes and providing for the unexpected changes, e.g. fuel prices, inflation rate, rupiah exchange rate.

### Transmission and Distribution Losses

From 1974 to 1994, the government successfully improved transmission and distribution losses. Losses in distribution and transmission were 23.8 percent in 1974, then they decreased to 21 percent in 1979, 20.8 percent in 1984, 16.9 percent in 1989, and 12.5 percent in 1994. In 1985, the government enacted Law No. 15/1985 the Electricity Law. From this time onwards all activities in the electricity sectors were governed by this law.

### Electricity Standard

Standardization is a very important aspect of economic efficiency. There was also a growing public awareness of the need to improve safety, efficiency and environmental aspects of electricity utilisation. So the government issued a decree on electricity standards. The standard covered; (a) a standard for association/agency/institution; (b) an Indonesian electricity standard; (c) an international standard. Again in 1994, the government made an attempt to improve national electricity standards establishing 22 Technical Committees for Standards. The committees were responsible for the formulation of Indonesian National Standards (SNI) in electronic technology.

### Rural Electrification Program

The Indonesian rural electrification program began in 1976. In this year, the government assigned PLN additional tasks to manage the rural electrification program. In 1979, in an attempt to follow up the rural electrification program, the Minister of Mines and Energy in co-operation with the Minister of Trade and Co-operatives issued a Joint Ministerial Decree which regulated co-operation between PLN and Rural Co-operatives (KUD) in carrying out the development of the rural electrification program. In 1994, the electrification program had successfully electrified 34,790 rural villages. In an attempt to encourage electricity production by co-operatives and private sectors, the government issued the public Electricity Venture Permit (IUK) and the Electricity Producing Permit for Own Use (IUKS). About 1,348 Electricity Producing Permits for Own Use (IUKS) had been issued in 1995. The number of units amounted to 5,136 with a total capacity of 7,783,725 kVA.

## 2.5.2.5 Other Energy Resources' Policies

*Geothermal Energy.* The search for geothermal energy was stimulated by the world energy crisis at the end of 1973. Starting from this year, the Indonesian government began to intensify the search for geothermal energy and develop plans for its usage in the future. In 1975, PERTAMINA built a 30 MW Geothermal Power Plant in Kamojang. In 1983, PERTAMINA and The State Electricity Company (PLN), with the assistance of the New

Zealand Government, completed the construction of a Geothermal Power Plant of 30 MW capacity in Kamojang. In 1987, the Kamojang Geothermal Power Plant (PLTP) started the operation of an additional 55 MW geothermal power plant. By 1994, the total installed capacity of Geothermal Power Plants in Indonesia was 309.5 MW.

*NRSE.* New and Renewable Sources of Energy, which may not be feasible or economic for other countries, have proved to offer more prospects for Indonesia when geographical factors are taken into consideration (DGEED, 1998). Indonesia with more than 17,000 islands and 60 percent of the population living in rural and remote areas, is expected to view NRSE as prospective alternatives. Attempts to establish programs of NRSE utilisation for rural energy needs, have not had strong support from the government. To date the majority of the NRSE programs have turned out to be unsuccessful and it is argued that they perhaps only serve "ceremonial" purpose and the interest of the official who inaugurated the NRSE installation. The role of the NRSE in the total domestic energy mix is still very low, below 1 percent (DGEED, 1998).

### 2.5.3 Energy Indicators

*Domestic Oil Production.* Domestic oil production increased from 779,000 barrels per day in 1968 to 931,000 barrels per day in 1971. Stimulated by the first oil shock, the production reached more than 1.5 million barrels per day in 1976 and rose to 1.7 million barrel per day in 1977. In 1979, oil production went down to 1.5 million barrels per day. In 1984, domestic crude oil production (because of the OPEC quota) was decreased to 1.2 million barrels per day. In 1991, the crude oil production quota became 1.33 million barrels per day.

*Natural Gas Production.* In 1976, total natural gas production reached 312.4 billion standard cubic feet (BSCF), which was a three fold increase on the 1966 production (106 BSCF). By 1994, natural gas production had increased reaching 800 BSCF per year.

*Electricity Production.* During the period of 1969 to 1994, the development of electricity infrastructures was speeding up, shown by an increase in power capacity amounting to 1,510 MW in 1994. At the end of 1994, the total capacity of non-PLN (privately own-use) reached 8,500 MW. In 1994, the total electricity production of PLN had increased to 61,287 GWh. Per capita electricity production increased from 25 kWh in 1970 to 381 kWh in 1997.

*Indonesian Oil and Gas Exports and Income.* In 1969 close to the beginning of the Soeharto's era, crude oil export was approximately 195 million barrels. In 1972, PERTAMINA expanded the Indonesian crude oil market to Japan through the establishment of a new joint-venture the Japan Indonesian Oil Company (JIOC). As a result, the export of

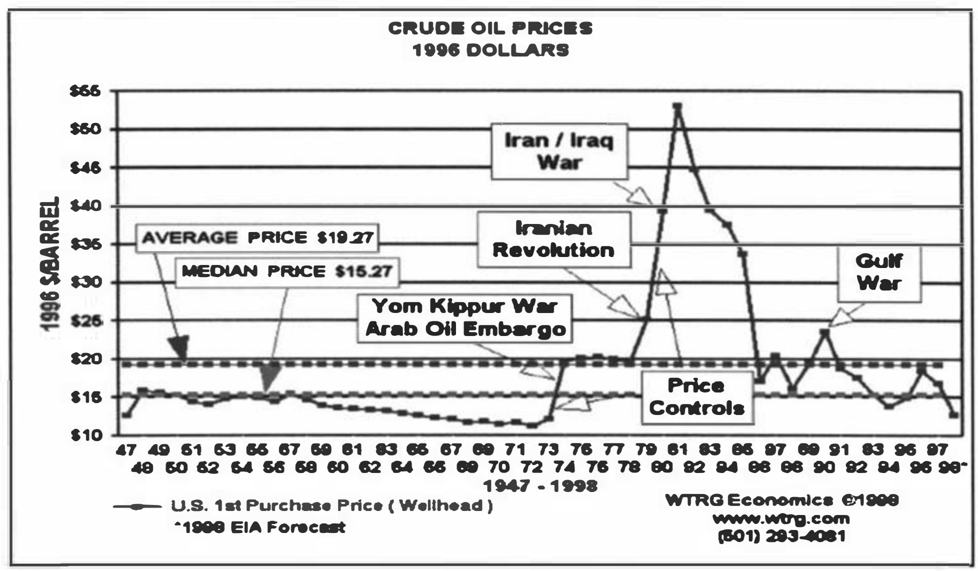
Indonesian crude oil increased from 450 million barrels in 1976 to 485 million barrels in 1977. Between 1969 and 1973, oil and gas contributed 44.58% of the total value of Indonesian exports. This figure increased rapidly. In 1980 the oil and gas income reached Rp.9.52 trillion or was equal to 66 percent of the domestic income. Meanwhile from 1979 to 1983, the oil and gas contribution to the state income reached a peak of 75.5 percent of the total Indonesian export figure. Foreign income from oil and gas increased reaching an average of 28 percent a year during the period of 1969 to 1995 (MME, 1995). The income from oil and gas in 1995 was equal to US$ 9,323 billions or 20.5 percent of the total exports (US$ 45,418 billion) (US Embassy, 1997). Energy per capita (Export) increased from 13 Peta-Joule (1970) to 22 Peta-Joule (1997).

*Energy Consumption.* Primary Energy Consumption rose almost 20 fold during Soeharto's era from 252 Peta-Joules in 1970 to 5063 Peta-Joules in 1997. Final energy (excluding biomass) consumption grew at 12.5 per cent annually from 1980 to 1997. The share of oil to total consumption (excluding biomass) dropped from 88 percent in 1970 to 60 percent in 1997. Final energy use per capita increased substantially from only 2 Peta-Joule in 1970 to 25 Peta-Joules in1997 (BAKOREN, 1998)

### 2.5.4 Energy Problems and Issues

The first and the most serious energy problem was the **PERTAMINA's affair** in 1975. This was an example of mismanagement of the state owned oil company, which had been placed under heavy military control. Under Ibnu Sutowo's (an army general) directorship, PERTAMINA developed into one of the largest corporations in the world. PERTAMINA contributed about 75 percent of Indonesia's gross foreign exchange. The PERTAMINA budget for 1974 was nearly US$ 2 billion, compared to total government expenditures for the same year of just US$ 3.7 billion. PERTAMINA was almost exclusively free of government control and stood unsteadily on a foundation of huge debt, messy management and corruption. In 1973, the government had actually tightened up the conditions under which Ibnu Sutowo could borrow money overseas, but seemingly it was not obeyed. In the process, PERTAMINA had run up debts to private bankers of about $1.5 billion, of which about $600-$900 million was due to PERTAMINA's creditors in 1975. In February 1975, PERTAMINA found itself incapable of repaying loans from the US and Canadian Banks. In March 1975, the Bank of Indonesia was forced to save PERTAMINA and to cover the payments of loans to the Republic National Bank of Dallas (US$ 45 million) and to a group led by the Toronto Dominion Bank ($60 million). The first National City Bank of New York turned out to be PERTAMINA's major creditor, with leverage over the entire Indonesian economy. It was also estimated that PERTAMINA owed the government US$800 million in taxes (Caldwell, 1975). The government took over the management of PERTAMINA and agreed to meet its debts, which were later said to be over US $ 10 billion. PERTAMINA was then put under government control, but at a heavy price (Ricklef, 1993).

The second energy problem during Soeharto's era was linked with the escalating oil and gas exports' revenue from the rise of world oil prices or **Oil Windfalls.** The primary source of Indonesia's huge inflation in the 1970s was its oil windfall revenues. In 1973, the first oil shock occurred as a result of Arab oil embargoes. The shock brought the price of oil up from about US$ 12 in 1973 to around US$ 20 in 1974 (the first shock) and it skyrocketed again (the second shock) between 1979 and 1981 reaching almost US$ 55 per barrel, (see Figure 2.1, Williams, 1996). This oil windfall caused Indonesian oil and gas export revenues to increase from $ 1.6 billion to $ 5.2 billion, during the first oil shock. Indonesia was flooded by a sudden inflow of petrodollars, which went beyond prediction (Prawiro, 1998).




*Source : Williams, J.L., WTRG Economics (1996)*

**Figure 2.1. Crude Oil Prices in 1996 United States Dollars**

The windfalls were similar to having money fall from the sky, with the special bonus that the money was in foreign currency. The inexperienced government at the time flooded banks with cash and the troubles began to unfold. The sudden influx of money provided easily available funds and brought about inflationary pressures. From 1971 to 1978, Indonesia suffered a cumulative inflation rate of 141 percent. The windfalls caused a set of economic troubles for which there were no policies in place. Prawiro (1998) describes that during these years there were four prominent factors stimulating inflation; firstly, rice shortages due to several unusually dry growing seasons; secondly, oil windfalls; thirdly, imported inflation; and finally, the influence of PERTAMINA itself. Prawiro (1998) argues that even if there was only a moderate portion of the company's revenue was channelled into domestic investment, it would have increased inflationary pressures. What happened to Indonesia during that time resembled what had happened to the Dutch economy in 1977 and therefore it was called the 'Dutch disease'. As quoted from Prawiro, 1998:

> *"The Dutch economy had become enriched by its natural gas holdings, but while the country's external economy appeared strong and healthy, internally the country was struck by growing unemployment and stagnation. This contrast between external health and internal ailments is the symptom of 'the Dutch disease'"* (the Economist, 1977 as quoted from Prawiro, 1998, p. 115).

This phenomenon also occured in other developing oil exporting economies, as Cadwell, (1975, p. 192) noted:

> *"History has demonstrated (e.g., Iran, Iraq, Venezuela, Indonesia) that petroleum revenues often tend to create a false and frivolous sense of wealth, to feed economic polarization and to strengthen corrupt or ineffectual leadership. Often neglected is the fact that the size of the local market may be constricted by price or limitations in physical infrastructure".*

The government was totally unprepared to cope with this sudden economic disaster. In an attempt to reduce the impact, the government quickly tried to develop a strategy for the optimal use of unanticipated funds. From this experience the government learned that the method for 'dealing with' the Dutch disease lies in the management of the windfalls. Dutch disease can be avoided if the benefits of the booming sector are distributed across the economy or the windfalls are 'sterilised' so that the boom will not stimulate inflation. When the second oil shock erupted in 1979, the government was experienced in handling windfalls. Spurred by the Iranian revolution and the Iran-Iraq war, the price of the world's oil increased from US$ 25 per barrel in 1979 to almost US$ 54 per barrel in 1981 (see figure 2.1, Williams, 1996). Indonesia was again confronted with the benefits and problems of how best to deal with huge oil windfalls. The government tried to 'sterilise' the oil windfalls to reduce the inflationary impact on the economy. Although the procedure of sterilisation was similar to Indonesia's first oil shock, the government was, to some extent, more successful during the second one (Prawiro, 1998). According to Prawiro (1998), based on Indonesia's experience, the essential techniques for sterilising foreign exchange earnings from oil exports are: to hold the money offshore either in liquid form or as foreign investments. The money can then be used to purchase imports and then introduce those imports into the economy with a minimal increase in the domestic money supply. Another way of using the money is to pay off the country's foreign debts or to build the nation's foreign exchange reserves.

The third energy problem was associated with the falling of world oil prices between 1982 and 1986. As was also the case with the oil windfalls, the fall of the oil price had similar detrimental effects on Indonesia's economy. This time the main source of the problem was the country's heavy dependence on oil revenue. Oil prices plunged in 1983, compelling the government to devaluate the Rupiah by 28 percent and restrict the budget for the next five year development plan (Repelita IV, 1984 to 1989). The OPEC price for oil dropped from its 1983 high of US$ 40 per barrel to below US$17, and it improved to US$ 20 in August 1986 (see figure 2.1 Williams, 1996). Because sixty per cent of government revenue was derived from oil, this signified a regime crisis (Ricklefs, 1993). The price drops caused increasing external indebtedness and the sudden decline in economic growth in 1984 signalling an end to the decade of oil-financed growth and abundance. The condition of the economy deteriorated further because much of the debt from the past 15 years was now maturing, and a sharp increase in important repayments lay ahead. Economic growth dropped significantly from over 7 percent during the oil boom period to only 3-4 percent. The government reacted promptly and decisively in its macroeconomic management (Hill, 1998). The rupiah was again devalued, this time by 31 per cent, in September 1986. Then the government adopted a floating exchange rate, resulting in a 55 percent depreciation in the real effective exchange rate. The results of government action were very encouraging, particularly in boosting non-oil exports. In only six years, the non-oil and gas exports almost tripled from US$ 5 billion (1983) to US$ 14.4 billion (1990), which indicated an increase in the share of total non-oil and gas exports from 25 to 56.2 percent (Kim, Knaap & Azis, 1992). The government also quickly cut back on expenditure, postponing, then cancelling, a number of large projects. Tax, customs, and banking reforms were also introduced. Many analysts praised the government for giving prompt, effective, and strong responses. Even the World Bank made favourable comments on the appropriate measures and well-timed stabilisation and adjustment policies (Booth, 1996).

## 2.6 Conclusion

It can be concluded from this chapter that throughout Indonesia's political history, the energy policy has been greatly influenced by the political and economic objectives of the government of the time. The following conclusions can be derived from each era.

During the Dutch era, the industrialisation of the world in the first quarter of the twentieth century, had intensified exploration and exploitation of mineral deposits all over the colony for export purposes to fulfil the world's demand. The outer islands, especially Central Sumatra and South Kalimantan, and the Indies' major oil fields, were certainly the main Dutch targets for oil and coal acquisition. The policies during the Dutch and Japanese eras were quite similar in terms of their primary purpose, which was to promote material and mineral acquisition. The first policies (Dutch) were for the development of welfare in their own country, while the latter policies (Japan) were for the Japanese war efforts.

In the Japanese era, the Japanese military government exploited the country's oil and mineral resources in an attempt to collect currency to support the Greater East Asian War. Indonesian crude oil and refineries were valued as vital for the running of the Japanese war machine. They set targets for oil acquisition either for export purposes or for meeting their domestic demand. Electricity was also regarded as playing an important role in strengthening Japanese occupation. Therefore, during the occupation, the Japanese instructed that all of the Presidents of electricity companies, during the Dutch era, be replaced with Japanese.

Sukarno's era was characterised by his ambition to nationalise all foreign mining companies and his closed door foreign policy, which was influenced by his hatred toward western interests. Consequently, oil and mining policies during Sukarno's era were characterised by an anti colonial and anti-imperialist position throughout his presidency (Barnes, 1995). The nationalisation of foreign mining and electricity companies, especially Dutch companies, including those dealing with domestic oil and gas supply and distribution also began during his era. Moreover, his over protective policies toward national interests and his preoccupation with political matters caused failures not only in advancing the oil industries, but also in developing the Indonesian economy as a whole. However, in certain areas, the development of oil industries during the Sukarno's era had progressed well. For example, the establishment of the PSC scheme was so successful, that it was later copied by many oil exporting countries.

Soeharto's economic policy, was the opposite of that of Sukarno's. His open door policy pursued foreign aid and foreign investment. He adopted a more receptive policy toward foreign private sectors participation in the economic development of Indonesia. He attempted to promote a climate conducive to foreign aid and investment in return for foreign aid and assistance. Soeharto maintained its 'open door' foreign investment policy throughout his era. One important lesson that Indonesia could learn from Soeharto's era was the PERTAMINA affair, which was a costly example. Pertamina's affair should be seen as more than a dramatic story. The affair had much to teach Indonesia (Radius Prawiro, 1998). Moreover, the unpredictable changes of the world oil prices that occurred during Soeharto's era taught Indonesia some important lessons. Two events, the rise and the fall of oil prices, had caused a total economic setback in Indonesia. The first was due to an imprudent government spending on oil windfalls and the second was due to a heavy government reliant on oil revenues. From these two events, the government had learned valuable lessons regarding managing oil windfalls and reducing the dependency of oil in government revenues.

The next chapter discusses the framework of the energy policy and planning adopted by the post Soeharto era. The chapter elaborates the planning process, the characteristic of the policy processes and the emergent energy policy objectives. The discussion on the emergent policy objectives aims at providing a direct input into modelling process.

# CHAPTER THREE

# INDONESIAN ENERGY POLICY FRAMEWORK

This chapter illustrates and discusses: *firstly*, the institutional organisation of the energy sector in Indonesia; *secondly,* the legal framework for energy policy and planning in Indonesia; *thirdly* how the policy and planning processes of the Ministry of Energy and Minerals and BAROKEN are explained by two paradigms drawn from the literature; *fourthly,* the key factors that characterise energy policy processes in Indonesia; and *finally,* the emergent energy policy objectives in Indonesia. All of these discussions are important in providing insights into how the energy policy and strategy of Indonesia operates; who is responsible for the decision-making processes in energy sector and most importantly what are the emergent energy policy objectives. This understanding should help define the policy variables and indicators that need to be considered in building the dynamic energy simulation model in Chapter 8.

## 3.1 Institutional Framework

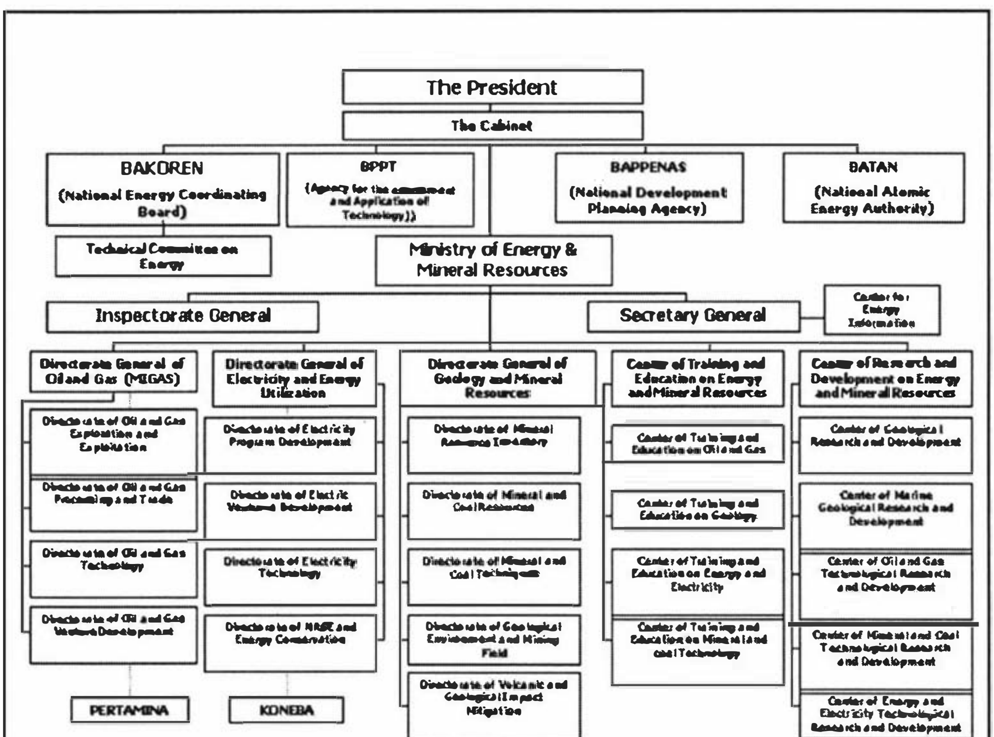



**Figure 3.1 Organization Chart of The Energy Sector**

The organization chart presented above describes briefly how the organization of the energy sector in Indonesia is carried out. On 2nd of March 2001, the Ministry of Mines and Energy of Indonesia was reorganized and its name was changed into the Ministry of Energy and Mineral Resources, through Ministerial Decree No. 150/2001. There were several reasons for changing its name; *first,* the previous name 'Mines' means activity in mining, whereas the actual activity is more on business 'commodity' (production, supply, export and import) than 'mining activity' (oil exploration); *second,* in accordance to the new Law on 'Regional Autonomy' No. 22/1999, mining activity will be transferred to the regional government, the national government will no longer conduct mining activity for mineral resources. Consequently, all units that previously handled mining activity, like the Directorate General of Mining, were dissolved and part of its activity and staff were transferred to the Directorate General of Geology and Mineral Resources. This is why the previously four Directorate Generals under the ministry were merged into three Directorate Generals; Directorate General Oil and Gas, Directorate General of Geology and Mineral Resources, Directorate General of Electricity and Energy Utilisation. The name of the later was also changed from 'energy development' into 'energy utilisation' as this directorate no longer handled 'development' activity. This will be handled by the two new units added to the new organization. Directorate General Electricity and Energy Utilisation will only handle the utilisation aspects of all energy resources. In the new organization, two new units, both in the form of centres, are added into the new organization. A possible reason for this addition is that the Ministry is trying to improve its services in the area of education, research and development in the field of energy and mineral resources to catch up with the rapidly changing global environment.

### 3.1.1 Ministry of Energy and Mineral Resources (MEMR)

The Ministry of Energy and Mineral Resources is one of the government's implementation bodies, which is chaired by a Minister who is directly responsible to the President of the Republic of Indonesia. According to decree, the MEMR is responsible for conducting part of the government's task in the field of energy and mineral resources. MEMR has the prime control over energy and mineral resource activities through three Directorate Generals, two Research and Training Centres and an Energy Information Centre.

*Directorate General of Oil and Gas:* This office is responsible for formulating and implementing policy and technical standards in the field of oil and gas. It prepares the formulation of policy for oil and natural gas and its implementation in accordance with existing effective law and regulations. The Directorate has been proposing reform legislation aimed at improving the efficiency of PERTAMINA (State Oil and Gas Company) and foreign oil companies, and gradually opening Indonesia's downstream sector to foreign competition (a move aimed at removing the government's substantial subsidies to PERTAMINA). On 24 October 2001, Parliament agreed to ratify the draft legislation for of oil and gas reforms. This is likely to open a new era in oil and gas policy for Indonesia, and allow more room for foreign participation and competition in Indonesia.

*Directorate General of Electricity and Energy Utilisation:* This directorate is responsible for formulating and implementing policy and technical standards in the field of electricity and energy utilisation. This office is influential in the drafting of national energy policy and its implementation. In the past, however, most of the policy products of this office have not been effectively adopted and disseminated.

*Directorate General of Geology and Mineral Resources:* In line with the reorganization of the Ministry, the former organization, The Directorate General of Mining, was merged into this unit and consequently all task and functions of The Directorate General of Mining were transferred into this unit. The new directorate is responsible for formulating and implementing policy and technical standards in the field of geology and mineral resources. The office is also responsible for the formulation of peat and coal policy and in charge of policy decisions on coal mining and utilisation-related environmental impacts.

*Centre of Training and Education on Energy and Mineral Resources:* The Centre has the responsibility to carry out training and education in the field of energy and mineral resources. The Centre also formulates programs and coordinates training and education activities in the field of oil and gas, energy and electricity, coal and mineral technologies.

*Centre of Research and Development of Energy and Mineral Resources:* The Centre is responsible for conducting research and development activities in the field of Energy and Mineral Resources. It should also formulate programs and coordinate the activities in research and development in these fields.

*Centre for Energy Information:* The Centre is a supportive body, which helps the Ministry of Energy and Mineral Resources to carry out the implementation and development of energy information systems, energy policy reviews and provide data and information on energy and mineral resources. The Centre is under the Secretariat General and also functions as the Secretariat of BAKOREN (National Energy Coordinating Board). The unit is a very important element in energy policy formulation as it serves as a think tank on the energy information systems and supports the work of BAKOREN.

### 3.1.2 State Owned Companies Under the MEMR

*The State Oil and Gas Company (PERTAMINA).* PERTAMINA was established in 1971, through Law No. 8 of 1971. PERTAMINA is the main tool of government policy and activity in the oil and gas sector. It is the largest oil venture and owns the sole rights to almost all oil and gas sector activity in Indonesia. Law No. 8 of 1971, allows PERTAMINA to explore for and produce oil on its own account, to organize all foreign oil and gas contracts and control the activities of the domestic and foreign contractors. PERTAMINA also has the task of supplying oil products to the domestic market and practically monopolises domestic fuel distribution.

*Energy Conservation Consulting Company (KONEBA).* In 1987, the first state-owned energy conservation company PT KONEBA was established. Its tasks cover the promotion, training, consultancy, and services on the implementation of energy conservation programs. The investment in PT KONEBA was shared by five State Owned Fertiliser Companies, plus a loan from the World Bank. PT KONEBA was first placed under The Ministry of Trade and Industry. Later in 1992 and 1993, the government restructured PT KONEBA through Ministerial Decree No. 703/M/6/1992, followed by Ministerial Letter No. S-986/MK.013/1992 and State Decree No. 2/1993. Its status was changed to a State Owned Company (Persero), and the company came under the supervision of the Ministry of Mines and Energy in accordance with its function and tasks (previously it was under the Ministry of Industry).

## 3.2 Legal Framework

In formulating the policy on energy and mineral resources, the Ministry of Energy and Mineral Resources must adhere to the existing Laws and Regulations. The law, in Indonesia, as a rule, broadly formulates do's and dont's. The Law only defines general principles from which rulings can be crafted to suit specific circumstances. The Indonesian hierarchy of Laws & Regulations are as follows; the first or the highest rank of Law is the 1945 Constitution, the second hierarchy is the Decrees of The People Consultative Assembly (TAP MPR), the third is Acts (UU), the fourth rank is Government Regulations (PP), the fifth is Presidential Decrees (Keppres), and the sixth is Implementation Regulation (such as; Ministerial Regulations, Ministerial Instructions). In the case of energy and mineral resource matters, the decision maker should always adhere to article 33, Paragraphs 2 and 3 of 1945 Constitution. Paragraph 2 of the article 33 states that branches of production, which are important for the State and which affect the life of most people shall be controlled by the

State. Whereas, paragraph 3 asserts that land, water and the natural riches contained therein shall be controlled by the State and used for the maximum prosperity of the people.

*Oil & Gas Matters: A*ccording to the 1945 Constitution paragraph 2, 'the State has the authority over oil and gas resources'. The Ministry of Energy and Mineral Resources through the Directorate General of Oil and Gas is responsible for the management, administration and supervision of the mining of oil and gas resources. PERTAMINA, which is under the Directorate General of Oil and Gas, is responsible for the execution of the mining of oil and gas in Indonesia (ARCO, 1998). This is in accordance with Law No. 44/1960, article 3, paragraph 2, which stipulates that the mining of oil and gas are exclusively carried out by a State Enterprise. Moreover, according to Law No. 8/1971, article 11 and 12, PERTAMINA may also enter into co-operation with other parties in the form of Production Sharing Contracts or PSCs (ARCO, 1998). For the last several years, the government of Indonesia has been considering the liberalisation of Indonesia's downstream oil and gas sector as well as the plan to consider the termination of PERTAMINA's monopoly. The government has also enacted regulations in 1992 permitting 100 per cent foreign ownership of refineries and petrochemical plants worth more than US$50 million. Consequently, some projects formerly considered as fully owned by PERTAMINA may in the long run become foreign owned. In line with the government's privatisation policies, PERTAMINA has licensed private operators. PERTAMINA has recently been making an effort to break its own monopoly in importing fuel by licensing an independent power producer to import diesel fuel. Under the proposed 1999 legislation, the government, through the Ministry of Mines and Energy, would take over the function, currently carried out by PERTAMINA, of granting and supervising production sharing contract (PSC) with foreign oil companies. To improve the efficiency of foreign oil companies, the government would also free them from many regulatory approval requirements. Gradually, Indonesia's downstream sector would also be opened to foreign competition, a move aimed at removing the government's heavy subsidies to PERTAMINA. Barnes (1995) viewed that the changes may continue but neither mainstream political nor popularist views seem likely to allow a large-scale observable shrinking of PERTAMINA's domination of the oil and gas sector for many years to come.

*Coal Matters: The* policy on coal has been set within a broad legal, regulatory and policy framework. As with oil and gas, the 1945 Constitution, article 33 provides the most fundamental basis for coal policy formulation. Similarly, the 1967 Basic Provision of Mining Law No. 11 is a key legal building block though this is currently under review and some of the implementation strategies in this policy will be subject to the issuing of an update of this law. National policy as defined in the 1998 National Guidelines (GBHN) and the

General Policy for the Energy Sector (KUBE) have also provided the foundation on which this policy has been built (DGM, 1999). General policy regarding coal development include: increasing employment opportunities and alleviating poverty; bringing economic and social development to more remote areas; and developing significant new export industries. With regard to energy specific matters, the policies are: adding to the diversity of energy resource use and its sustained development; assisting in the intensified search for additional energy resources; applying the principle of following the market mechanism in energy pricing; producing, transporting and utilising energy resources with due care for the environment, and applying the principle of conservation in the exploitation and use of energy (DGM, 1999).

*Energy Matters:* The foundation of the formulation of National Energy Policy is the 1945 Constitution, article 33, paragraph 3. The Constitution asserts that land, water and the natural riches contained therein shall be controlled by the State and used for the maximum prosperity of the people. The first Policy on Energy was established in 1976, through Presidential Decree No.B-31/Pres/9/76. This policy is called The General Policy on Energy (KUBE), which consists of guidance on national and sectoral energy policy measures. It was later published as the National Energy Policy in 1980, following the establishment of a new institution, BAKOREN (National Energy Co-ordinating Board). BAKOREN was established through Presidential Decree No. 46/1980. National Energy Policy is the management of energy resources from upstream to downstream, covering all energy policy measures, e.g. conservation, diversification, and intensification of energy. The policy is revised every five years, in accordance with "the five year national development plan".

## 3.3 Paradigms Operating in Indonesian Energy Policy and Planning

Policy and planning theorists have devised a number of models to describe and explain the process of policy making and implementation. (Dunn, 2003; Levy, 1994). It is useful to employ these models to elaborate on the policy processes in Indonesia, as the strengths and weaknesses of the different policy models/paradigms are well known and documented in the literature. Caution, however, needs to be displayed in extrapolating these lessons to the Indonesian situation.

The discussion of these models is restricted to analysing the policy and planning functions of the Ministry of Energy and Mineral Resources and BAKOREN (National Energy Coordinating Board) as they are the two most significant institutional agencies responsible for energy policy in Indonesia.

### 3.3.1 Mixed Scanning Approach: Ministry of Energy and Mineral Resources

The planning mode of the energy sector within the Ministry of Energy and Mineral Resources (MEMR) is very much that of *'Mixed Scanning'* which according to Etzioni (1968) is a blend of *'Rational Comprehensive Planning'* and *'Disjointed-Incrementalism'*, since it draws components from both. Faludi (1973, p. 155) defines Rational Comprehensive Planning' as an approach:

> *"...whereby the programmes put forward for evaluation cover the available action space and where the action space has itself been derived from an exhaustive definition of the problem to be solved".*

He further described, in this mode of planning, all conceivable courses of action must be identified and evaluated against all relevant ends to avoid harmful and sub-optimal courses of action because some areas are left unconsidered. However, rational comprehensive planning was extensively criticized for the impossibility of meeting its paramount requirements. Etzioni (1968), for example, has claimed that decision-makers do not have all the information needed to examine all important consequences of the various alternatives (Etzioni 1968, as stated by Camhis, 1979).

Contrary to 'Rational Comprehensive Planning', the 'Disjointed-Incremental Mode' developed by Lindblom, limits the range of alternatives and fragments decision-making between various units (Faludi, 1973). According to Etzioni (1968), disjointed-incrementalism is:

> *"... intended to limit the scope of rational decision-making to what relates to the ends and alternatives which clearly identifiable (or self-identifying) groups would consider. There are no "macro-decision-makers" making fundamental choices in Lindblom's image of society, so that it has been characterized as atomistic"* (Etzioni, 1968 as quoted by Faludi, 1973, p. 154).

Etzioni (1968) said that incrementalism is 'conservative' because the decision taken represents only the concerns of the most influential groups in society. He further pointed out that 'the values and interest of the poor, ethnic minorities, untouchables, and so forth' are not represented because the adjustments are made based on the relative power of the decision makers not based on the amount of protest or discontent. Therefore, decisions are not made in the direction of a 'political free-for-all' (Etzioni 1968). He also said that 'incrementalism' is anti innovatory, because it tends to proceed without risk by continuing in the same direction.

As mentioned in the beginning of this section the characteristic planning strategy in MEMR can perhaps be categorised as 'Mixed Scanning'. This is supported by the fact that there has been a tendency within the energy related units of the ministry the move from the disjointed-incremental mode towards rational-comprehensive planning. In energy planning or the decision-making process, each energy related unit within MEMR is making efforts to not only cover their available action of space (disjointed-incrementalism), but also making attempts to cover larger segments of their action space than they have been able to cover hitherto (comprehensive-rationalism). The Directorate General of Electricity and Energy Utilisation, for example, have been making efforts, notably in the last 5 years, to involve other energy related units within MEMR, particularly in the examinations of goals, objectives and selection of alternatives. All elements of the energy concerns within the ministry are starting to be given equal importance in contributing to the energy planning effort. Other Directorate Generals within MEMR are implementing similar approaches in planning strategy. This is probably caused by the recognition that each unit is accountable for its decisions to a wider interest than itself and a comprehensive set of actions need to be pursued.

According to Etzioni (1968), as quoted by Camhis (1979), because Mixed Scanning draws elements from 'rationalism and incrementalism' which are 'antithetical'. It can neutralize the peculiar shortcoming of each and jointly creates an approach that is more realistic and more transforming than each of its elements. However, 'mixed scanning', which Etzioni claims as the combination of 'rationalism' and 'incrementalism', was criticized by Camhis (1979) as much nearer to 'rationalism' and he accused Etzioni of siding with 'rationalism' on most principal issues; *firstly*; with regard to the question of values and goals, it is claimed that Etzioni considers they can all be rationally identified and be classed; and *secondly* on the issue of the alternatives, it is claimed that Etzioni considers that all relevant alternatives can be analysed. Therefore, Camhis (1979) said that Etzioni's real contribution was not so much to the concept of 'mixed-scanning' but rather in the procedure of implementation which is perceived as being an essential part of decision-making and planning.

### 3.3.2 Towards Rational-Comprehensive Approach: BAKOREN

When BAKOREN was established through a presidential degree in August 1980, the prime objective was to create a National Board for the consideration of very important energy decisions, particularly domestic energy production, utilisation and pricing. The Board includes, amongst others, Ministers of energy related departments, Heads of energy related State Owned Companies, the Chairman of the National Development Planning Board (BAPPENAS) and representatives of Universities/Academies and NGOs. BAKOREN is a non-structured coordinating body in energy matters, which reports directly to the Cabinet and is chaired by the Minister of Energy and Mineral Resources as the highest figure in energy policy matters. BAKOREN is the key institution in energy matters, because it is the forum for the highest-ranking officials, ministers or presidents of state enterprises and is a forum for consideration of very important energy decisions. National Energy Policy and other important energy decisions like energy pricing, nuclear utilisation as well as energy-related environmental decisions, are among the products of this body. In carrying out its tasks, BAKOREN is assisted by the Technical Committee of Energy Resources (PTE). PTE helps prepare and formulate the draft national energy plans and provides assistance and recommendations to the Board on energy matters. PTE is very important for BAKOREN for it serves as a think-tank or as a medium for information analysis, a crucial element in the planning and decision making process. PTE's members are representatives coming from government and non-government organization dealing with energy matters as well as some experts from prominent universities and the private sector. BAKOREN also has the responsibility to pull together the potentially conflicting activities of the Energy Ministry and other ministries and bodies with an involvement in managing energy resources. All energy policy decisions regarding pricing, production volumes and relations with contractors are initiated by or require BAKOREN's consensus and agreement before implementation.

Is BAKOREN a manifestation of 'Rational Comprehensive Planning'? When its tasks, memberships, goals and objectives are discussed as above, we might conclude that it is indeed the realisation of the government's dream for "multi-planning boards". BAKOREN falls within the criteria defined by Camhis (1979) as characteristic of a 'Rational Comprehensive Planning Board' According to him, a rational comprehensive approach has a variety of the following aspects; 1) it satisfies all goals of the various interest groups for the achievement of the general goals of the public interest, (2) it implies a comprehensive view of future desired state of affairs, (3) it means the assessment of all possible alternatives open to a decision maker for achieving his goals (4) it refers to the idea of giving equal importance to all elements of the area of concern. He also defines the following requirements for 'Rational Comprehensive Planning', which further confirm the above statement:

> *"...(1) A general set of values expressed as goals and objectives, (2) Generation and examination of all alternatives open for achieving the goals, (3) The prediction of all consequences that would follow from the adoption of each alternative, (4) The comparison of the consequences in relation to the agreed set of goals and objectives, (5) The selection of the alternatives whose consequences correspond to a greater degree with the goals and objectives"* (Camhis, 1979, pp. 30,31).

As a 'rational comprehensive planning board', has BAKOREN so far achieved its prime goals and objectives, that is 'a rationality and comprehensiveness of its energy decisions'? The facts point to quite an opposite direction. Some energy analysts offer the criticism that despite its vital role in energy decisions, BAKOREN's forum has not been adequately utilized by the government. They believe that some important energy decisions have been made outside this forum, particularly where there are time constraints. Some argue that lengthy procedures in the decision-making process in BAKOREN have been the main cause of the problem. Some analysts said that critical decisions had been made without involving important stakeholders and energy-related institutions, leading to the failures of or inefficiencies in policy implementation (Camhis, 1979).

The BAKOREN meeting was hardly carried out once a year as planned. BAKOREN meetings are scheduled to be held at least once a year or as needed to discuss an urgent energy matter that needs an immediate decision. In its early years, BAKOREN actively contributed to important decisions on national energy matters. However, in the last five years, BAKOREN meetings have been infrequent and the participants sub-ordinates which impacts on the quality of important energy decisions and the ability to implement the decisions. The BAKOREN's policies (since they were mostly formulated outside the meetings) were often criticized as merely adopting the top-down policy-making approach disregarding the interests of the stakeholders and not adequately accommodating public needs. All of the above facts pointed out that BAKOREN has failed to carry out a 'rational-comprehensive' energy coordinating forum.

The failures of BAKOREN can possibly be linked to the followings points made by Lindblom, the developer of 'disjointed-incrementalism' and one of the critics of 'rational comprehensive planning'. Lindblom (1965), as quoted by Faludi (1973, p. 150), for example, summarizes his points regarding rational-comprehensive planning (or what he variously labels as the '*synoptic ideal*') under the following statements:

> *"... The synoptic ideal is not adapted to man's limited intellectual capacities; the synoptic ideal is not adapted to inadequacy of information; nor is it adapted to the costliness of analysis; the synoptic ideal is not adapted to failure, which must be anticipated in many circumstances, to construct a satisfactory set of criteria, as for example, in the form of a welfare function..; the synoptic method is not adapted to the closeness of observed relationship between fact and value in policy making ...; The synoptic ideal is not adapted to the openness of systems of variables with which it must contend ....; the synoptic ideal, lastly, is not adapted to the diverse forms in which policy problems actually arise".*

Lindblom (1965) also argues against rational-comprehensive planning because decision-makers cannot practice its suggestions in real life. He states that the very attempt to plan rationally diverts decision-makers from more feasible approaches, for example, methods to simplify the decision problems (Faludi, 1973). BAKOREN, although it is a coordinating board whose members are prominent figures, does not have adequate power to influence all aspects required to guarantee implementation. According to Faludi (1973, p. 166):

> *"... single purpose authority may have control over some variables but it will not plan comprehensively. For any agency to be able to plan comprehensively, it must be able to influence most of the factors that have a bearing on its problems, and it must have the powers of using its resources in alternative ways, which is clearly what a single-purpose agency cannot do so that low relative autonomy acts as a constraint".*

From its long years of experiences (more than 20 years), it is obvious that a planning board like BAKOREN cannot be expected to command either wide enough vision or enough autonomy to engage in truly rational-comprehensive planning. According to Solesbury (1974), in general, despite all the weaknesses, the rational comprehensive method has never really been thrown away. Many planning agencies are still holding it for the reason it served well, and still serves, the process of justification of 'rational' and 'irrational' decisions alike. Some argued that even though the 'rational and purpose policy making model is both a simplification and an ideal', it still is 'an ideal which has to be strived for, mainly because government institutions are responsible for their decisions to a wider interest than themselves' (Solesbury 1974, as cited in Camhis, 1979). For this reason, I believe that a rational comprehensive planning board, like BAKOREN, is still worth maintaining and improving, so it performs closer to its main objective, of achieving 'comprehensive planning' of the energy sector.

## 3.4 Key Characteristics of Indonesian Energy Policy and Planning

According to the Oxford English Dictionary, policy means:

> *"...a course of action adopted and pursued by a government, party, ruler, statesman etc.; any course of action adopted as advantageous or expedient"* (as quoted from Hill, M., 1997, p.6).

Lindblom et al. (1993, p. 5) affirms that policy making is a complex, long and intricate endeavour. He believes:

> *"... understanding these broader aspects of policy making goes a long way toward unravelling the mystery of why governmental problem solving is not more effective".*

### 3.4.1 The Influence of Culture and Tradition

The process of policy-making in Indonesia has been much influenced by the culture and traditions inherited long before Indonesia became an independent nation. The Javanese Kingdom era and Dutch colonization has largely influenced the process. Inefficiencies and the lengthy procedures in the decision making process is an influence from the Kingdom era. Many said that the Dutch did not help in improving this 'inefficiency' and some critics even blamed the Dutch for worsening the attitude of native people. One of the reasons sugested was to avoid the natives embracing the modern and becoming competitors, especially in international trading markets. The Dutch, however, argued that they wanted to preserve the traditional values of the Javanese aristocracy (Legge, 1964). The notorious principle '*asal bapak senang*' or 'for the boss of happiness' has been blamed for the creation of policy decisions that merely serve the purpose of making the boss happy rather than for the interests or the welfare of the people. It can be argued that many of the energy policies look 'spectacular' on the surface but do not serve any real purpose. Often policies are carelessly and hastily made just to achieve targets and to serve a ceremonial purpose, but very weak in the implementation aspect. Energy policy development often lacks a systematic approach from inception to implementation and as a result many of the policies are only shelved and never followed up. For example, the National Energy Policies that have been issued since 1980 and reformulated every 5 years, have hardly been used for national energy policy guidance either by the government or private institutions (national or regional offices) dealing with energy matters. This was confirmed by many regional planners at a seminar entitled 'The Follow Up of the General Electricity Plan' which was held recently in Jakarta on May 17, 2004. Regional planners admitted that in preparing and formulating the regional plan as well as the regional utility plan for electricity in their region, they had never linked their analysis to the National Energy Policy or the General Electricity Plan. They argued that the National Energy Policy was 'too normative' and lacked important information and necessary implementation guidance required for regional policy analysis.

### 3.4.2 Inadequacy of Analysis and Information

Information and analysis is very important in helping solve complex problems, which require objective rational solutions. People's capacities for defining social problems and probing policy options are often very limited. According to Lindblom (1993, p. 10) "policy-making is a complexly interactive process without beginning or end".

Despite their important role in policy making, Indonesian policy-making is lacking two elements: adequate analysis and information. With adequate information and analysis energy policy can be made more effective in actually solving social and economic problems. The Government of Indonesia recognises this and has gradually been trying to enhance the supply of organized information and analysis for effective energy policy making.

Lindblom (1993, p. 15) acknowledged that in a poor, developing country, information and analysis can be inadequate:

> *"... In a wealthy country like the United States, analysis pertinent to policy goes far beyond the studies conducted by government agencies. There runs a deep and wide river of information and opinion fed by many springs, from formal research projects to letters to the editor, some of which makes its way into the thinking of those with direct influence over policy. The flow of analysis is thinner in poor countries that cannot afford it, of course, and authoritarian government stifle it".*

This certainly has been the case in Indonesia and to some extent continues to be the case in spite of the modernisation of the Indonesian economy and efforts of the Indonesian government to improve the level of analysis and research.

Energy analysts and decision makers realize their weaknesses and often feel that their tasks are beyond their capabilities and not supported with sufficient information. Lindblom (1993, p 16) said that "too much and too little information are both perilous" That is why it is common, that many people are perplexed about the basis of expert findings. Many of them do not know whom to trust when they are offered conflicting findings or recommendations. As a result scepticism and resistance often characterize the acceptance of the policy recommendations (Lindblom et al, 1993).

Much energy decision-making in Indonesia need to be made quickly, especially with regards to 'energy price'. Analysis, especially for complex problems, usually takes time and uses a lot of resources. If the decision makers have to make many policy decisions in a very limited time, then the 'mission' becomes impossible. According to Lindblom et al. (1993, p. 21) complete analysis and information is not feasible:

> *"...most policy questions therefore are decided by faster, cheaper methods than by analysis; most commonly, by delegating responsibility for decisions to designated officials who must decide, drawing on whatever information is available".*

### 3.4.3 The Need for Participatory Decision-Making

Another issue is public participation. Effective public participation is necessary if policy objectives are to be fulfilled and programs successfully implemented. Effective mechanisms must be found for encouraging and integrating citizen participation in policy formulation.

Unlike other nations, especially developed nations, it can be generally said that Indonesia has not yet adequately involved the public, interest groups or business sectors in the decision-making process, particularly in energy policy formulation. The past national energy policy formulation (from 1980 up to now) did not involve stake-holders. The national energy policies (KUBE) were prepared and formulated every 5 years by the Ministry of Mines and Energy and disseminated to the public and stake-holders. Indonesia can learn from developed countries like Belgium and Japan. These countries provide good examples of how public participation can be incorporated into policy formulation. According to the OECD (1990), the success of policy formulation and implementation in these countries was very much determined by the participation of community organizations and citizens. As Lindblom (1993, p. 75) said:

*"Interest-group activities are generally believed to constitute an exercise of free thought, speech, petition, and assembly and hence the exercise of those liberties for which liberal democracy was established. Whatever their contribution to liberty, interest groups also perform specific policy making functions. Everyone knows that the activities of interest groups often distort policy making, an issue addressed later in this chapter. But interest groups also perform more positive functions. In addition, interest groups are helpful and perhaps necessary for bringing diverse viewpoints, factual information, and other ideas into the policy-making process ".*

Time constraints are commonly cited as the reason for not involving other players or interest groups in decision-making. Many decisions in energy matter in Indonesia, especially those which relate with energy pricing and investment needed to be made quickly. The involvement of stake-holders prolongs the decision making process.

Besides, many policy analysts claim that interest groups do not possess enough information to adequately contribute to policy solutions and sometimes they are not really representing the interest of the public at large: they are fighting for their own interests. Lindblom (1993) contends that although the involvement of interest groups is often problematic, their input is indispensable and actually needed to help solve the complexities of policy problems. Interest groups help clarify and articulate what citizens want and they can monitor government actions and provide important feedback to responsible officials. They are important actors in building working coalitions (Lindblom, 1993)

The business sector should also have a greater role in energy policy decision-making in Indonesia. However, they have so far not been given a chance. Lindblom (1993) stressed that business interest deserve to participate in decision making, since they (and their workers) are among those most affected by government policy-making. Besides, a lot of information required for policy analysis is the hands of the business sector, so how can bureaucrats make decisions without involving them in the process. Involvement need to be granted to them to enrich the alternatives or options for problem-solving. Lindblom (1993) asserted that the fundamental challenge is how to encourage the business sector to do a better service for the society. Another challenge arises because some business executives also are major participants in political life. They could potentially intervene in the governmental side of public policy-making, hoping to gain much greater funding than that enjoyed by other social interests and they posses considerable resources for resisting government efforts to insert certain policy decision.

The Ministry of Energy and Mineral Resources (MEMR) should make sure that the process of decision-making in energy is a public one as this will support the openness of decision-making. The process should not be restricted within a single directorate or group of units within the Ministry only. The Ministry of Energy and Mineral Resources has recently tried to involve stake-holders in the formulation, socialisation and dissemination of energy policy. For example, the socialisation and dissemination of information regarding changes in the electricity tariff and measures by involving non-government organisations, energy consulting companies, energy-related institutions, business sectors, universities etc. In the process, the issue of the level of tariff in Indonesia has always been very sensitive to the public. Many criticism have been addressed at the government (Ministry of Energy and Mineral Resources) especially regarding the basis, criteria and assumptions the government use to determine the tariff. The involvement of stake-holders is, therefore, a step towards increasing understanding and transparency of the price setting process.

### 3.4.4 The Role of Politicians and Planners: Decision Taking Versus Decision Making

In Indonesia, the Minister is a political figure and his/her viewpoint is considered as being paramount because of his/her authority. No matter whatever the results of analysis are, they tend to be ignored if they are not in line with or contradictory to the political will. There has been a tendency for newly appointed ministers or government officials to issue new policies purely for popularity and political reasons or to show that he/she has produced new policies during his/ her term. For examples the policy on the use of coal briquettes to replace kerosene for cooking purposes in the household sector which was enacted in February 1993 by the Ministry of Mines and Energy (Presidential Instruction no.17/1993) and the policy on the efficient use of energy in energy consuming sector which targeted 17 percent energy saving nationally by the year 2000 (BAKOREN, 1995). Both policies were criticized as too ambitious and was not based on a thorough study of the practicalities of implementation. Both policies later proved to be no more than moves to gain political popularity.

Lindblom (1993) contends that politics and analysis always intertwine in the decision-making process and all governmental policy making can be labelled 'political' because it involves the use of authority. Many people distrust the result of democratic majority based decision-making for it brings contentiousness not reason (analysis) into the policy making (Lindblom, 1993). Many energy-decisions in Indonesia are indeed the results of 'political will' rather than 'analysis'. This characteristic undermines the role of planning and analysis and is summarised by Friend and Jessop (1969) as cited in Faludi (1973, p.233):

*"Most importantly, it prevents planners from criticizing politicians: the servant does not question the motives and the wisdom of his master. It thus casts planners into an inferior role. They frequently compensate by emphasizing privately their superiority as the providers of the knowledge-base and denouncing the whims and the pettiness of politicians (thus satisfying their psychological needs); and by using subversive tactics to get their way, even against the will of their political masters (thus making the politicians even more suspicious and insistent on his prerogatives). The result is the lack of mutual respect and of trust which appears to characterize the relationship between planners and politicians".*

According to Faludi (1973), decision-taking is undeniably the privilege of politicians, however, they should not control the whole process of decision-making. Both planners and politicians should work together openly as equal partners, equal contributors and responsible actors through out all phases of the process of planning (Faludi, 1973). He further elaborates:

*"The role of the politicians: Acceptance of Risks. Because it is the politicians who must 'carry the can' for assumptions entering the formulation of any programme. His prerogative is therefore not so much that of setting the ends of action towards which planners work as their loyal and unquestioning servants (which is not really feasible, anyway), but more of choosing deliberately to accept the risks of pursuing one course of action in preference to others, including the assumptions on which this course of action is based"* (Faludi, 1973, p. 236).

Whereas the role of planner is to analyse the risks involved in the politicians' decisions, which apply to every phase. In this way the politician can weigh the risks more accurately and operate more consciously and take the decisions, which commit public resources and affect people's lives (Faludi, 1973). In the Indonesian case, every law which is prepared and formulated by government should be examined by the House of Representative. The House of Representative and the government work together in preparing laws which exert minimal risk and give a great benefit to the society. The regulations, policies or decrees that are issued by the government should be in line with the law and consistent with other policies in the hierarchy.

### 3.4.5 The Role of Inter-Departmental Committees

In the past, there have been criticisms of the government, regarding the inconsistencies between energy policy and the programmes or projects formulation. The lack of integration between energy policy and programme formulation, can be reduced by developing common policy objectives and defining an appropriate programme scope and scale among the energy-related departments and institutions. It is important that integrated objectives flow through policy into specific programmes. These can perhaps be achieved by the establishment of interdepartmental task-forces, committees and boards. The government needs to make the best use of an interdepartmental committee, like BAKOREN and the PTE, because these are the right type of institutional structure to serve this purpose.

### 3.4.6 The Role of Regional Offices.

In the past, there was little devolution of energy policy and planning to the regional level. However, with the government plan to give greater functional power to regional offices and to rationalize the number and boundaries of national government authorities in line with the Regional Autonomy Policy (Law no. 22/1999), which was supposed to start in 2002, there is now greater awareness of the necessity of involving the regional level in the decision-making and implementation process. This process is aimed at encouraging regional offices to have a more active role and limiting the role of national government in the decision-making process. Today, therefore, regional offices must be a major participant in terms of decision-making, finance and responding to public opinion. Regional offices are the level of government closest to the people. Indeed where appropriate, programmes can and should be delivered by the affected community and regional groups. This is because the regional offices are more in tune with local needs, more willing to implement systems locally designed than centrally imposed. Obviously, national governments have an important role to play; but they should have less hands on control, and instead perform the important role of facilitation, advocacy, leadership, and performance control rather than prescription of specific approaches, which might not be optimal in the regional context. Central government would be most effective if it deployed its human and financial resources to support and enhance a regional initiative and in so doing make that initiative a locally sensitised articulation and instrument of national policy. National governments are perhaps in the best position to monitor success and failure in regional experience and to disseminate innovative approaches.

In line with the enactment of Law no. 22/1999 regarding Regional Autonomy, the Ministry of Energy and Mineral Resources has issued a Technical Guidance document on the Implementation of Energy and Mineral Resource Management by Regional Offices. The guidance document covers several aspects of energy and mineral resources management such as technical guidance, standard and norms. It also sets criteria for: the management of underground water, inventory of energy and mineral resources; geological mapping, mining activities; oil and gas activities; electricity generation; transmission and supply, etc. A task force team has been established to facilitating the implementation of regional autonomy in the field of energy and mineral resources. The task force will work from 2001 to 2005 (KEPMEN ESDM/2001).

### 3.4.7 Successful Implementation

Another problem with energy policy-making in Indonesia is the inadequacy of policy implementation. The energy policy programmes were rarely implemented or when they were implemented the results were disappointing. Faludi (1973) said that successful implementation relies on the twin aspects of knowledge and authority. Both aspects are always limited in the energy decision making-process in Indonesia. As a consequence, this influences the capability of many energy institutions to not only formulate but also implement energy programs. Faludi (1973) also emphasized the need for the government to manipulate its control variables to reduce sources of tensions and thus ensure successful implementation. This can be done, by converting resources into control in accordance with a programme. He further claimed that difficulties during implementation are likely to be caused by short-comings in the process by which the programme has been designed. The inadequacies during programme formulation may be caused by a lack of knowledge about the world outside or misinterpretation of the control process and or unavailability of resources. Faludi (1973) emphasizes that it is important to improve images and knowledge of control processes including converting of resources into control in order for the planning institutions to be able to implement their programmes.

### 3.4.8 Leadership

Another possible improvement to policy-making in Indonesia is committed leadership. Indonesian culture is similar to the Japanese culture in highly respecting seniority status. The continuing commitment and leadership profile of a key politician or senior administrator is, therefore, necessary for the successful implementation of any energy policy. This is especially true when the policy requires 'example' from the leadership. For instance, a vigorous energy savings campaign without a 'good example' on the part of high profile figures will be ineffectual and a waste of time and money. It is most likely that without determined, courageous leadership, any policy decision will be unable to come anywhere close to realising its full potential.

### 3.4.9 Limitations on Bureaucratic Intelligence

It can be argued that many bureaucrats in MEMR do not have adequate knowledge and skills especially in analysing social problems, and this decreases the capacity of policy-makings.According to Lindblom (1993), bureaucrats often pay attention only to the process rather than the results and put more emphasis on personal ambition rather than the program's goal. Their tendency to focus on procedural strictness may be used as a way to avoid responsibility, even if it means wilfully continuing actions that are accomplishing nothing or that are obviously useless.

Bureaucrats in Indonesia are often criticised for their slowness in responding to public demand. Sometimes they prefer inaction rather than action due to their limitations.

Moreover, they are notorious for defensively disguising mistakes rather than admitting and adjusting them. This leads to the weakening of bureaucratic intelligence. As Lindblom (1993) argues bureaucrats in general are prone to protecting their budgets, and, usually to short term-narrow vision rather than setting broader-long term goals.

## 3.5. Emergent Policy Objectives

In the formulation of energy policy for Indonesia, there are several emergent policy objectives that need to be taken into consideration, as they are very important particularly for determining the country's policy options for the next 20 years.

Economic and environmental considerations have increased in importance in Indonesia and are now major inputs into decision-making in the energy sector. There is an emerging interest in the Indonesian energy sector to ensure that energy efficiency, economic growth and protection of the environment be included in the objectives of the national energy policy. This was explicitly stated in the 1998 National Energy Policy (BAKOREN, 1998). These important policy objectives can be further broken down into specific elements, i.e. energy security, economic efficiency, energy efficiency, $CO_2$ reduction, energy self sufficiency, more renewables, foreign exchange earnings and robustness. These objectives will be considered carefully in the policy analysis to make sure that robust and optimal policy options are recommended. The discussion on these emergent policy objectives will be focused particularly on the definition of the elements, operational measurement, the current status, barriers, and possible actions for Indonesia. This review of Indonesia's energy policy objectives is important as it will be used to define the policy drivers in the systems dynamics model in Chapter 8.

### 3.5.1 Economic Efficiency

Ironically, 'economic efficiency' as an energy policy objective in Indonesia has only in recent years attracted the attention of the policy makers. This is partly provoked by the reality, that there has been continued excessive exploitation of the country's natural resources, particularly oil and gas either for domestic or for export purpose, but this has not produced an adequate improvement to the welfare of the nation. The urgency to put *'economic efficiency'* on the top of the national agenda emerged during the last decade, particularly when energy analysts faced the reality that domestic oil reserves could no longer be expected to support domestic need and sooner or later the country would have to rely on foreign oil. This likely changing status of Indonesia from an energy exporting country to an energy importing country has further opened the eyes of energy policy makers and put the need to consider economic efficiency onto the country's top national agenda. In addition, the country's reliance on exported oil as a source of foreign exchange will have to be reduced or stopped due to this scarcity concern. This has provoked energy policy makers to find ways to generate more optimum added value from oil utilisation. One of the ways is to regulate so that oil and gas can no longer be exported if it is more economically beneficial (creating more added value) for oil and gas to be used domestically. The 1998 General Energy Policy put emphasis on the need to obtain maximum added value from energy utilisation:

> *"The utilisation of energy, particularly from fossil resources, which are needed both as fuel and as raw material in industries, should be carried out wisely and thoroughly assessing its optimum benefit in order to yield large added value"* (BAKOREN, 1998, p. 18).

**Definition**

There are several definitions of economic efficiency. Luxton (1992) for instance, defined economic efficiency as the 'lowest cost to the economy as a whole'. This can also be defined as an effort to ensure that the physical output obtained from a given level of inputs is at maximum or produces maximum value of output given the amount of resources available to a country. Luxton (1992) also suggested that economic efficiency is comprised of three main components, first; *pricing or allocative efficiency*, which requires that prices equal the marginal costs of producing those goods and/ or services, all through the whole economy; second; *technical or productive efficiency*, which requires the minimisation of the costs of operations; this is the same as the attainment of maximum technical efficiency and the cost minimisation condition; third; *dynamic efficiency,* which involves the optimisation of investment decisions (Gunn, 1997: p. 243 quoted from Luxton, J. (1991a). In a similar way to Luxton (1992), Clough (1999) defines economic efficiency as 'maximising outputs obtainable from a given set of inputs, or minimising inputs required to obtain a given set of outputs'. Also, like Luxton (1992), he states that economic efficiency basically consists of three types of efficiency; (i) *technical or productive efficiency,* which he defines as producing a given output at the lowest possible cost in light of known technologies and given resource prices, which is near to the concept of cost effectiveness (ii) *allocative efficiency*, which is obtained by 'allocating existing stocks of resources and technical knowledge to produce the collection of goods and services that buyers value most highly, as indicated by their collective willingness to pay for them'. According to him, allocative efficiency differs from technical efficiency in two things: *first,* it considers the demand for the produce and, *second*: it allows for resource reallocation between various products and activities in accordance to the balance between marginal cost and benefit of each activity. Clough also includes; dynamic or innovative efficiency, which happens when "the present value of net benefits associated with products and production processes is maximised over time". (Clough, 1999: p. 10).

Moreover, according to Clough (1999), these three types of efficiency are not always compatible. He gives examples:

> *"It is possible to be technically efficient in producing goods which no-one wants to buy, which would lead to allocative inefficiency. Similarly dynamic efficiency may be obstructed if decisions are made which, although efficient in the short term, 'lock in' particular production processes and resource uses in ways which are difficult to reverse"* (p. 10)

The International Energy Agency (IEA, 1991, p. 44) stresses that economic efficiency is a combination of economically efficient use, efficient pricing of inputs, minimum cost of production and the optimal allocation of resources:

> *"Economically efficient use is the use of energy that results, in combination with other inputs, in the least cost production and in optimal allocation of resources, assuming efficient pricing of all inputs. The economic notion of efficient energy use may thus even result in a rational increase in energy use, if the relative prices of energy and other factors of production would dictate such a shift in productive inputs".*

**Operational Measurement**

In view of the above definitions, we can define the operational measurement of economic efficiency as the simple ratio:

$$\textit{Economic efficiency} = \frac{\textit{Output of economic activities (\$)}}{\textit{Energy and other inputs to the economy (\$)}}$$

The ratio is maximised by minimising inputs (energy and other natural resources as well as production costs) to the economy and maximising output of the economic activities that use these inputs. Both numerator (output of economic activities) and denominator (energy and other inputs to economy) are in economic value ($) terms.

### 3.5.2 Energy Efficiency

There are justifications for promoting energy conservation activities in Indonesia. *First,* is to reduce the rapid depletion of conventional energy resources due to uncertainty about the future availability of those resources. *Second,* is the concern over the security of supply of these resources considering the likely changing status of the country to an energy importing country in the not too distant future. *Third,* is for the purpose of improving economic competitiveness by ensuring that the use of energy along with the use of capital, raw material and other inputs, is minimised subject to the overall criteria of cost-effectiveness, so as to boost the competitiveness of the economy. *Fourth,* is for the improvement of the social well-being of the nation by enhancing standards of living through minimising unnecessary expenditure by consumers on energy, particularly those on low incomes. *Fifth,* is due to the concern over local, regional and global environmental impacts of energy utilisation by curbing the detrimental effects of fossil-fuel burning pollutants through energy efficiency implementation together with a wide range of other measures both within and outside of the energy sector.

Energy efficiency offers not only a safety measure against the threats caused by increasing energy consumption, but also provides appropriate and readily available measures to reduce dependence on fossil fuels. Moreover, investment in energy conservation and efficiency offers the fastest and least uncertain means to reduce $CO_2$ emissions. It is widely known that maintaining services while reducing the amounts of fuel used are possible with current technologies. Hill (1995, p. 81) stated, "the potential rewards of energy efficiency to consumers, humanity and the environment are so great that it must be pursued with urgency".

There have been efforts to implement efficiency programs by the government in almost all economic sectors in Indonesia. Energy conservation activity began to be promoted and implemented following the Energy Conservation Symposium held in 1979. It took almost 3 years after the symposium for the government to start to enact the first regulation for energy conservation implementation (Presidential Instruction No. 9/1982). This decree stipulates the need for conducting energy conservation implementation in state-owned buildings and vehicles. This was aimed at setting an example for the public about energy conservation awareness. Another important attempt was made in 1987, when the government established an energy conservation consulting company PT KONEBA. Its tasks cover promotion, training, consultancy, and service provision to assist with the implementation of the energy conservation program. In 1993, the government issued a ministerial decree to boost energy conservation in the Mining and Energy sector. The decree required that all state owned companies under the Ministry of Mines and Energy implement energy saving measures through energy auditing and energy saving. Moreover, in 1990 The National Energy Conservation Team was established by the Minister of Mines and Energy (Ministerial Decree No. 0604K/702/MPE/1990) aimed at promoting the implementation of a national energy conservation program.

In 1992, considering that energy conservation was a vital element in reducing the rapidly increasing domestic energy demand, the President of Indonesia (Soeharto) appealed for more efficient and wise use of energy. In this occasion he also declared "Public Awareness and Action on Energy Conservation" (BAKOREN, 1995). Following the President's appeal for more efficient use of energy, energy conservation became a national concern on the national agenda. The energy conservation program, was included (stated explicitly) in the 1993 State Guidelines. Energy efficiency objectives, especially those not requiring a big investment or moderate/low investments were considered as important and to be implemented in the short run.

**Definition**

Energy efficiency can be described as producing the same amount of services using less energy or as maximum output obtained from a given amount of energy resources by keeping resource waste to a minimum. Hill et al. (1995) defined *energy efficiency* as sustaining the same levels of service with less fuel. According to Christie and Ritchie (1992), *energy efficiency* is associated with the reduction of energy inputs per unit of output. The output can be measured in terms of useful heat, light and mechanical work, miles per gallon or in terms of industrial production either in physical or economic units ($). Gunn (1997) stated that *energy efficiency* is using a lower level of energy input to obtain the same quality and level of some 'end use' of energy (e.g. heating, cooling, lighting, motive power and watching television). Brookes (2000, p. 356) defined *energy efficiency* in different way;

> *"... it is deliberate action to raise the cost effectiveness of the use of fuel and electrical energy by such means as: (1) raising the engineering efficiency of conversion of fuels to useful heat or work; (2) increasing the effectiveness of the associated energy service by, for example, higher standards of insulation. These two actions are examples of action to lower the cost of the energy input to a given energy service or of raising the level of the service obtainable from a given energy input cost".*

Christie and Ritchie (1992) categorised *energy efficiency* into two types in accordance to the way energy is saved. They stated there are two categories of energy efficiency, technical potential and economic potential. The technical potential shows how much energy could be saved by the application of various technologies, either current or future best practice technologies. Whereas, the economic potential indicates the amount of energy that could be saved under specified investment criteria, for example, a rate of return or payback period. Christie and Ritchie (1992, p. 49) stated:

> *"... the economic or cost effective potential is dependent upon judgements about current and expected fuel prices, the availability and cost of capital, technological change and the underlying rate of replacement of capital stocks of energy using appliances, plant and equipment".*

Moreover, Christie and Ritchie (1992) also group energy efficiency into two measures: the supply side energy efficiency measures and demand side energy efficiency measures.

*The supply side energy efficiency measures* are principally those measures, which deliver the same amount of final energy demand to consumers, but minimize the losses in connection with the delivery of that energy. The largest value for such measure is provided by combined heat and power (CHP) generation. Whereas, *demand-side energy efficiency measures* emphasizes the way in which energy is consumed by the consumer at the point of demand. For example, the use of delivered energy for space heating requirements in the domestic sector. The potential for reducing the demand for delivered energy in the domestic sector depends on the efficiency of space heating and the other end-use services.

**Operational Measurement**

Patterson (1996) defined the operational measurement of energy efficiency in three categories; thermodynamic, economic and mixed (economic-thermodynamic).

$$\textit{Thermodynamic} = \frac{\textbf{Useful energy output}}{\textbf{Energy input}}$$

$$\textit{Economic} = \frac{\textbf{Output of service delivery}}{\textit{Energy input}}$$

$$\textit{Mixed} = \frac{\textit{\textbf{Output (service delivery) of process}}}{\textit{Energy input}}$$

In thermodynamic efficiency, the values of useful energy output and energy input are both measured in thermodynamic units. In economic efficiency, energy input measurements are transformed from physical units into monetary units by using appropriate energy prices. The mixed efficiency is the combination of thermodynamic and economic efficiency. The numerator or output (service delivery) of process is measured in monetary units ($) and the denominator or energy input is measured in physical and thermodynamic units.

**Key Barriers to Greater Energy Efficiency in Indonesia**

A key issue for energy efficiency in Indonesia is the price of energy. With heavily subsidised prices for energy (electricity, oil and gas) in the domestic market over the past three decades, there seems to be very little motivation for domestic or business energy users to invest in energy efficiency. Moreover, some policy analysts are critical of the energy office (under the MEMR) and its ability to implement policy decisions due to barriers, such as the lack of incentives and the low price of conventional energy.

Energy savings policies and programs are produced every year, but many analyst regard them as only good to be shelved due to the absence of stakeholders' participation and government commitment. Some state owned energy companies, like PERTAMINA and PLN, have paid very little attention to least-cost planning on the supply side. Whereas, on the demand side, problems are primarily caused by insufficient energy efficiency standards for buildings, energy labelling standards for appliances, energy efficient technologies and the failure of public agencies to set a good example in making their own buildings energy efficient though the regulations require this (Presidential Instruction no. 9/1982). Many argued that the slow development of the market for energy efficient products and services was fundamentally caused by inadequate market signals due to subsidies or inadequate information provided by the government and energy offices. The lack of consumer awareness and of useful advice to households and businesses on energy saving was frequently noted (MME, 1999).

**Possible Solutions to Greater Energy Efficiency in Indonesia**

The potential for energy saving in Indonesia is quite significant. Based on the survey conducted by the MME in 1995 to 1998, the potential for energy saving (with or without investment) in industry ranges from 10 to 30 percent, transport 15 to 25 percent, and households 10 to 20 percent. The manufacturing sector has the highest potential (25 percent), followed by the construction and glass sectors each with 20 percent potential saving. According to BAKOREN (1995), most of these potential energy savings have not been realised and there is still ample room for energy saving. Many energy conservation analysts recommend elimination of energy supply subsidies, especially for oil products and electricity and rationalising energy prices as the key solution to greater energy efficiency in Indonesia. (MME, 1999). Energy efficiency investment in Indonesia is low compared to other ASEAN countries, but there are several possible policy instruments to promote energy efficiency - for example: (1) improving the flow of information, (2) setting targets for energy efficient performance, (3) providing financial incentives for energy efficiency investments (tax exemption, low interest rates, etc.). Equally important is stimulating the role of private or non-governmental organizations (NGOs). For energy efficiency-environmental impact issues, particularly on the issue of climate change, the Ministry of Environment has started to involve the NGOs in the decision-making process.

### 3.5.3 $CO_2$ Reduction

In the last two decades, environmental concern has also been widened to include not only local and regional impacts, but also the possible disturbing levels of global impact. That 'global warming' is caused by the so called 'greenhouse gases' (mainly $CO_2$, $CH_4$. etc.) is a theory now widely accepted by both scientists and decision makers. Long (2000) wrote that in the second half of the 1980s, the international community intensified its efforts to find concrete evidence about whether carbon dioxide and other gases being produced by human activities were causing global climate change. Scientific results were discussed during major international conferences in 1983, in Villach (Austria) and in 1988, in Toronto (Canada). Later, in 1989, WMO and UNEP set up the Intergovernmental Panel on Climate Change (IPCC), as well as three working groups: on likely climate change and its causes; on possible impacts; and on policy responses (Long, 2000).

Since then, many countries have started to focus their attention on these energy-related emissions, particularly carbon dioxide ($CO_2$), methane and nitrous oxide ($N_2O$) as sources of global climate change. The energy industry, which is one of the main sources of $CO_2$ emissions, is faced by demands that it should reduce its emissions from fossil fuel fired power stations. Shifts to more environmentally clean fuels and more sustainable energy technologies are encouraged. According to Long (2000), by the year 2010, the world's population will have increased from 5.5 billion in 2000 to more than 7 billion and most of this increase will be in the developing world. The demand for energy outside the industrial countries will rise considerably and, therefore, the drastic reduction of polluting emissions becomes an even more urgent demand in the developing countries, notably Indonesia with its current 215 million people.

Following the increasing recognition of the global scale of climate change impacts, Indonesia joined international efforts to reduce green-house gases emission, particularly $CO_2$ emission from fossil fuel burning. Indonesia ratified the Framework Convention on Climate Change in 1996. At the national level initiatives, like a National Committee on Climate Change, national response strategy, national communication, and national inventory on greenhouse gases emission are being established. However, global warning is not an immediate concern of the Indonesian government due to the economic costs of reducing the emissions and the relatively low or even negative net $CO_2$ emissions of the country (due to the country's rich rain forests resources which can absorb its current level of $CO_2$ emission) (BAKOREN, 1998).

**Definition**

Carbon dioxide ($CO_2$) reduction can be defined as minimising $CO_2$ emissions from fossil fuel burning caused by human activities. $CO_2$ emission reduction can be carried out on the demand side as well as on the supply side through efficiency improvement, reducing energy consumption, utilizing some alternative energy technologies, and using a less carbon/cleaner energy.

**Operational Measurement**

*$CO_2$ emission reduction (t) = $CO_2$ emission per capita at year (t-1) – $CO_2$ emission per capita at year (t)*

According to Hill (1995), there is no practicable technology for eliminating $CO_2$ from flue gases. The potential for changing from one kind of fuel to another is also very restricted. The other options for minimising carbon dioxide emissions are either to reduce the energy generated from fossil fuel sources, by shifting from conventional to renewable or nuclear energy technologies, or to decrease the total consumption of energy. Decreases in the quantity of energy consumed can be achieve by either lowering the level of services provided by energy, or by increasing the efficiency of energy equipment and appliances used to produce those services.

**Key Barriers to Implementing $CO_2$ Reduction and Possible Solutions**

The barriers to implementing $CO_2$ emission reductions are greater than the barriers of implementing energy efficiency and energy diversification programs. Energy efficiency and diversification are clear advantages to energy consumers, energy producing companies and to the country's economy. On the other hand, the $CO_2$ reduction is commonly perceived as providing advantages (preventing global warning) to the global community and adding financial burdens to energy consumers or producers. The success of $CO_2$ reduction will be greatly influenced by: *first*, the global recognition that there is a real and proven threat from green-house gas emissions; *second*, the global commitment for $CO_2$ reduction. However, the facts show that there are still some persisting doubts about the eminent danger of $CO_2$ accumulation and the inadequacy of commitments given by many developed countries to an agreed solution. Christie and Ritchie (1992: p. 20) stated :

> *"... there have been various calls for $CO_2$ emission reduction, but only a limited number of various countries have pledged themselves to actual reductions in $CO_2$ emissions".*

This situation does not motivate the developing countries, in particular, to promote $CO_2$ emission reduction. Presently, the Indonesian government's efforts in dealing with greenhouse-gases emissions are discouraged by the fact that even the Annex-1 countries like the United States do not want to commit to green-house gases emission reduction and are not signing the 'Kyoto Protocol'.

Possible approaches to $CO_2$ reduction, for Indonesia would be to promote energy efficiency and energy diversification efforts without linking them to global issues. The government could also encourage investment in more energy efficient and environmentally benign technologies. More positive effects on energy conservation and on renewable energy technologies would also be gained if subsidies were removed which would increase conventional energy prices.

**The Current Level of $CO_2$ Emissions in Indonesia**

According to the study conducted by the State Ministry for Environment Indonesia (1999), the 1994 total level of $CO_2$ emission from all energy sectors (fuel combustion + fugitive) was 170 Tg. This $CO_2$ emission level was projected with (1994 as the base year) to reach 229 Tg in 1995 and to reach 680 Tg in 2025. Thus, $CO_2$ emission are predicted to grow at the rate of 3.7 percent per year during the period 1994 to 2025. According to the study, in 1995 petroleum was the major contributor (60 percent of total $CO_2$ emissions), followed by natural gas (26 percent) and coal (18 percent). In 2025, coal will contribute 55 percent of total $CO_2$ emissions, petroleum and natural gas will decrease to 34 percent and 14 percent respectively. After 2005, the main producer of $CO_2$ emissions will be power generation, because the annual growth rate of energy consumption in the demand sector will be lower than the annual growth rate in the supply sector (State Ministry for Environment, 1999).

### 3.5.4 Foreign Exchange Earnings

Oil and gas have provided the main foreign exchange revenues for Indonesia, especially since the first oil shock in 1973. During 1976 to 1977, Indonesian crude oil exports increased from 450 million barrels in 1976 to 485 million barrels in 1977. Between 1969 and 1973, oil and gas contributed 44.6 percent to total Indonesian exports. During 1979 to 1983, the oil and gas contribution to state income reached a peak of 75.5 percent of the total Indonesian exports. In the period of 1969 to 1995, foreign income from oil and gas increased rapidly reaching an average of 28 percent a year. In 1969 it was US$ 92 million, while in 1995 it reached US$ 3,176 million (US Embassy, 1997). The government realizes the effects of heavy dependence on oil revenues (the oil windfalls in 1973 and 1979 ironically had negative economic outcomes) in particular the impact on domestic inflation. The government has been trying to reduce its dependency on oil and gas incomes. At the OPEC meeting in Bali in November 1994, President Soeharto told the assembled delegates that oil *'no longer plays an important role in the Indonesian economy'*. Foreign income from oil and gas will continue to rise in the future, but the non-oil foreign income will also continue to escalate significantly, possibly at a faster rate This was shown by the fact that in 1995, oil and gas contribution to state income decreased from 44.5 percent in 1990 to only 20.5 percent in 1995, while income from non-oil and gas sources increased substantially (US Embassy, 1997). In the next two decades, it is likely that the role of oil and gas in foreign exchange earning will decrease substantially in line with the government policy to use oil and gas for domestic purposes as stated by the new Energy Policy Guidelines (KUBE) (BAKOREN, 1998).

**Definition**

Foreign exchange is the instruments used to make payments between countries in the form of paper currency, notes, checks, bills of exchange etc. for the transaction of goods or services (Downes and Goodman, 1995). Foreign exchange earning in this thesis can simply be defined as the foreign exchange gain by the government, which results from foreign exchange transactions. This section will only address two categories of foreign exchange earnings; the oil and gas foreign exchange earnings and the non-oil and gas foreign exchange earnings.

**Operational Measurement**

Two operational indicators for measuring progress towards the policy objective of maximising foreign exchange earnings from oil can be expressed in percentage terms:

$$\frac{\textit{Foreign income from oil and gas exports (\$) per year}}{\textit{Total foreign exchange earnings (oil and gas + non-oil and gas) (\$)}} \quad x\ 100$$

***And***

$$\frac{\textit{Foreign income from the non-oil and gas exports (\$) per year}}{\textit{Total foreign exchange earnings (oil and gas + non-oil and gas) (\$)}} \quad x\ 100$$

Both of the above types of foreign exchange gains are measured in monetary units US($). The foreign income from oil and gas exports is measured as a percentage of the total domestic foreign exchange income earnings.

**Recent Government Policy on Foreign Exchange Income from Oil and Gas:**

The recently established policy guidelines on oil and gas stated that oil and gas exports for foreign exchange earnings would no longer be encouraged. This General Energy Policy of Indonesia (BAKOREN, 1998) underlines the need to reduce oil exports and encourage the use of oil for domestic purpose to increase the added value of oil utilisation, *"We are cognizant of the fact that we still need to export oil to obtain foreign exchange to fund our development. Nevertheless we should in stages reduce oil exports and gradually use oil for industrial products, including industrial products based on oil. In this way, oil will gradually be used domestically as fuel and as raw material for industry, which will generate higher added value. Adhering to the principle of optimisation, we should not discount the possibility of importing energy, if this would provide the maximum net benefit and at the same time conserve our own natural resources"* (BAKOREN, 1998; p. 4).

The policy of gas exports is similar to that of oil :

*"Our needs for foreign exchange to provide funds for development, should be gradually reduced such that an optimum usage rate is reached in the utilisation of this valuable natural resource. Its domestic use as fuel and as raw material with higher added value need to be encouraged to reach an optimum level of usage. The requirement for export in order to earn foreign exchange and domestic supply to meet fuel and raw material demand should both be met in a dynamic fashion and gradually the need to export gas should become secondary, whereas export of industrial products should become the main foreign exchange earner. The general energy policy is aimed at supporting the achievement of such a situation"* (BAKOREN, 1998: p. 5).

### 3.5.5 Energy Self Sufficiency

In the last ten years, energy analysts have alerted the government to the fact that oil reserves will soon be depleted and the country may have to import oil to fulfil domestic oil needs. The government is very concerned that the country will turn into a net importer of crude and petroleum products early in this century as oil production goes down and domestic consumption escalates (US Embassy, 1997). It seems that the country will possibly face a self sufficiency problem in the not to distant future, if it does not hurriedly embark on energy diversification and accelerate its attempts to intensify oil exploration activity.

Indonesian energy policy in 1991 stated that the country's self sufficiency in energy should be maintained through enhancing natural resource development; conserving the use of depletable natural resources and pursuing renewable-based development. The policy stated that survey and exploration activities, to identify the potential economically exploitable energy resources, have to be promoted. The new exploration has been focused on front line areas, mainly in eastern Indonesia, which are much more isolated and problematical regions to explore than those of western and central Indonesia. The government has also been accelerating attempts to enhance the maintenance of existing oil fields (BAKOREN, 1992). However, Indonesia's national energy policy (issued in 1998) does not explicitly mention energy self-sufficiency objective. The new policy only states the need to ensure the availability of domestic energy supply and to assure it. The policy calls for the enhancement of energy exploration activities, efforts to save energy consumption and the commercialisation of renewables to increase their role in the domestic energy mix (BAKOREN, 1998). What is emphasized in this new policy, is that the government is determined to ensure the country's self sufficiency in energy supply particularly by promoting exploration activities in the short run and commercialisation of renewables in the long run.

**Definition**

Energy self sufficiency may be defined as the independence of a country from foreign countries regarding an energy commodity in order to avoid a serious threat to the country's sovereignty and political independence. Energy self sufficiency will maintain or enhance national resilience as it is concerned with managing energy resources optimally and to coping with the constraints and challenges for the fulfilment of future energy demand. Energy self sufficiency is aimed at lessening national dependence on imported energy (BAKOREN, 1998).

**Operational Measurement**

*Total energy imports < (Total domestic supply + Total energy exports + Stock Change) - domestic energy demand*

All of the above variables are measured in physical units (Petajoules). The total energy imports are kept at a minimum amount by enhancing domestic production and reserves as well as diversifying domestic energy supply.

### 3.5.6 More Renewables

Renewables and other energy alternatives to oil and gas are priorities in any consideration of energy supply options. Globally, a move from non-renewable to renewable energy resources is being encouraged. Depleting conventional resources, particularly oil in Indonesia, has meant renewables get more attention from the government. Rural and remote households, which are about 60 percent of the total number of households in Indonesia, continue to depend heavily on woody biomass for their energy, especially for cooking. Currently, the Indonesian energy policy in these areas is to promote the establishment of local small-scale generation plants using available renewable sources - micro-hydro, geothermal, solar, wind, or waste biomass (DGEED, 1998). According to a study conducted by the renewable energy office, the quality, reliability and durability of small-scale electricity generation plants remains the main handicap to the development of renewables (DGEED, 1998). Because the renewable energy technologies are site-dependent, they tend to rely on local/rural construction and manufacturing causing concerns about quality, reliability and durability.

According to the IEA (1997) renewables are still in the process of building the substantial track record necessary to prove their cost-effectiveness, reliability and maintainability in commercial markets. Research and development is important to build confidence in renewables to enable them to be regarded as reliable energy sources by energy supply industries and financial institutions. Some argue, however, that it will take quite some times before most 'new' renewables will be fully competitive with other conventional energy technologies.

**Definition**

*'More renewables'* means utilising more renewable sources of energy for domestic energy needs, taking economic (cost effectiveness), technological (reliability and applicability) and political (public acceptance) aspects into consideration (OECD, 1998). The implementation of renewables for energy sources is prefered in remote or rural areas. Ideally the technology selected should utilise locally available renewable resources, involve local people's participation and, if possible, locally manufactured equipments/parts.

**Operational Measurement**

An operational indicator for measuring progress towards the policy objective of 'more renewables' can be expressed in percentage terms:

$$\frac{\textit{Total renewable energy utilised (PJ)}}{\textit{Total domestic energy supply (PJ)}} \times 100$$

**Barriers to More Renewables Utilisation in Indonesia**

There are several key factors which hamper the competitiveness of renewables in Indonesia. As is the case of other countries, according to DGEED (1998), the largest barrier to greater renewable energy use in Indonesia is cost. The cost reductions on renewables, which have been made over recent years, have yet to improve its competitiveness. Other key barriers, especially for renewable electricity, are the prices of conventional fuels, which are still heavily subsidised; lack of full cost pricing when determining the cost of competing energy supplies, for instance, each renewable energy technology has its own set of environmental problems and benefits which represent added or avoided costs, but these are not always compared with those of conventional generation on an equal basis. These cost barriers can put renewable generation at a disadvantage. DGEED (1998) also pointed out several non-cost barriers to greater renewable energy implementation in Indonesia. The non-cost barriers include the inadequate flow of information and the lack of integrated planning procedures and guidelines; strong opposition at the local level to renewable energy projects; site dependency for optimising the performance of renewable energy technology; the lack of local planning experience in renewables which can prevent or delay construction; and, the lack of commitment by stakeholders. The latter includes renewable energy offices, inter-governmental agencies, utilities and independent power producers (PLN), local manufacturers and local and regional planning authorities, renewable energy associations, financial institutions and development assistance agencies. These barriers have hampered greater uptake of renewable technologies in Indonesia in the recent years (DGEED, 1998).

Indonesia has already ratified the Framework Convention on Climate Change (FCCC) and established National Strategies to Climate Change, thus making a commitment to reduce green-house gases. As an APEC member country, Indonesia has also agreed to include and implement the 14 binding principles of APEC in its national energy policies. It is likely that such commitments will increase the impetus for greater renewable energy penetration and may result in governments accelerating or strengthening policies to promote renewable energy.

**Actions Needed to Boost Renewables Utilisation in Indonesia**

The current contribution of renewable energy to total domestic energy needs is about 12 percent if we include hydro and geothermal plants, but drops to less than 1 percent if these are excluded (DGEED, 1998). According to DGEED (1998), there are several key measures to enhance immediate as well as longer term prospects for renewables in Indonesia, depending on the types of renewables and the needs of local demands. The first three of the six categories are considered as top priorities by the government.

*The first*, is eliminating subsidies for fossil fuels and giving economic and fiscal incentives for renewable. This can be through subsidies, grants or tax exemptions for renewables, a variety of market stimulation measures on agreements with utilities (PLN) to increase renewable energy utilisation for electricity in rural and remote areas. This program was carried out for several years by PLN in several remote and rural areas in Kalimantan, Sulawesi and other outer islands of Indonesia. To realise these measures, there needs to be modifications to legislation or restructuring to allow market access to renewables. Such measures will encourage investment in renewable energy, allow realisation of economies of scale, and help to build up a track record for successful commercial operation (DGEED, 1998). The competitive position of renewables will improve if policies to integrate environmental costs into the price of conventional energy supply and use were adopted and price subsidies on conventional fuels withdrawn. Investments in new energy supply plants and infrastructures would then be optimised from both the economic and environmental standpoints. Such policies would have a direct and immediate effect on investment decisions concerning energy plant and infrastructure. However, the idea of including environmental costs in the energy pricing is new for Indonesia and will not be implemented in the short-term. The government considers full cost pricing as problematic due to uncertainties in the magnitude of external costs, and it also gives rise to political problems. The removal of subsidies for competing energy sources, particularly fossil fuels, is gradually being carried out by the Indonesian government. The government realised that energy subsidies lead to end-use prices below true costs, and restrict the competitiveness of renewables in some applications where they would be most suitable.

*Second,* is setting up national targets for renewables. This involves determining quantified plans for renewable energy development either by source or by sector in certain targeted locations. To achieve targets, the government could carry out selective introduction of temporary incentives and market stimulation measures in some areas to overcome the reluctance of private and public sector financial institutions to invest in renewable energy projects. Projects or measures, which have proved successful should be replicated, where appropriate, in other areas. Renewable energy institutions and companies need to commit to the targets and actively make provision for them to play a greater role in energy supply.

*Third,* is enhancing information and education campaigns to increase knowledge on current renewable energy technology performance, availability and incentives. Priority needs to be given to raising the public's awareness of the benefits and the importance of renewables. The government needs to provide those responsible for planning decisions with information on how to measure the benefits and environmental impacts of renewable energy schemes. Production and dissemination of market analyses of the short, medium and long-term commercial prospects of renewable energy technologies together with publication of success stories of renewable energy policies and projects will build up credibility and confidence. Wide publicity for successful private sector experience with renewable energy plans is also important for providing stimulation for further activities.

*Fourth,* is substantial, continuing research and development (R&D) commitment, including demonstration and monitoring programmes. The government should promise to develop renewable energy technologies that are feasible and applicable in remote or rural areas in Indonesia and to reduce their costs and increase their reliability and maintainability to competitive levels in the shortest possible time. Higher levels of investment in these research, development and demonstration programmes are needed to bring down further and faster the costs of renewable energy technologies. The government also needs to carry out measures to address technical impediments and maximise technical potential through this R & D program. When installing renewable energy projects, the government often faces strong opposition at the local level. In order to limit the negative impacts and perceptions, continued R & D and dissemination of information to the local people, where the renewables are installed, is of importance.

*Fifth,* enhanced direct involvement of the commercial sectors (domestic and international) will be needed if the government wants to integrate renewables into domestic energy supplies in an appropriate timescale. Pioneering work done by private sector organizations should, therefore, be more widely published, in order to strengthen interest amongst other organizations. Financial institutions can play an important role in helping the commercial sectors, through providing financial incentives. Most bank and other financial institutions in Indonesia regard renewable energy technologies as risky investments. This negative perception needs to be overcome by a more selective selection of reliable renewable energy supplies.

*Sixth,* is promoting international cooperation in the development and application of renewable energy technologies with other countries, especially countries developing the technologies suited to Indonesia. Most countries are dealing with similar technical issues and generally facing the same impediments to increased market penetration of renewables. There is also the need to identify and implement effective arrangements for enhanced international cooperation in industrial development activities in the renewable energy field. However, the IEA (1997) argues that commercial interests by protecting certain information makes such co-operation difficult to set up. Development of commercial technology transfer links and mechanisms between industrialised and developing countries can help the later take advantage of appropriate renewable energy options. In the past recent years, Indonesia and other ASEAN countries have developed energy cooperation (including renewables) with the European Community through a joint EU-ASEAN cooperation body called AEEMTRC (now called ACE), which is based in Indonesia.

### 3.5.7 Energy Security

Security of energy supply is an integral part of guaranteeing an efficient service to end users combined with lower prices, for both the short and long term. Any government must ensure that security is maintained or even strengthened through appropriate improvements to its energy policy. The IEA (1985), for example, indicated the importance of diversity of supply to ensure energy security by reducing the potential impact of interruptions of any single source and providing additional options for its replacement (IEA, 1985). However, the IEA (2000) stated that security of supply could be achieved by maintaining diversity of energy supply and providing back-up systems as an insurance against supply failure, or by maintaining high operational standards to reduce the risk of system failure. Many IEA countries presently pursue two courses of action to protect security of supply: *firstly* to ensure that available resources of oil and gas are developed to the maximum extent possible; *secondly* to develop alternatives to conventional oil and gas, for example, coal liquefaction, coal gasification, coal-liquid mixtures, oil shale, gasoline from natural gas, and alcohol fuels from biomass.

Indonesia, in the National Energy Policy (1992), stressed the need: *firstly* to continuously develop national energy systems so that systems that depend primarily on renewable energy sources could be established; *secondly* to pursue efficient supply of non-commercial energy demand with due consideration to environmental protection; and *thirdly* to manage mining and depletable energy sources in such a way that the optimal service life of energy sources can be attained and degradation of the environment by mining can be avoided (BAKOREN, 1992). The recently established National Energy Policy (1998), stated:

> *"... in order to ensure the availability of domestic energy supply, activities in exploration for energy sources need to be intensified and efforts to save energy consumption from upstream to downstream needs to be promoted. The use of new and renewable energy resources need to be promoted and increased in stages, in view of their environmentally friendly characteristics. In this regard, the commercialisation of new and renewable energy technologies needs to be promoted to increase their competitiveness"* (BAKOREN, 1998: p. 22).

From the above description, it can be seen that security of supply for Indonesia is basically being carried out through energy intensification, energy diversification, energy conservation and energy-environmental programs. These actions are explicitly stated as elements of principal energy policies. For Indonesia, high dependence on a very few energy resources is seen as creating vulnerabilities, to routine breakdown or to sabotage. The energy security issue is closely related to the depletion of non-renewable resources. By pursuing energy diversification much of this vulnerability may be reduced.

**Definition**

*Security of energy supply* is broadly defined as an adequate supply of energy at a reasonable cost (IEA, 1985). Hill, et al (1995, p. 34) stated that energy security is a major energy policy objective and aspects of it are part of all energy policy considerations. In his views energy security usually embraces high military spending both to secure access to resources and to guarantee their continuous supply. He gave the example of the Gulf oil crisis, where according to him it was shown that,

> *"... countries, which rely largely on an energy resource, particularly if it is near depletion, will spend heavily and take high risks to secure access to a constant supply".*

Schmidt (1999, p. 4) as quoted by Yergin (1990) and May & Calabrese (1998), defines 'energy security as:

> *"... ensuring a sufficient and a secure supply of energy so that shortages do not jeopardise national interests. It encompasses environmental concerns, the matter of supply security, and developing mechanisms to deal with disruptions of supply that can lead to economic and political costs for nations. 'Energy and security' is a term that denotes the link between energy matters and security of countries and regions. This term moves beyond the idea of supply security and considers the impacts upon other areas of security concerns, such as geopolitical relationships and the impact upon foreign policy issues".*

Schmidt (1999) also makes the point that unlike 'energy and security', the term 'energy security' is not concerned with the danger of proliferation of nuclear material. The World Energy Council defines 'energy security' as the continuous availability of energy in various forms, in sufficient quantities, and at reasonable price and it has several aspects. Energy security means limited vulnerability to transient or longer disruptions of imported supplies (WEC, 2000).

**Operational Measurement**

Energy Security = Reducing Indonesia's vulnerability to disruptions of imported supplies, by ensuring adequate alternative domestic and international supply sources

**Possible Actions to Enhance Energy Securities in Indonesia**

As is the case for other countries, security of supply remains a constant concern for the Indonesian government, and, therefore, it has been a part of energy policy considerations since the first energy policy was established in Indonesia in 1980 (BAKOREN, 1992). To enhance energy security, the Indonesian government policies can be designed to safeguard themselves from supply disruption through a number of measures. There include a diversification of fuel sources and supply technologies; encouraging the rational and efficient use, transformation, generation, production, and distribution of energy; to ensure that energy is supplied and utilised in an environmentally clean, healthy and safe manner; promoting the generation of, and granting access to, the basic technological knowledge and competence which will provide long-range energy options; making available the best allocation of wide-reaching energy resources, and the advancement of robust, adaptable energy systems.

### 3.5.8 Robustness

Robustness has to do with measuring the possibility that a certain decision is accurate. According to Voss & Egberts (NATO, 1980), in order to ensure the accurateness of a certain decision, a broad range of alternative futures of important system parameters such as energy demand and fuel cost needs to be tested. Robustness is important because future developments are full of uncertainties and, therefore, the robustness of say the energy system to uncertain shocks has to be tested. For example, there is uncertainty about future energy demand. Demand is influenced by life style; fluctuations in energy costs; the technology availability; and societal acceptance of new technology (NATO, 1980). According to Lonergan and Cocklin (1990), the New Zealand energy system was not robust or resilient because of its inability to deal with the oil price shocks in 1973 and 1978. In the past years, the energy decisions in Indonesia have never been tested against possible future energy system parameters, and therefore, the decisions have always been vulnerable to potential changes, causing the decisions to be no longer relevant. During the first and second oil price shocks, Indonesia's energy system also faced the difficulties of oil windfalls causing major economic setbacks. For this reason, it is a good time to begin to test the robustness of future energy policies in Indonesia, especially the long-term energy policy, to improve its resilience against future uncertainties. The current General Energy Policy Guidelines state one of the principal aims of energy development in Indonesia is:

> *"... to enhance national resiliency in the management of the energy system, particularly when faced with the challenges and the constraints in meeting current and future energy demand, through the development of science and technology capability and their application in industry and in the execution of energy planning and management"* (BAKOREN, 1998, p. 19).

**Definition**

Voss and Egberts, (1980) defines *robustness* as the probability that a certain decision is correct, which can be tested using a broad set of future options of important system parameters (NATO, 1980). Alternatively, Lonergan and Cocklin (1990, pp. 114, 115) defined robustness as:

> *"... resiliency or the ability of a system to absorb or bounce back from internal changes or, alternatively, as the persistence of the relationships between the elements of a system".*

**Operational Measurement**

Lonergan and Cocklin (1990) developed general measurement for robustness as follows:

$$R = p\ (1\text{-}a) = \frac{Prob\ (X_t \ \Xi\ P \ and\ X_{t+n}\ \Xi\ P)}{Prob\ (X_t\ \Xi\ P)}$$

$R$ = is the recovery rate, or the resiliency of a plan

$X_t$ = the state of the system at time t

$p$ = the probability of inconsistency between the system and the plan

P = the plan in question

$a$ = the reliability of the plan

*(1-a)* = Risk of failure.

According to Lonergan and Cocklin (1990), in the energy planning perspective, an accurate measurement of resiliency or robustness can not be achieved. However, measurement permits the identification of design features that can be integrated into plans to improve resiliency, among others, they are; the integration of energy planning and policy making; updating and evaluation of the appropriateness of plans, the development of scenarios; and, a proper combination of short and long term projects (Lonergan & Cocklin, 1998).

## 3.6 Conclusion

Energy policy making in Indonesia is characterised by many challenges that stand in the way of integrated policy development. Particular problem areas include: the inadequacy of analysis and information, the lack of other participants' involvement in the decision making process, and finally the lack of policy implementation.

Many energy-decisions in Indonesia are created or dictated by 'political will' rather than 'analysis'. Inconsistencies between the energy policy and the programmes or projects formulated have also characterised the policy products. These can perhaps be reduced by developing common policy objectives and by defining an appropriate programme scope and scale.

In spite of their importance, energy policy making often lacks two elements: analysis and information. Only with adequate information and analysis can energy policy be made more effective in actually solving social and economic problems. In Indonesia, as in many developing countries, there is a lack of reliable and comprehensive data which is needed to undertake many analytical tasks. Furthermore the required analytical skills are very thinly spread within the Ministry of Energy and Minerals and other policy agencies.

In addition to this, it can perhaps be said that Indonesia has not yet sufficiently involved the public, interest groups or business sectors in the decision making process, in general and particular not in energy policy formulation. Regional offices, according to the government plan to provide greater functional power to regional offices and to rationalize the number and boundaries of national government authorities are also future players in the decision making and policy process.

In the formulation of energy policy of Indonesia, there are several *policy objectives* that need to be taken into consideration, as they are very important particularly for determining the country's policy options for the next 20 years. Economic and environmental considerations have increased in importance in Indonesia and are now major inputs into decision-making in the energy sector. There is emerging interest in the Indonesian energy sector, that energy efficiency, economic growth and protection of the environment be included in the objectives of the national energy policy. These important policy objectives are further broken down into elements, i.e. energy security, economic efficiency, energy efficiency, $CO_2$ reduction, energy self sufficiency, more renewable energy, foreign exchange earnings and robustness. These objectives need to be considered carefully in the policy analysis to make sure that the best policy options are recommended. These policy objectives are represented and accommodated in the five scenarios built for the energy systems dynamic simulation model outlined in chapter 9.

# CHAPTER FOUR

# ENERGY SUPPLY AND DEMAND PATTERNS

This chapter aims to provide an overview of the pattern of energy supply and demand in Indonesia. The discussion covers energy resource potential, imports and exports and delivered (consumer) energy use. The historical trends of the energy supply and consumption patterns from 1980 to 1998 are presented and the underlying causes of these trends discussed. This overview, which consists of important quantitative data, is crucial for developing the model in chapter 8. The discussion on the potential of indigenous energy resources covered in this chapter, for instance, will be needed in evaluating the future policy alternatives in the model.

## 4.1 Introduction

Indonesia is an archipelago of about 17,500 islands that spread 3,200 miles from east to west, comparable with the distance from London to Moscow. It is located on the equator, from 15 degrees above to 15 degrees below the equator, with the Indian Ocean streaming into the archipelago from the west and the Pacific Ocean from the east. The country's land is fertile with abundant volcanic soil and a tropical climate. The country is also very fortunate to own rich mineral deposits and a diversity of marine and other resources (Barnes, 1995). It is estimated that there are 300 different dialects and hundreds of ethnic groups. The country's population in 1999 was 221.11 million (CountryWatch, 2001). In terms of global rankings (since the break up of the Soviet Union) Indonesia has been placed as the fourth most populous country out of 191 countries in the world after China, India and the United States. More than 50 percent of the population live in Java, 25 percent in Sumatra, 7 percent in Sulawesi, more than 5 percent in Kalimantan, and the rest are distributed almost evenly throughout other provinces (Bali, West and East Nusa Tenggara, Maluku and Irian Jaya). During the ten years, 1990 to 2000, the population grew at a rate of more than 1.5 percent annually. Currently, approximately 60 percent of the population live in rural areas and 40 percent in urban areas. The population of the urban areas is growing at the rate of 4.5 percent annually, while the rural population is growing at the rate of less 0.2 percent annually (CBS, 1999).

## 4.2 Primary Energy Supply

This section of the thesis discusses the range of primary energy sources *currently used* in Indonesia, and *potential* primary energy sources such as nuclear, wind and solar energy. This discussion focuses on the actual level of use of the various sources of primary energy over the 1980-1998 period, as well as on the future availability of these energy sources.

### 4.2.1 Overview

There are six types of primary energy supply in Indonesia - coal, oil, natural gas, hydro, and geothermal, together with combustible renewables and waste. Combustible renewables and waste were the main energy sources before 1992, then they were replaced by oil products. Combustible renewables were used mainly in rural areas for cooking purposes when about 70 percent of the country's population lived in rural areas. According to BAKOREN (1998), these combustible renewables and waste resources came from the agricultural sector, gardens and plantations. Their current potential of energy resources was estimated at 49,807 MW.

The supply for natural gas, coal, hydro and geothermal energy increased rapidly, especially after the first oil shock in 1973 (see Figure 4.1). Coal started to be used intensively after 1984, increasing by almost 4 times, following the commissioning of a newly built coal powered electricity generating plant in Suralaya in 1984.

The growth of primary energy supply was 4.81 percent per annum over the last 10 years (1988-1998). However, if we exclude combustible renewables from the energy mix, the growth was 8.9 percent per annum, which was very high compared to the world's growth. This was estimated as only at 2.2 percent per annum from 1971 to 1997 (IEA, 2000). The growth in Indonesia primary energy supply (excluding combustible renewables) is still predicted to be high at about 6 to 7 percent over the next 20 years which is primarily driven by relatively small ratio of electrification and unsaturated demand for energy in many remote and rural areas. This demand is still high compared to the predicted world primary energy supply growth, which is about 2 percent from 1997 to 2020 (IEA, 2000).

In the last 10 years (1988-1998), the growth in geothermal generated energy was the highest (15.63 percent), followed by coal (9 percent), natural gas (8.3 percent), oil (6.92 percent), and hydro (4.5 percent). Meanwhile, the growth of combustible renewables was only 1.43 percent annually, indicating that primary energy supply is shifting toward more conventional energy sources rather than traditional energy sources.

During the 1997-1998 period, use of primary energy, especially oil, natural gas and coal decreased sharply (minus 0.26 percent). This was quite possibly caused by the ASEAN economic crises which started in 1997 and was still occurring for 4 more years until 2001.

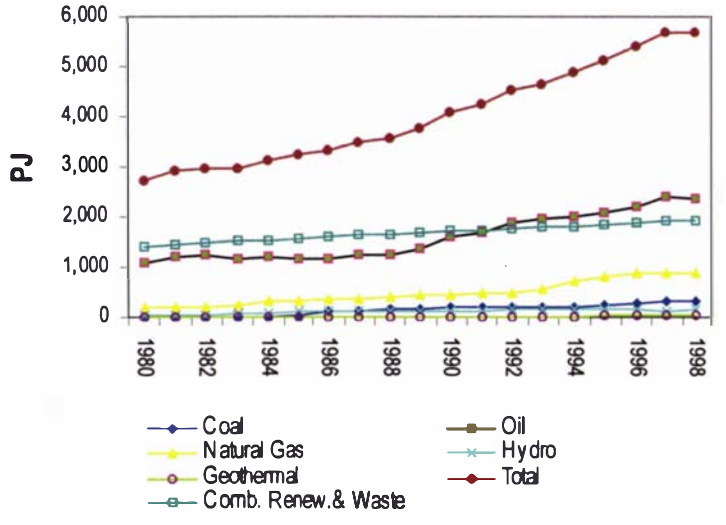


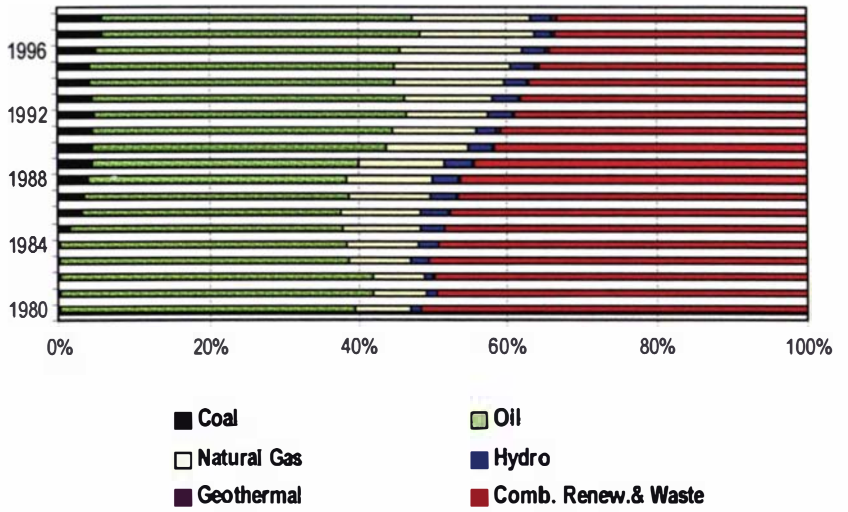

**Figure 4.1 Indonesian Primary Energy Supply, 1980-1998**

The use of non-conventional energy sources (combustible renewables) decreased from more than 70 percent in 1980 to 30 percent in 1998 (see Figure 4.2). The role of combustible renewables is expected to continue to decrease very rapidly in the next few decades and to be replaced by conventional fuels, especially kerosene and LPG. The role of oil as a domestic energy source also decreased from 40 percent in 1980 to 30 percent in 1998. This compares with about 40 percent internationally (IEA, 2000). In contrast to oil, the use of natural gas and coal increased rapidly during this period. The country's coal role increased from less than 1 percent in 1980 to more than 3.5 percent in 1998, while natural gas use increased from 3 percent in 1980 to more than 5 percent in 1998. This is perhaps the result of Indonesia's energy diversification policy after the first oil shock in 1973. The natural gas and coal shares are expected to increase rapidly in the next 20 years. In comparison, the current world's coal and natural gas share is about 26 and 22 percent respectively and their use as an energy source in 2020 are predicted to decline to 24 percent for coal, but increase to 26 percent for natural gas (IEA, 2000).

The role of hydro energy also increased but only very slightly from 0.2 percent in 1980 to 0.3 percent in 1998. Many analysts have said that Indonesia has not adequately tapped its hydro resources despite its potential hydro resource availability which is estimated at about 75,625 MW, spread all over the Indonesian islands of Sumatra, Java, Sulawesi and Irian Jaya. According to BAKOREN (1998), only 2,178 MW of the total hydro potential is utilised currently mainly due to institutional and investment barriers.

Over the same period, the harnessing of geothermal energy commenced but this was still only 0.2 percent in 1998. As with hydro, the geothermal resource is under utilized at about 2.67 percent of the total potential. The geothermal potential is currently estimated at about 19,658 MW, of which 5,331 MW is in Java, 9,562 MW in Sumatra and the remaining 4,765 MW spread over Sulawesi and the other outer islands of Indonesia (BAKOREN, 1998).

The role of oil is expected to still be high over the next 20 years. BAKOREN has predicted that oil will account for more than 30 percent of the total primary energy supply in the next 50 years. This is however less than the projected world use which will be about 40 percent in 2020, almost identical to its share today (IEA, 2000).




Source: IEA (2000) and DJLEB (1999)

**Figure 4.2 Indonesian Primary Energy Supply Mix (%) , 1980-1998**

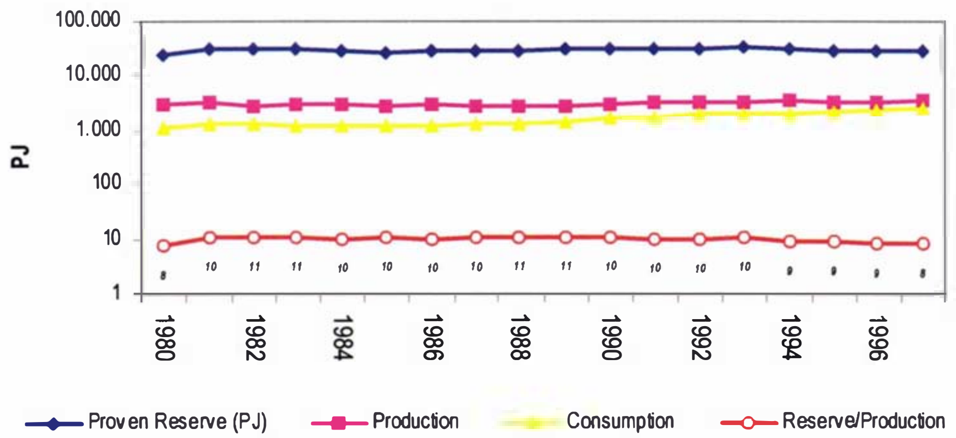
### 4.2.2 Oil

Currently, Indonesia is one of the key oil producers, ranked 16th after Canada, producing about 2.4 percent of the world's total daily production (US Embassy, 1997). The largest parts of Indonesia's oil producing grounds are situated in the central and western regions of the country, mainly Sumatra, Kalimantan (Borneo) and Sulawesi. The country's oil reserve was increasing steadily at the rate of 1.5 percent annually during the last two decades (see Figure 4.3), while the annual production was increasing at the rate of 0.8 percent. However, this pattern was changed during the last decade, in which the reserve was recorded as decreasing 0.5 per cent annually, while the production pattern was increasing at the rate of 0.6

percent annually. As a result, the reserve to production ratio (R/P) during the period tended to decrease from 11 years to 8 years or a negative growth of R/P at around minus 5 to minus 7 percent annually. By comparison, other countries like the United Arab Emirates, Iraq, and Kuwait have a R/P ratio of more than 75 years (OPEC, 1998). Ironically, the level of the country's oil consumption was increasing quite rapidly at the rate of 4.7 percent during the last two decades. According to the US Embassy (1997), the country will possibly turn into a net importer of crude and petroleum products early in this century. It is likely that the country will face energy self-sufficiency and energy security problems if it does not embark on energy diversification and intensify its exploration efforts. According to Hill (1995: p. 34),

> *"... countries, which rely largely on energy resources, particularly if they are near depletion, will spend heavily and take high risks to secure access to a constant supply".*

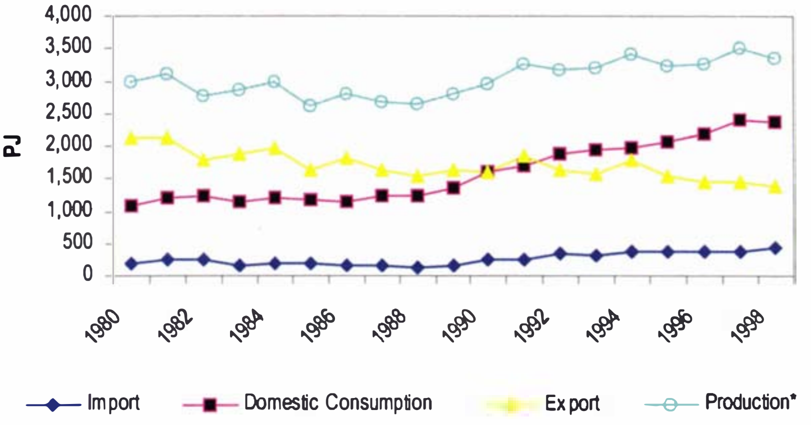
For this reason, the government has been accelerating attempts to enhance the maintenance of existing oil fields and boost the exploration for new fields (BAKOREN, 1998). According to the US Embassy (1997), the new exploration has been focused on front line areas, mainly eastern Indonesia, which are much more isolated and problematical regions to explore than those of western and central Indonesia.




Source: IEA (2000) and DJLEB (1999)

**Figure 4.3 Indonesian Oil: Reserves, Production, Consumption and R/P Ratio, 1980-1998**

The Government has also encouraged the energy sector to shift away from oil toward other alternative sources, mainly coal and natural gas, and has reduced the use of oil for export purposes (BAKOREN, 1998). During the last two decades, oil exports were in fact decreasing at the rate of minus 1.8 percent (see Figure 4.4). The aim of decreasing oil exports was to fulfil the increasing demand of domestic oil consumption, which was growing at the rate of nearly 5 percent annually. Realising that the current R/P ratio is only 8 years, it is expected that crude oil will no longer be exported after the next 5 to 6 years and will be used for fulfilling domestic oil demand. Even in the near future, the government will have to import some more oil to balance supply and demand in the domestic market. Oil and gas have been the main foreign exchange revenues in the past decades. Realising that past experiences of heavy dependency on oil revenues have caused a total set of economic problems i.e. inflation and the Dutch decease, the government has been trying to reduce the country's dependency on oil and gas foreign revenues. In the new Energy Policy guidelines, it was stated that the role of oil and gas in foreign exchange earning will be decreased substantially, and that oil and gas will be used more for domestic purposes (BAKOREN, 1998).



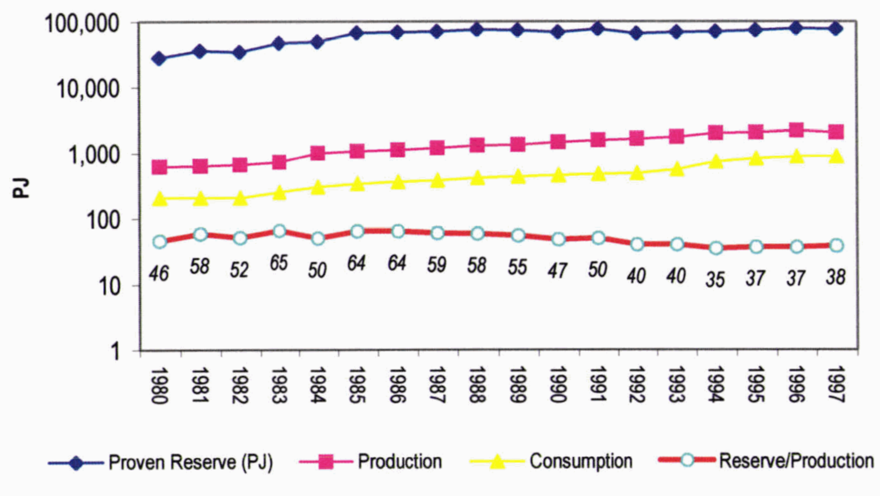

Source: IEA (2000) and DJLEB (1999)

**Figure 4.4 Indonesian Oil : Production, Consumption, Imports and Exports , 1980 - 1998**

### 4.2.3 Natural Gas

In addition to crude oil, Indonesia produced approximately 2048 PJ of natural gas liquid and condensate in 1997. Its proven natural gas reserve (1997) was about 78381 PJ. According to CountryWatch (2001), most of the natural gas reserves are situated close to the Arun field in North Sumatra and in the region of the Badak field in east Kalimantan (Borneo), the Kangean Block offshore East Java, a number of blocks in Irian Jaya, and the Natuna D-Alpha field, the largest in Southeast Asia (CountryWatch, 2001).

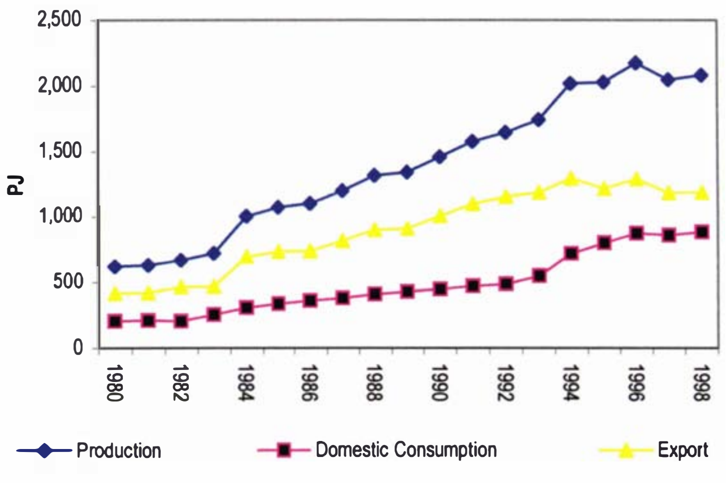
Over the last decade, the natural gas reserve has been decreasing at the rate of minus 0.5 percent annually despite the major reserve findings in 1983 and 1985, which caused the increase of more than 36 percent from the previous figure. The decrease of the country's natural gas reserve was perhaps caused by the fact that in the last 10 years, no significant natural gas reserve was found. Meanwhile, the annual gas production of natural gas was increasing at the rate of 7.2 percent during the same period, possibly due to the government's vigorous efforts to increase domestic natural gas use to replace oil (see Figure 4.5). The country's reserve to production ratio (R/P) showed a rapid decreasing trend of minus 7 percent annually, causing the R/P ratio to drop significantly from 60 years in the early 1980s to only 38 years in 1998. If the condition continues and no major natural gas reserves are found, Indonesia's natural gas might be depleted in less than three decades, particularly as domestic natural gas consumption has increased rapidly over the last decade at the rate of 8.7 percent annually. As was the case with oil, the policy on gas export may also be reconsidered if the country wants to maintain its self-sufficiency and secure its long-term domestic gas supply, by reducing its dependency on foreign exchange earning from gas exports.




Source: IEA (2000) and DJLEB (1999)

**Figure 4.5 Indonesian Natural Gas: Reserves, Production, Consumption, and R/P Ratio, 1980 - 1998**

In 1983/1984, natural gas production was increased substantially to almost 40 percent to meet the increasing domestic consumption (which was increasing at 22 percent per annum) and perhaps, to fulfil the need to increase foreign exchange earnings from natural gas (see Figure 4.6). Natural gas exports were also increased in line with the increase in production. Over the last two decades, the exports have grown 6.5 percent annually. In 1994/95 and 1996/67, however, natural gas exports were drastically decreased due to the declining gas reserve in Arun, the large gas field in North Sumatra. Domestic gas consumption was increasing at a faster rate than that of exports and production, which was 8.8 percent over the same period. This is a very rapid rate of consumption compared to the world's rate which was only about 2 to 3 percent annually during the same period (IEA, 2000). Barnes (1995) argued that the mounting significance of gas to the economy is not merely in the form of additional exports, but increasingly a result of its role as a substitute for oil in the domestic market. Therefore, he stressed that the policy evaluation to be made on the future management of gas development is crucial to the economy and wealth of Indonesia (Barnes, 1995).




Source: IEA (2000) and DJLEB (1999)

**Figure 4.6 Indonesian Natural Gas: Production, Consumption and Exports, 1980-1998**

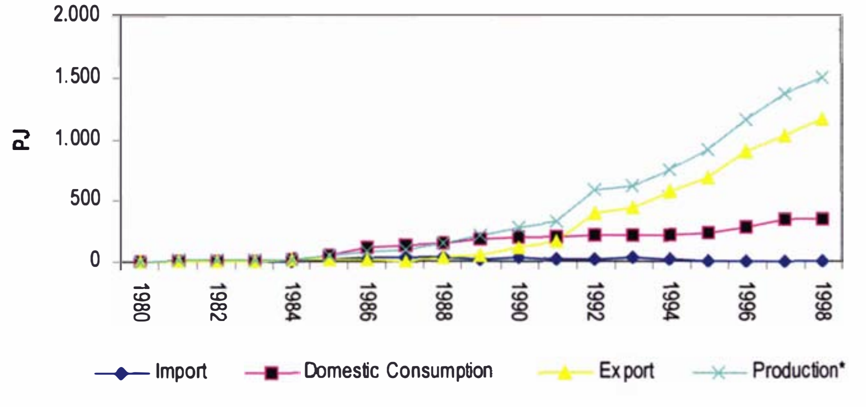
### 4.2.4 Coal

Indonesia possesses 5.8 billion short tons or about 130000 PJ of proven and recoverable coal reserves, of which 85 percent is lignite and 15 percent is anthracite. The development of coal reserves particularly accelerated in 1980, after the government invited many foreign companies to explore and develop potential coal reserves in the Indonesian islands. Approximately two thirds of Indonesia's total coal reserves are in Sumatra, and some are in Kalimantan (Borneo), West Java, and Sulawesi.

In 1998, Indonesia exported 1155 PJ short tons of coal, which was about 77 percent of its coal production. Indonesian coal is mostly exported to Japan, South Korea, and Taiwan. In the last 10 years, more than 70 percent of domestic coal production was exported, about 20 percent was consumed domestically, and less than 5 percent was imported from other countries. According to CountryWatch (2001), Indonesia expects to double coal production over the next five years, mostly for export purposes to East Asia and India (CountryWatch, 2001).

A big increase in coal production occurred in 1983/84, when production was increased by 84 percent (from 13 PJ to 24 PJ) to meet the increasing demand which increased at the rate of 43.4 percent in that year along with the increase of coal export, which increased 100 percent from the previous year (see Figure 4.7). The production increase was perhaps stimulated by the success of the PSCs system (production sharing contracts with foreign contractors) in the coal industry which was started in 1981 (Presidential Decree No. 49/1981). Whereas the increase in coal demand was mostly due to the operation of a new coal power plant in Suralaya in 1984, a substantial increase in coal production also occurred in 1989/90 (107.5 percent) and in 1991/92 (145.6 percent), caused by the increased use of coal in the industrial sector, especially in the cement and steel industries.

Indonesia also imports coal from other countries, like Australia. Over the last two decades, coal imports have increased at the rate of 4.7 percent annually, while coal exports have increased at a far more rapid rate of 59.5 percent annually. Coal production has increased at the rate of 36.7 percent annually during this period.




Source: IEA (2000) and DJLEB (1999)

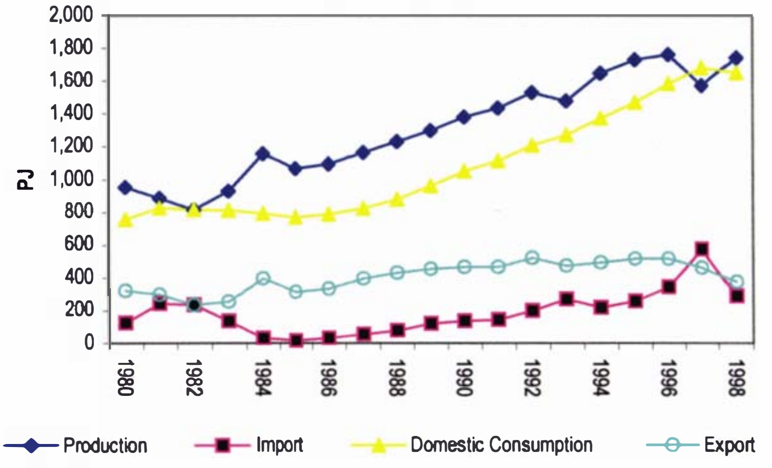
**Figure 4.7 Indonesian Coal: Production, Consumption, Imports and Exports, 1980-1998**

### 4.2.5 Hydrocarbons

Indonesia also produces hydrocarbon for domestic consumption as well as for export purposes. A small portion of hydrocarbon is imported. Over the last two decades, there were two occasions, 1981/82 and 1996/97 (see figure 4.8) when domestic hydrocarbon production could not meet the domestic consumption. To overcome the shortage of hydrocarbon supplies, the government decreased the export of hydrocarbon in those years. Exports were decreased 21.8 percent in 1981/82 and 10.6 percent in 1996/97. Imports were also increased to almost 95 percent annually in 1981/82 and about 66.7 percent in 1996/97. In an attempt to meet the domestic demand, in 1981 the construction for refinery expansion was started and in 1985, domestic hydrocarbon demand could be catered for from the domestic refinery (MME, 1995).

Over the last two decades, the import of hydrocarbons was growing at the rate of 18.7 percent annually, whereas the export of hydrocarbon was also growing at the rate of 2.2 percent annually, indicating that Indonesia is moving toward being a net importer of hydrocarbons. This was shown clearly in 1997, when imports exceeded exports. Over the same period, hydrocarbon production was growing at the rate of 3.8 percent annually.

Possibly stimulated by the high increase (around 6 percent) of hydrocarbon demand in the domestic market during 1986/87, the government substantially increased hydrocarbon production by 6.6 percent and imports by 87 percent in these years. However, it is interesting to see that also in that year that the highest hydrocarbon export occurred, with about a 19.3 percent increase. This indicates that the increase of hydrocarbon production was probably not only aimed at meeting the increasing domestic demand, but was also for export purposes.




Source: IEA (2000) and DJLEB (1999)

**Figure 4.8 Indonesian Hydrocarbons: Production, Consumption, Imports and Exports, 1980-1998**

### 4.2.6 Renewables

In general, Indonesia possesses considerable NRSE (New and Renewable Sources of Energy) potential. During the early 1970s, the use of renewables, like wind energy, solar energy, geothermal, and hydro energy was still very insignificant. Even now, if we exclude hydro energy, biomass and geothermal, the share of renewables is still less than 0.1 percent of the total domestic energy mix. Only in early 1974/75, notably after the first oil shock, had the development of new and renewable energy, like geothermal, micro-hydro and solar energy been focused on its commercialisation, both small-scale and large-scale. There were allocated not only in remote areas but also as substitutes for fossil fuel.

Indonesia has a fairly large potential of combustible renewables & waste energy. The total potential of this type of energy is currently about 49,807 MW, which comes from forestry, agriculture and estates. Combustible renewables and waste energy is the oldest form of energy, which has been used since a long time ago and has a substantial role (about 35 percent) in supplying domestic energy demand in the country. The country uses combustible renewables and waste for a variety of purposes, such as household (cooking and home industries), prime-mover for rice-milling, the drying of agriculture products, the wood industry, and power generation in the wood and sugar industries. According to BAKOREN (1998), the use of waste wood-fuel for power generation has presently reached 177.8 MW. The potential for biogas energy is quite big, however, only a very small portion of this potential has been used for cooking and lighting. Meanwhile, the use of biogas from human waste is still at the stage of a demonstration project (BAKOREN, 1998).

Wind energy potential in the country is small, as wind speeds are low (ranging from 3 and 5 m per second). However, in certain parts, especially in the eastern part of Indonesia, the wind speed is higher than 5 m per second. According to BAKOREN (1998), the total potential is approximately 448,342 MW. Wind energy has been used for a variety of purposes, such as rural electricity, water pumping and for battery-charging. The current installed capacity of wind generators is still small, about 220 kW, mainly in rural areas.

Solar energy potential is relatively good with a daily solar intensity of 4,825 kWh per $m^2$ on average. With a total land area of 2 million km2 Indonesia has a total theoretical potential of $9.63 \times 10^6$ MW. Solar thermal energy in the country, is generally used for cooking (solar stove), for the drying of agricultural and fisheries products, and for hot water. Solar application for cooking and drying is still very limited, but in the area of making hot water, it has reached the commercialisation stage. According to BAKOREN (1998), solar photovoltaic is used for rural electrification, water pumping, and for TV-sets, telecommunications and refrigerators in people's health centres (PUSKESMAS), with a total capacity of about 3 MW. The use of solar energy in the form of Solar Home Systems, (SHS) has reached the semi-commercial stage.

Hydro-power potential for electricity generation is quite substantial, about 75,625 MW. Most of this potential is located outside Java Island. Although the potential is high, the amount being exploited is relatively small, only 2,178 MW.

Geothermal potential is about 19,658 MW, of which 5,331 MW is in Java, 4,765 MW in Sumatera, and the rest in Sulawesi and other islands. Of this potential, only a small portion has been utilised, namely 525 MW or 2.7 percent.

In general, the potential of wave energy is quite substantial, with an average wave front about 20-70 kW per meter. In other words, a one km coastline could generate 20 to 70 MW. Presently, a demonstration project is being built at Baron beach near Jogyakarta with a capacity of 1.1 MW.

The potential of renewables, particularly solar, geothermal and small-scale hydro energy is quite promising, however its utilisation is still facing some financial and institutional barriers. Many criticised that 'a lack of attention' was also the main handicap of developing this resources. If the country wants to embark on *'more renewable'* and *'less $CO_2$ emission'* policy objectives, the opportunity is there, provided that the barriers are overcome and these objectives are given high priority in the national agenda.

### 4.2.7 Nuclear

Indonesia has prospective land areas for deposits of radioactive minerals, especially uranium. The potential of Indonesian uranium is said to be moderate, varying in quality, and located in Sumatra, Java, Sulawesi and Irian Jaya (100,000 $km^2$ area), which have never been surveyed. BATAN (National Energy Atomic Agency) has conducted some exploration and investigation activities and has found a deposit around Kalan, West Kalimantan. More intensive exploration on an industrial scale in Kalimantan, Sulawesi and Irian Jaya, could lead toward proven reserves.

As is the case in other countries, nuclear energy development in Indonesia is still facing harsh public opinion especially in regard of its operational safety and the impacts of radioactive waste. The government has long intended to build its first nuclear plant in Mount Muria on Central Java, 440 km, east of Java. This plan, however, has provoked severe public debate because of the plant and its waste sites, which are in a volcanic location. There has been something of a stop-go policy on the nuclear project, which was associated with the influence of environmentalists and some elite politicals.

During the High Ranking Official Meeting for Mining and Energy Matters (4 May 1995), President Soeharto made a statement regarding nuclear energy. The statement basically underlined that nuclear energy is the last option. He stated as follows:

> *"With cautious manner, starting from now on we have to be prepared and ready to embark on nuclear energy to fulfil our energy need. We realise that the risks for utilising nuclear energy are still high, particularly when it leaks. We therefore, will have to carefully learn about the success and the failures of other countries in developing and utilising this resource. We shall utilise the technological advancements that have been achieved so far and prevent the accident from happening as much as we can. The society that will take the benefits as well as bear the risks of nuclear energy will have to be equipped with adequate skill and knowledge. Someday, we will have to embark on nuclear, especially when other sources of energy are inadequate for fulfilling our energy need"* (MME, 1995; p 454).

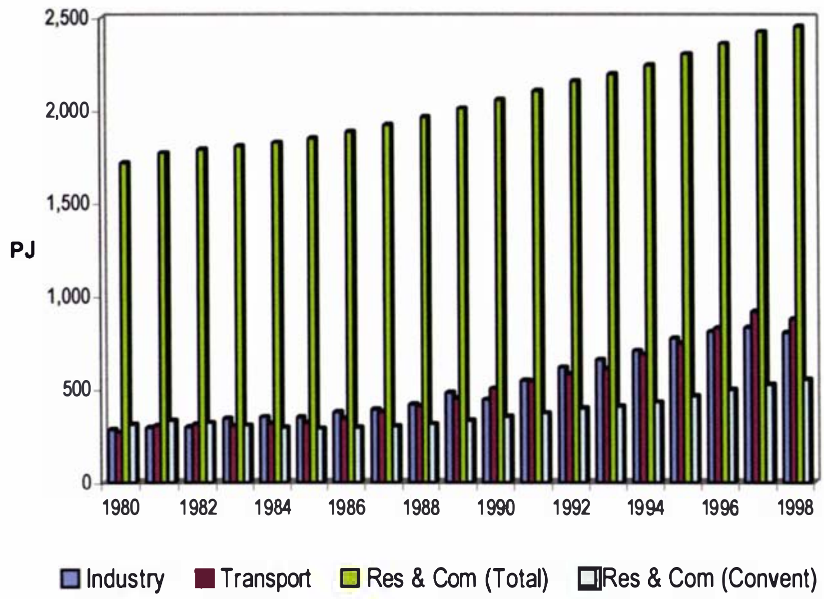
It was also said that in order to realize the full electrification program to the quantity required for a newly industrialised country, Indonesia will surely need to install substantial amounts of generating capacity, perhaps having to add some 30 GW by the year 2010 and nuclear energy was considered as an option to meet some of this increment (Barnes, 1995). However, judging by what had been said by President Soeharto and the past experiences that indicated a very low public acceptance toward nuclear energy, we may be sure that it will be the last option after conventional energy source.

## 4.3 Delivered Energy Demand, By Sector

### 4.3.1 Overview

During the last two decades, if combustible renewables (which were mainly used in the residential sector) were excluded, we can see that during the early 1980s, the residential and commercial sectors were the largest energy consumers sector followed by the industry and transport sectors (figure 4.9). However, starting from 1983, the industrial sector began to take over the role as the largest energy consuming sector, followed by the transport sector as the second largest. Since 1996, the transport sector has become the largest energy-consuming sector. This has caused the government concern, since more than 98 percent of delivered energy demand of this sector is oil based products (gasoline, solar, diesel, etc.). The growth of delivered energy demand in the transport sector was higher than any other sectors. It was 6.9 percent per annum, followed by 6.2 percent per annum in the industrial sector, and 2 percent per annum in the residential sector during the last two decades. The declining share of the residential sector's energy use was probably caused by the rapid development of the infrastructure in the transport sector and industrialisation in line with the escalation of economic activity during the last two decades. Since the 1970s, Indonesia's economy has expanded rapidly with consequent expansion in transport, which has grown at nearly double the rate of the economy. The fourth and fifth Five Year development Plan (1984/85 to 1993/94) stressed the need for infrastructure improvements based on sound economic and financial appraisals. Under these plans, the transport and communication sectors have gained the largest share of public investment (Kim, Knaap, Azis, 1992). This meteoric growth in infrastructure development had stimulated real increases in the development of the transport and industrial sectors leading to rapid growth of energy use in these sectors. The fast growth of motorisation (15 percent per annum in 1980 to 1987) has perhaps contributed to rapid energy use not only in the transport sector, but also in industrial as well as commercial and public sectors (Kim, et. al. 1992). The growth of transportation acted as a 'catalytic agent' in inducing the increases of energy use in the industrial sector in Indonesia, because transportation is viewed as one of the prerequisites for invigorating economic activity and sparking economic change (Kim, et. al., 1992).

Total delivered energy demand was growing at the rate of 5 percent during the same period. Negative growth was observed in the industrial sector, in 1984/85 (-0.2 percent), in 1989/90 (-7.4 percent), and finally in 1997/98 (-3.3 percent). The latest was primarily caused by ASEAN economic crises. The transport sector was also experiencing negative growth in 1982/83 (-2.7 percent) and in 1997/98 (-4.4 percent). The latest negative growth was also attributed to the ASEAN economic crises. The total delivered energy demand experienced negative growth in 1997/98 (-0.92 percent).




Source: IEA (2000) and DJLEB (1999)

**Figure 4.9 Indonesian Delivered Energy Demand by Sector, 1980-1998**

### 4.3.2. Industrial Use

The industrial sector consumed electricity, hydrocarbons, natural gas, LPG and coal products. The total growth of the industrial sector's energy demand during the last two decades averaged 6.1 percent annually. By comparison, the growth of industrial energy demand in Thailand was 8.9 percent, and in Malaysia was 9.6 percent per annum during the same period (APERC, 1998). From 1980 to 1998, coal demand in the industrial sector was growing rapidly at a rate of 23 percent per annum, followed by electricity, 12.7 percent, and natural gas 6.6 percent per annum (see figure 4. 10).

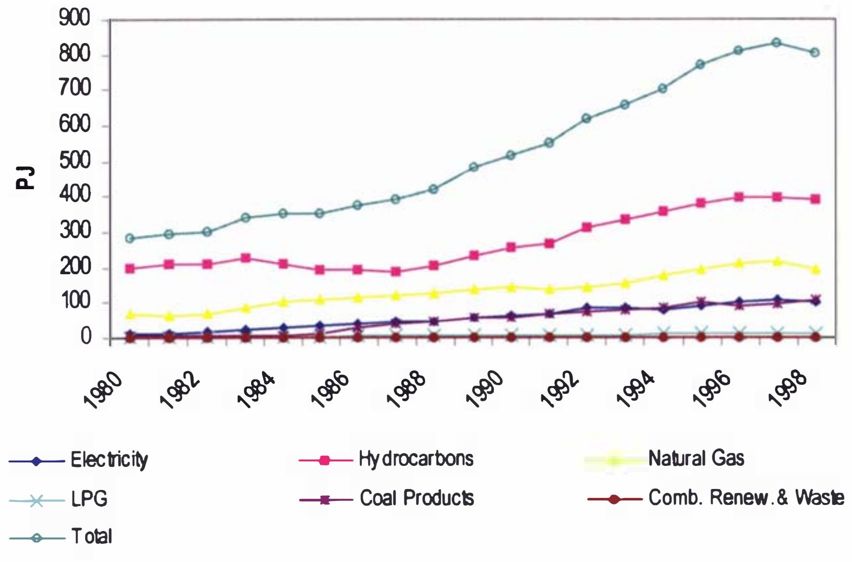
During 1981 to 1986/87, hydrocarbons experienced negative growth averaging at the rate of 4 percent annually, possibly by shifting from hydrocarbons use to the use of coal, LPG and natural gas. The use of hydrocarbons in 1984/85 had dropped about 8.6 percent from the previous year, whereas the use of coal, LPG and natural gas increased respectively to 93.9 percent, 13.6 percent and 5.4 percent in that same year. The growth of hydrocarbons use had further decreased from almost 10 percent in 1989/90 to less than 5 percent annually in

1995/96. In 1992, in line with the national policy on the development of gas utilisation, the State Gas Company was assigned to plan, construct and develop transmission and distribution lines of natural gas for domestic use. Since then gas utilisation in the industrial sector has started to gain momentum (MME, 1995).

The growth of electricity demand in this sector was also increasing very rapidly, 12.7 percent in the period 1990 to 1998, and a higher 13.6 percent during 1980 to 1998. This probably indicated fast growing increase in the use of electricity from the national electricity company (PLN) by the industrial sector. According to IEA (1997. p. 134):

> *"... this distinct jump of electricity demand in this sector in Indonesia may be related to the drop of oil prices in 1986, which forced the economy to diversify, leading to greater output from industries that were more electricity intensive than oil and gas".*

During the ASEAN economic crises, which started in 1997/98, almost all energy types experienced negative annual growth, which was –7.6 percent for electricity, -2.2 percent for hydrocarbons, -9.3 percent for natural gas, -16.4 percent for LPG. This shows that small-scale industries, the LPG users, suffered most from the crises. Only coal growth was recorded as positive, which was 11.2 percent per annum during 1997/98, indicating that the coal sector had not been affected by the crises.




Source: IEA (2000) and DJLEB (1999)

**Figure 4.10 Indonesian Industrial Energy Consumption by Energy Type, 1980-1998**

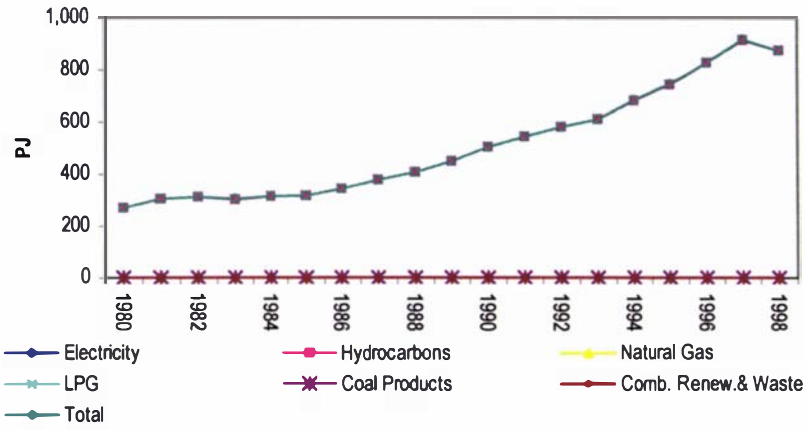
### 4.3.3 Transport Use

More than 98 percent of energy demand in the transport sector was oil-based products (hydrocarbons) (see figure 4.11). The total energy demand growth of this sector was 6.9 percent on average per annum over the period (1980 – 1998). In comparison, the other ASEAN countries like Malaysia and Thailand were 8.5 percent and 10.4 percent per annum respectively over the same period (APERC, 1998), and Korea was 15 percent (1981 to 1991). The average growth in East Asia was about 9 per cent per year over the 1980s (IEA, 1994), whereas in North America was only about 1.6 percent per annum during the same period (IEA, 2000).

As mentioned above, over the last two decades, the growth of hydrocarbons demand in this sector was 6.90 percent per annum. The fastest growth was recorded during 1993 to 1994, 12 percent per annum, possibly related to rapid infrastructure development, especially for road rehabilitation projects, during the fourth and fifth Five Year Development Plan (REPELITA IV and V) (Kim, et al., 1992). IEA (2000) indicated that world transport-demand growth will tend to increase by an average 2.4 percent per annum in the next 20 years and growth will mainly come from industrialisation, urbanisation and increased incomes in developing countries. This growth is faster than in all the other world's end-use sectors, which is predicted to be about 1.8 percent. This will cause an increase in demand for oil, which becomes increasingly concentrated in transportation because of the lack of substitute oil products, particularly aviation kerosene, gasoline and diesel fuel (IEA, 2000).

Coal was used in the earlier years, around the 1960s, but its use has decreased since 1980/81 and in 1986/87, and now coal is no longer used in this sector. Natural gas started to be used in this sector in 1987 though not significantly (less than 1 percent to the total energy use in this sector). Its use was increasing, particularly in 1991 through 1998 especially with the introduction of CNG (compressed natural gas) use in 1987. Up to 1994, there had been 8 CNG stations owned by PERTAMINA and 2 CNG stations owned by the private sector, in operation. All of them were located near the capital, in Jabotabek (Jakarta, Bogor, Tangerang and Bekasi). The government has planned to construct several other CNG stations outside Jabotabek (Medan, Palembang, Cirebon, Cikampek, and Surabaya). Many are pessimistic that this plan will not materialize, since there have been some problems that mayhinder its realisation, i.e. relatively cheap oil prices and an unhealthy ego-sectoral way of thinking (MME, 1995). LPG started to be used in the transport sector in 1997 and currently it is still used but in insignificant amount (DGEED, 1998). There have been more than 1000 taxies operating in Jakarta alone using LPG and CNG as alternative fuels to oil

As with the other sectors, because of the ASEAN economic crises, the transport sector's energy demand experienced negative growth in 1997/98, which was – 4.4 percent per annum during the year.




Source: IEA (2000) and DJLEB (1999)

**Figure 4.11. Indonesian Transport Energy Consumption by Energy Type, 1980-1998**

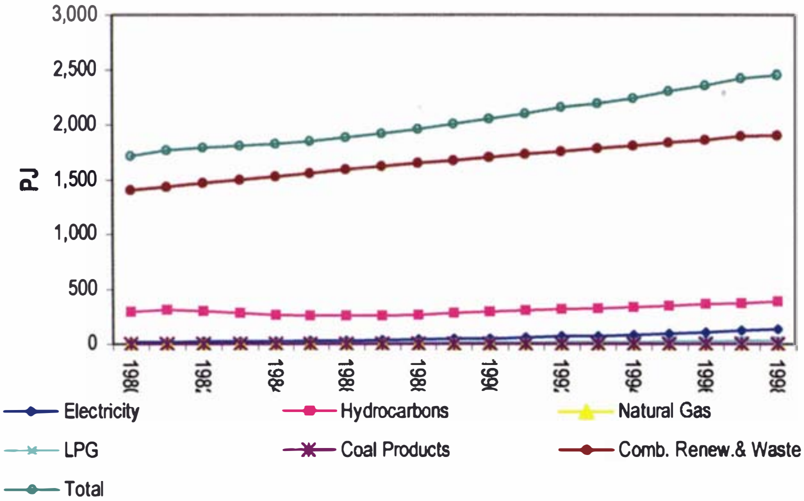
### 4.3.4 Residential-Commercial Use

Over the period, the growth of total residential-commercial energy demand was only 2 percent per annum. However, if combustible renewables and waste were excluded, the average growth of energy demand in the sector was 7.3 percent per annum in the same period. According to APERC (1998), other ASEAN countries, like Thailand, Malaysia, and the Philippines for example, have an annual energy demand growth (combustible renewables & waste excluded) of 10.9, 8.7 and 4.7 percent respectively in the same sector over the same period. In comparison, North America has an annual energy demand growth of only 0.8 percent per annum in the same sector, over the same period (IEA, 2000). Combustible renewables and waste was the energy type mostly used in the residential sector, accounting for more than 70 percent. Hydrocarbons were the second largest, accounting for 20 percent, while the third and the fourth were electricity and LPG (see figure 4.12). The high percentage of combustible renewables used in this sector is due to the fact that about 70 percent of the population live in rural and remote areas, and most of them rely on combustible renewables and waste for cooking purposes. The use of combustible renewables was increasing insignificantly, only 1.6 percent per annum in the last 10 years and decreasing in term of percentage of total energy use in the sector due to a substantial shift to LPG and hydrocarbons (mainly kerosene). This is similar to the pattern shown in South Korea, Singapore, Argentina and Venezuela as observed by IEA (1994) over the period 1971 to 1991. According to IEA (1994) in almost all cases commercial fuel has grown more rapidly than combustible renewables (traditional fuels) in these countries which results in a drop of traditional fuels' share in total residential energy demand (IEA, 1994).

The growth of LPG in this sector increased very rapidly during the last 2 decades, reaching more than 17 percent growth per annum. LPG has gradually replaced kerosene and combustible renewables for cooking. There are two possible explanations for this shift of location of consumption. The growth of urbanisation and the higher income per capita level has accelerated the shift from traditional combustible fuels to LPG and natural gas. The level of urbanisation in Indonesia in 1981 was 23 per cent and this has increased to 31 percent in 1994, whereas the GDP per capita between 1971 to 1991 has increased 4.2 percent per annum. As urban densities rise, the inconvenience of traditional combustible fuels, in terms of both transportability and storage, becomes a more important constraint, thus leading to the increased consumption of commercial fuels (IEA, 1994). Natural gas was also used mainly for commercial sectors and its growth was relatively high, increasing at the rate of almost 5 percent per annum during the last two decades.

Electricity grew very rapidly (12.2 percent per annum during that period), perhaps this was caused by the rural electrification program carried out by the government in the last 10 years. According to MME (1995), in 1994/95 only 34,790 villages out of the total 61,975 villages or about 56 percent of the total are currently connected to the electrical grid. Therefore, substantial room exists for expansion in this sector (MME, 1995). A study by IEA (1994) revealed that the growth in sales of electricity per capita was caused almost entirely by the electrification of new households, except in Korea (IEA, 1994). The unsaturated level of consumption of electricity in Indonesia will still maintain or even accelerate the already high growth of electricity in the country. Even the increased price of electricity in the last ten years has had little effect on the growth of the electricity demand in either the residential/commercial or the industrial sector. Surprisingly, even the 1997's ASEAN economic crises had little impact on the use of electricity in this sector compared to the other sectors.

If we exclude the use of renewables & waste, the total energy use in this sector grew at the rate of 7 percent in the last two decades, which is very high compared to that of other ASEAN countries, like the Philippines, which was only 4.7 percent in the same period (APERC, 1998).




Source: IEA (2000) and DJLEB (1999)

**Figure 4.12 Indonesian Residential and Commercial Energy Consumption by Energy Type, 1980-1998**

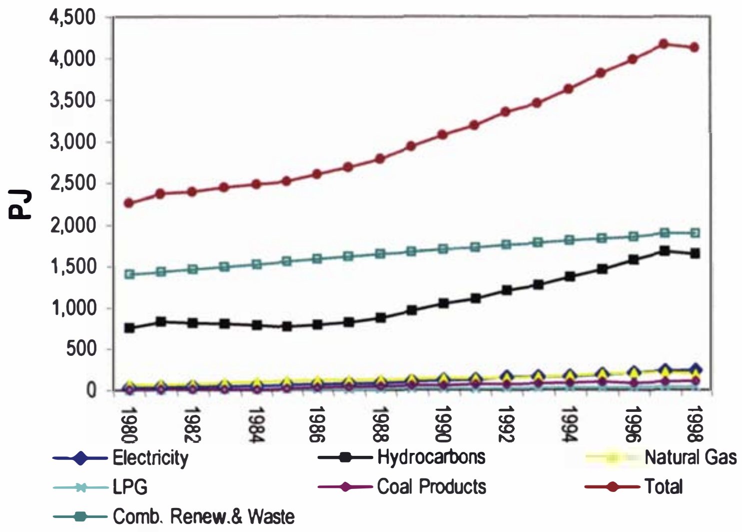
## 4.4 Delivered Energy Demand, by Energy Type

### 4.4.1 Overview

Over the past two decades, delivered energy demand in Indonesia comprised of electricity, hydrocarbons, natural gas, LPG, coal products and combustible renewables & waste. Delivered energy demand grew at the rate of 4 percent per annum over the last 10 years (see figure 4.13). However, if combustible renewables are excluded from the consumption pattern, the growth was 9.2 percent per annum during the same period and even reached 12.5 percent per annum in the last two decades. This is very high compared to the world's delivered energy growth, around 2 to 3 percent during the same period (IEA, 2000). It is even higher compared to other ASEAN countries like Malaysia (9.1 percent), Philippines (3.1 percent) and Thailand (9.9 percent) per annum during the last two decades (APERC,1998). This high growth of delivered energy demand, was primarily due to the fast growth of industrialisation, increased income and the rapid increase of energy demand in the transport sector.

Electricity grew at the rate of 10.9 percent, almost 4 times the world's electricity growth, of about 2.8 percent per annum during the same period (IEA, 2000). Hydrocarbons grew at the rate of 6.6 percent. Meanwhile coal and LPG grew very rapidly at the rate of 10.5 and 13.1

percent respectively during the same period. The rapid growth of LPG is attributed primarily to the fast growth of LPG use to replace kerosene and combustible renewables in the residential sector and small-scale industries. The percentage of combustible renewables use (as a total of delivered energy demand), was decreasing and replaced by LPG and oil products (hydrocarbons). Rapid growth of urbanisation, which was about 3 percent in Java and 2.6 percent outside Java during the period, (Kim, et. al., 1992) as well as the changing life style and the heavy government subsidy on kerosene and LPG had probably been the main reasons for this change. Major life style changes occurred in this sector during the period since the population started to use more modern household appliances like kerosene and LPG stoves rather than traditional wood-stoves, and also began to use more consumptive goods like radios, irons, tape recorders, TV and other electric appliances.




Source: IEA (2000) and DJLEB (1999)

**Figure 4.13 Indonesian Delivered Energy Consumption by Energy Type, 1980-1998**

### 4.4.2 Electricity Use

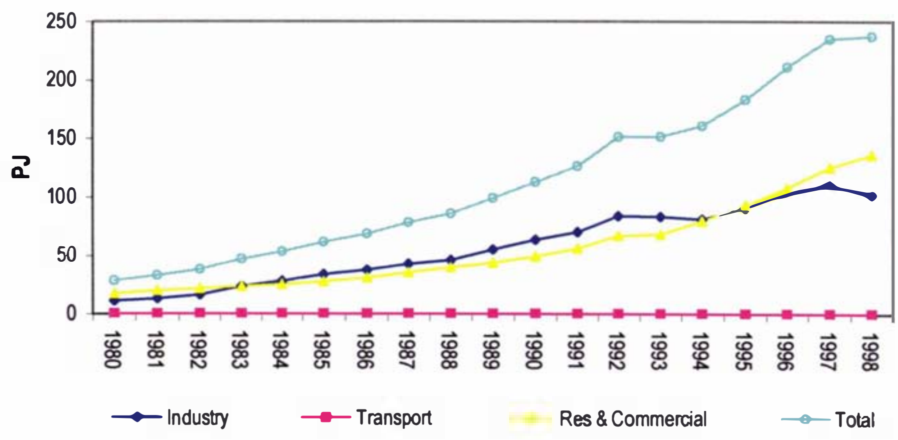
Electricity was used only in two sectors, the commercial-residential sector and the industrial sector. Only an insignificant amount was used in the transport sector (about 0.1 PJ) for electric train operation around Jabotabek (Jakarta-Bogor-Tangerang and Bekasi). Electricity consumption in Indonesia grew very rapidly, more than 12 percent annually during the last two decades (see figure 4.14). Other ASEAN countries like the Philippines and Malaysia experienced 3.8 and 11 percent per annum respectively, during the same period (APERC, 1998)

The growth in the industrial sector was the highest, 13.6 percent per annum, followed by the residential and commercial sector, 12.2 percent per annum during the period. The growth of electricity in the industrial sector reached its peak in 1982/83, almost 45 percent per annum, causing power supply crises in that year. With the construction of Suralaya Coal Power Plant in 1984, the power crises were solved (MME, 1995).

For the residential and commercial sector, the highest electricity growth (almost 20 percent of growth per annum) was recorded in 1991/92, possibly caused by the initiation of the rural electrification program by the government. From 1980 to 1983, the residential-commercial sector was the highest consumer of electricity, and in 1984 the industrial sector started to take over the role as the highest consumer of electricity. However, in 1994, again the commercial-residential sector took over the role.

The growth of electricity demand in the industrial sector, however, subsequently experienced negative growth in 1992/93 (-0.9 percent per annum), in 1993/94 (-2.7 percent per annum) and in 1997/98 (-7.6 percent). The latest negative growth was primarily caused by the ASEAN economic crises which occurred in 1997, and also caused negative GDP growth of almost – 15 percent per annum.

It is interesting to note that the use of electricity in the commercial and residential sector was not affected very much by the ASEAN economic crises which occurred in 1997 and still experienced the positive growth of 8.7 percent that year (97/98), though it substantially decreased from 16.1 percent in the previous year (1996/97).




Source: IEA (2000) and DJLEB (1999)

**Figure 4.14 Indonesian Electricity Consumption by Sector, 1980-1998**

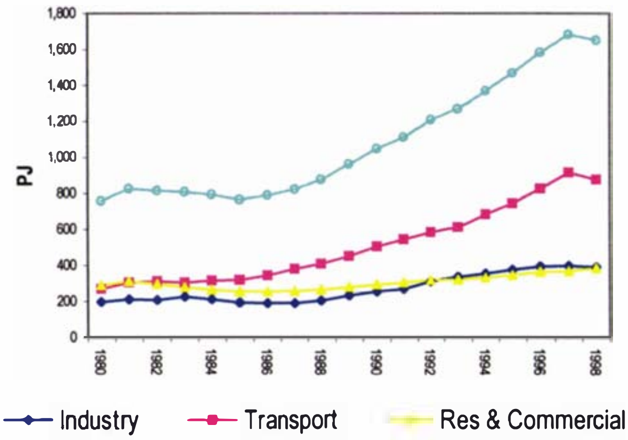
### 4.4.3 Hydrocarbons Use

Hydrocarbon fuels are consumed in transport, industrial and commercial-residential sectors with the transport sector being the largest hydrocarbon consumer. Currently, more than 98 percent of the transport energy use is hydrocarbons. From the total domestic hydrocarbons demand, more than 50 percent was consumed in the transport sector, especially during the last 10 years.

Figure 4.15 below, shows that the total hydrocarbon consumption growth was 4.5 percent during the last two decades. From 1981/82 to 1984/85, the total hydrocarbon consumption experienced negative growth, ranging between –1 to –3 percent per annum, but were increasing very rapidly from 1988/89 to 1991/92, about 9 percent on average per annum. The fastest growth was in the transport sector, about 6.9 percent per annum, followed by the industrial sector, 4 percent per annum, whereas the commercial and residential growth was around 1.7 percent per annum during the last two decades. The rapid growth of hydrocarbon demand in the transport sector has been attributed to the fast development of the transport infrastructure in the fourth and fifth years of the Five Year Development Plan (during 1984/85 to 1993/94). More of the government budget was allocated for the development of this sector during these periods (Kim, et. al. 1992)

The growth of hydrocarbon consumption in the industrial sector was recorded as very high, subsequently 13.8 percent in 1988/89 and 16.2 percent in 1991/92, possibly caused by rapid industrial development during these years. In 1992, Industrial hydrocarbon consumption exceeded that of the residential and commercial sector and this continued until 1998 and possibly will remain so in the years to come.

In 1997/98, affected by the ASEAN economic crises, the hydrocarbon growth was negative for the industrial and transport sectors, but positive for the residential and commercial sector, i.e. industry (-2.2 percent), transport (-4.4 percent), and residential & commercial (4.84 percent), indicating that the residential & commercial sector was not affected by the crises.



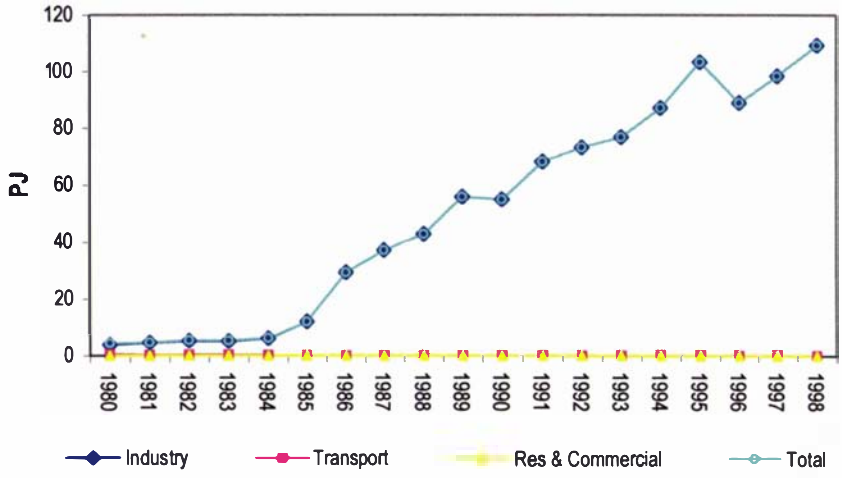

Source: IEA (2000) and DJLEB (1999)

**Figure 4.15 Indonesian Hydrocarbon Consumption by Sector, 1980-1998**

### 4.4.4 Coal Use

Coal is mainly consumed in the industrial sector and only a small portion was consumed by transport (for trains) in the past years, and it was no longer used in 1987/88. Coal started to be used more intensively in 1984/85 after the construction of the coal power plant in Suralaya. In that year, the consumption was almost double that of the previous year, a 94 percent increase and in 1985/86, the consumption growth was even higher, about a 144 percent increase from the 1985/86's consumption figure (see figure 4.16). Compared to other type of energy sources, coal consumption growth was recorded as the highest during the last two decades. The growth was 24.2 percent on average per annum, during the last two decades, and about 23.2 percent during the last 10 years. However, negative growth was recorded in 1995/96, which was probably due to the decrease of coal use in the power supply industry because of the over supply of national electricity.

It is interesting to note that in 1997/98, the coal demand was not affected by the ASEAN economic crises, while other sources of energy, mainly oil and natural gas were severely affected. This is perhaps because natural gas and oil were priced in US dollars, while the coal price in the domestic market is still valued in rupiah, and the government attempted to keep the coal price stable in the domestic market.



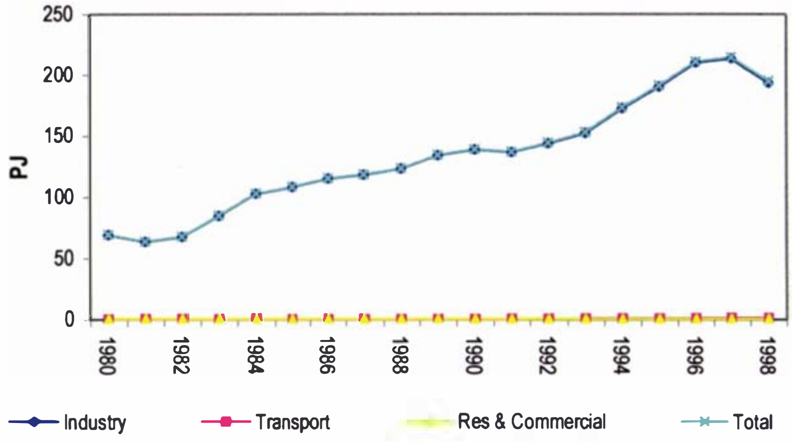

Source: IEA (2000) and DJLEB (1999)

**Figure 4.16 Indonesian Coal Consumption by Sector , 1980-1998**

### 4.4.5 Natural Gas Use

Natural gas was mainly consumed in the industrial sector and only a very small portion in the residential-commercial sector, in particular for Hotel and commercial building utilities. The growth of natural gas consumption in the industrial sector, and residential-commercial sector were respectively 6.6 and 4.6 percent annually over the last two decades (see figure 4.17).

In the residential-commercial sector, the highest growth occurred in 1986/87, which was about 23.8 percent and the lowest growth was in 1982/83, -15.4 percent per annum. It is interesting that in the beginning of the ASEAN economic crises in 1997/98, natural gas demand in this sector was not affected by the crises, which was shown by the positive growth of 13.5 percent. The industrial sector experienced the highest growth of natural gas demand in 1993/94, which was about 13.3 percent per annum and the lowest growth in 1997/98, which was about -9.3 percent per annum, which was clearly caused by the ASEAN economic crises.




Source: IEA (2000) and DJLEB (1999)

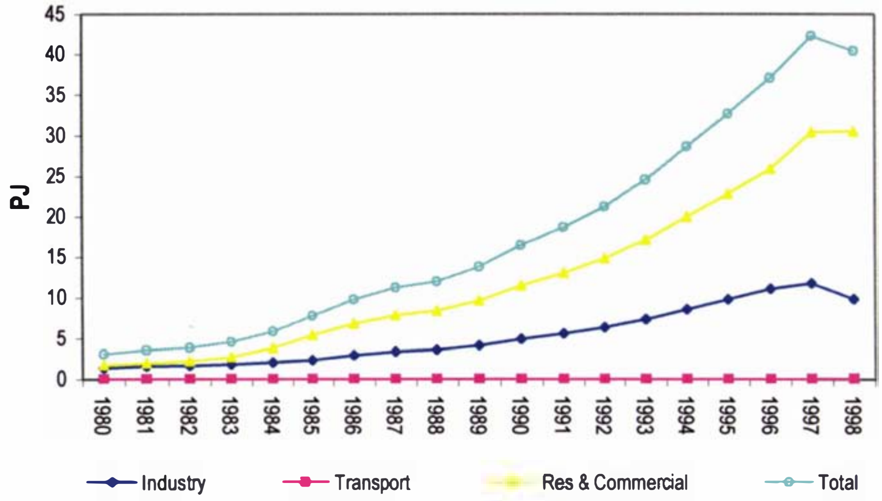
**Figure 4.17 Indonesian Natural Gas Consumption by Sector, 1980-1998**

### 4.4.6 LPG Use

Over the last two decades, LPG was mainly consumed in the residential-commercial and industrial sectors, with the percentage of 70 and 30 percent respectively. The transport sector also consumed a small amount, less than 0.1 PJ in 1987, increasing to 1 PJ in 1997/98. The average LPG demand growth was 15.6 percent during the last two decades. In this period, LPG grew at 17.6 percent per annum in the residential-commercial sector, and 12.1 percent per annum in the industrial sector (see figure 4.18).

The rapid growth of LPG in the residential-commercial sector was mainly attributed to the shifting of the consumption pattern from kerosene to LPG. This condition is expected to continue for the next twenty to thirty years with many LPG stoves now replacing kerosene stoves.

The fastest growth was recorded from 1983 to 1985 in the residential-commercial sector at more than 40 percent per annum. Negative growth was also recorded for natural gas during the ASEAN economic crises in 1997/98, which was about –16.4 percent. The drop was perhaps caused by the drastic reduction on demand for LPG from small-scale industries, which suffered the most from the crises.



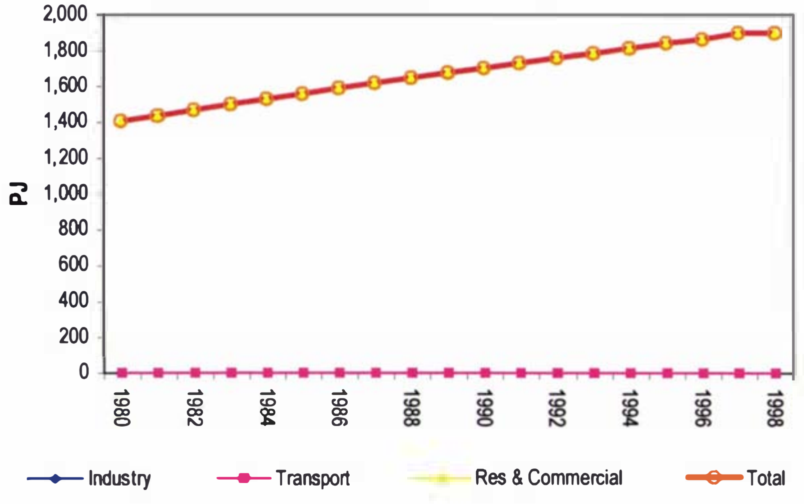

Source: IEA (2000) and DJLEB (1999)

**Figure 4.18 Indonesian LPG Consumption by Sector, 1980-1998**

### 4.4.7 Combustible Renewable & Waste Energy Use

Combustible renewable & waste is consumed only in the residential sector. The current level of consumption (1998) is about 1900 PJ per annum. Most rural people, who account for 70 percent of the total Indonesian population, consume this type of energy for cooking purposes. Consumption growth was relatively constant around 1 to 2 percent annually during the last two decades. However, as a percentage of total delivered energy consumption, its use has decreased from 50 percent in early 1980 to around 30 percent at present (see figure 4.19). This indicates the shifting of the consumption pattern from combustible renewable to kerosene and LPG for cooking possibly as a result of urbanisation and changes in life style.

The use of combustible renewable was not affected by the economic crises of 1997/98, as most of the resource was collected or obtained free from local gardens and wood plantations in rural and remote areas.




Source: IEA (2000) and DJLEB (1999)

**Figure 4.19 Indonesian Renewable and Waste Energy Consumption by Sector, 1980-1998**

## 4.5 Conclusion

### Trends in Primary Energy Supply

*Over the last 18 years* (1980 – 1998) the growth of primary energy consumption was 4.8 percent per annum. However, if we exclude combustible renewables from the energy mix, the growth was 8.9 percent per annum, which was very high compared to the world growth, which was only at 2.1 percent per annum from 1980 to 1998. Over the period (1980 to 1998), the use of *non-conventional energy sources* (combustible renewables) decreased from more than 70 percent to 60 percent. The role of combustible renewable (biomass) is expected to continue to decrease very rapidly in the next decades and be replaced by conventional fuels, especially kerosene and LPG. The role of oil has also decreased from 40 percent in 1980 to 30 percent in 1998.

The growth is still predicted to be high at about 6 to 7 percent *over the next 20 years,* which is still high compared to the predicted world's primary energy demand growth, which is about 2 percent from 1997 to 2020 (IEA, 2000). In the last 10 years, the growth of geothermal was the highest (15.6 percent), followed by coal (9 percent), natural gas (8.3 percent), oil (6.9 percent), and hydro (4.5 percent). Meanwhile, the growth of combustible renewables was only 1.4 percent annually, indicating that primary energy use is shifting from traditional energy sources (biomass) toward more conventional energy sources.

**Trends in Delivered Energy Demand**

*Over the last 18 years*, delivered energy demand grew at the rate of 4 percent per annum. However, if biomass is excluded from the consumption pattern, the growth was 9.2 percent per annum during the same period and even reached 12.5 percent per annum in the last decade. This is very high compared to the world's growth in delivered energy demand, around 2 to 3 percent during the same period. It is also relatively high compared to other ASEAN countries like Malaysia (9.1 percent), Philippines (3.1 percent) and Thailand (9.9 percent) per annum during the last two decades. This high growth of delivered energy demand was due to the fast growth of industrialisation, increased incomes and the rapid increase of energy demand in the transport sector.

Electricity grew at the rate of 10.9 percent, almost 4 times the world's electricity growth, of about 2.8 percent per annum during the same period. Hydrocarbons grew at the rate of 6.6 percent, meanwhile coal and LPG grew very rapidly at the rate of 10.5 and 13.1 percent respectively during the same period. The rapid growth of LPG is attributed primarily to the fast growth of LPG use to replace kerosene and combustible renewable in the residential sector and small-scale industries.

The percentage of biomass as total to delivered energy demand decreased and was replaced by LPG and other oil products over the last 10 years. Rapid urbanisation, which was about 3 percent in Java and 2.6 percent outside Java during the period, as well as the changing life styles and the heavy government subsidy on kerosene and LPG have probably been the main reasons of this change.

# CHAPTER FIVE

# ENERGY DEMAND: ECONOMIC AND SOCIAL DETERMINANTS

This chapter discusses the results of a multiple linear regression analysis carried out on the energy demand data presented in Chapter 4. This data covers the time series 1970 to 1998 with a few minor exceptions due to data unavailability. Regression analysis quantifies the relationship between energy demand (dependent variable) and variables such as energy price, population, income growth and other economic-demographic variables (independent variables). The mathematical (regression) equations derived in this chapter are used as the core of the energy demand module of the system dynamics model developed in Chapter 8.

## 5.1 Methodology

In principle, the regression method is a statistical technique that explains the present demand for energy in terms of the part played by past and present explanatory (independent) variables. The relative degrees of influence of the explanatory variables have to be assessed and calculated and they can then be used (with appropriate caution) to project future levels of energy demand

The regression equations were derived using standard procedures (refer to Gujarati, 1988) for fitting equations to the empirical data. Standard statistical diagnostics (such as $R^2$, t tests, F tests, auto-correlation tests) and procedures (such as residual plotting) were used. Various functional forms (linear, log-linear) were used according to how appropriately they described the data. Auto-regressive models were used for data that exhibited time lags, which is frequently encountered when analysing energy demand data. However, none of these time-lag models, although thoroughly tested, were found to be statistically significant.

This study also used dummy variables to take account of "one-off" events or dichotomic shifts in policies that have an effect on energy demand. The dummy variable 'picks up' the effects on the dependent variable of a wide range of changes, which take place through time and which would otherwise be excluded from the analysis.

Generally the "backward elimination" method was used in developing the regression equations. That is, the total range of possible independent variables were included in the initial regression equation, with variables being systematically excluded until a satisfactory regression model was derived. Various statistical and non-statistical criteria were used for excluding such variables in this "backward elimination" procedure. In general terms, the variables with "statistically insignificant" t ratios were removed first, and then the remaining variables were configured to achieve a maximum $R^2$, as a well as ensuring that the model was statistically valid according to the other diagnostic tests. Sometimes variables had to be removed because their co-efficient trend was counter to *a priori* expectations.

It is widely acknowledged that the technique of multiple linear regression analysis possesses several inherent limitations, which may produce errors and biases in the results (Freund et. al, 1991). According to Archer (1976), the main difficulties results from an attempt to use linear equations to explain the relationships between one series of data and several other series, when in reality they are interdependent rather than independent of each other. In this analysis several of the explanatory variables are likely to be related to some extent and there will be some form of relationship, however slight, between several of the variables within the system and the size of the residual. Income and price data series, two of the most frequently used in energy demand analysis, are often highly correlated in a time series distribution (Archer, 1976).

In this study, population size was used to express other relevant variables in per capita terms. For example, energy consumption per capita, income per capita, vehicles per capita, and households per capita and so forth. The units of the data are petajoules for the "energy consumption" variable, millions for "population", billion rupiahs (1983 constant price) for "GDP", billion rupiahs (1983 constant price) per petajoule for "energy price" and thousand rupiahs per captia for "income". An electrification ratio was also developed which measures the number of households electrified per total number of households and the number of villages electrified per total number of villages for the rural electrification ratio.

Although disposable income data might be more accurate, the study calculated per capita income from per capita gross domestic product, due to problems with the availability and accuracy of the data. Also due to the limited availability of data as well as the accuracy of data, the coal price and natural gas price (in particular years) are assumed to be the same across all sectors.

Regression analysis was done for the period of 1970 to 1998. However, due to data availability and the problem of data accuracy, some data particularly on the price of certain fuels and some other variables, like the electrification ratio and the number of households for some years, were omitted.

Not all fuel/energy types are analysed in this study. Some types of energy like renewables, and charcoal are excluded in the analysis due to their relatively low share in the total domestic energy mix as well as data limitations and accuracy, particularly in relation to prices. The price of wood, for example, is almost nil, because most rural people use their own garden or a local plantation to obtain wood for cooking. Kerosene, gasoline, automative diesel oil (ADO), industrial diesel oil (IDO), avtur, and avgas are grouped and treated as a single fuel named hydrocarbons, although its price in each sector is determined through computations based on its calorific value and its share in the sector. Referred to Nomenclature for variables (Appendix H)

## 5.2 Regression Analysis, By Sector, By Fuel Type

### 5.2.1 Industry

**Electricity**

The best regression model was found to be:

*Log Electrity Demand (Industry) = -3.7921 + 1.3047 Log GDP (Industry)* (5.1)

$R^2 = 0.99$

*F ratio (for Model) = 4595.57 (p <0.0001)*

*t ratio (for Log GDP variable) = 34.36 ( p<0.0001)*

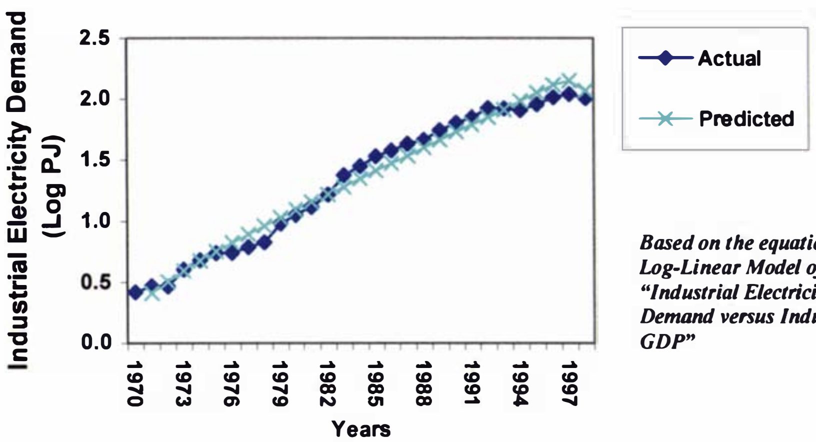
The independent variables considered for inclusion in this regression were:

- *Electricity Price in Industrial Sector*
- *Income per capita*
- *GDP Industry*
- *National Installed Power Capacity*
- *Number of Industrial Customers*
- Electrification Ratio

The inclusion of other independent variables (electricity price in the industrial sector, income per capita, national installed power capacity, number of industrial customer, electrification ratio) in the regression, led to an inferior regression model. The price variable for example, along with other explanatory variables, like, number of industrial customers, electrification ratio and the national power capacity (throughout the period of the model from 1971 to 1998), did not produce significant results, probably due to the 'non-saturated condition' of electricity utilization in the country. During the past 20 years from 1980 to 1998, for example, the price of electricity almost tripled, but the electricity demand increased nearly 10 times, producing a wrong or negative sign in electricity price variable of the demand variable. The lagged regression on the model (electricity demand versus GDP variable) did not give a more satisfactory result and this was indicated by lower t and F statistics.

This log-linear regression equation (5.1) showed that *electricity demand* in the *industrial sector* was quite elastic in respect to changes in the GDP variable, with a GDP elasticity of 1.3047. That is, a one per cent change in GDP output of the industry sector results in a 1.3047 increase in electricity demand in the industry sector. The corelation coefficient was quite high at $R^2 = 0.99$, being significantly higher than the comparable linear model $R^2 = 0.85$.

The plot actual versus predicted values shows some interesting pattems (see Figure 5.1 below). During 1974 and 1980 the residual values were negative, and from 1980 to 1987 were relatively high and positive, which was probably due to some electric tariff adjustments by the government. In 1973, the government slightly changed The Electricity Tariff Structure (TDL 1973). An exploitation cost (TBE) was added because it was considered a dominant/important cost. In 1980, the government again changed the tariff structure. The new tariff, TDL 1980 was classified into 19 categories. It no longer used a block tariff and started to apply the principle of long run marginal cost. Over the period 1980 to 1986, tariff structures were changed 4 times in line with the oil price adjustment. In 1983, the tariff for 'Hotel' was eliminated and included in the industry category. This was aimed at promoting tourism. The residual values were observed to be negative in 1994 to the end of the study period (1998). This was probably due to some changes in the electricity tariff. In 1993, the government made some changes in the electricity tariff through Presidential Decree No. 2/1993 and Ministerial Decree No. 76/49/MPE/1993. In this new tariff (TDL 1993) no basic change was applied when compared with TDL 1991 (in terms of category). The difference was the addition of components of capacity and usage costs in the new tariff (TDL 1993). In 1994, the government made an effort to improve the electricity tariff mechanism and aimed to cover the investment funds required to guarantee a healthy financial position for electricity venture enterprises. The new tariff to match its economic value was used by Presidential Decree No. 67/1994 and Ministerial Decree No. 2057.K/49/MPE/1994. The decrees led to improvements in the mechanism for formulating the Basic Electricity Tariff (TDL). Instead of using just basic electricity tariff system, it was divided into 2 segments: the basic electricity tariff, and the periodic electricity tariff. The periodic electricity tariff could be adjusted every three months to allow for uncontrollable changes, such as in fuel prices, private electricity prices, the inflation rate, and the rupiah exchange rate.




*Based on the equation 5.1: Log-Linear Model of "Industrial Electricity Demand versus Industry GDP"*

**Figure 5.1a Actual versus Predicted Values for Industrial Electricity Demand, for Indonesia, 1970 –1998**

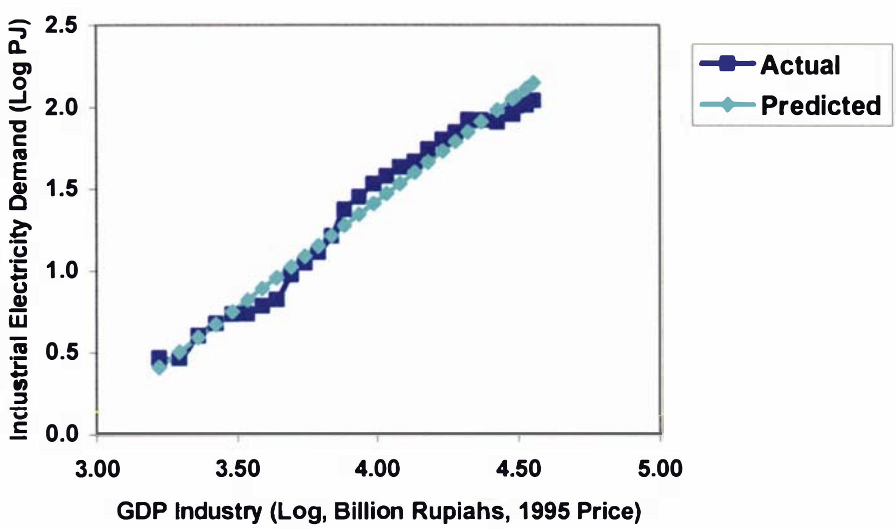



**Figure 5.1b. Actual and Predicted Values versus GDP Industry for Industrial Electricity Demand, For Indonesia, 1970-1998**

**Hydrocarbons**

The best regression model was found to be:

*Hydrocarbons Demand (Industry) = 100.960 + 0.0091 GDP (Industry)* (5.2)

$R^2 = 0.98$

*F ratio (for Model) = 811.94 (p <0.0001)*

*t ratio (for GDP variable) = 16.13 ( p <0.0001)*

The independent variables considered for inclusion in this regression were:

- *Hydrocarbon Price in Industrial Sector*
- *GDP Industry*

In the case of hydrocarbons demand in the industrial sector, the GDP elasticity was found to be only 0.0091 for the hydrocarbon demand in the sector (non-log regression). In the last 30 years, the industrial sector GDP increased by almost 20 times, but the additional demand for hydrocarbons was only six times greater. The saturation effect of hydrocarbon consumption in the sector, as opposed to that of electricity, is probably the main reason for this. The graph of actual versus predicted values (see Figure.5.2) shows that the residual (actual-predicted) values were positive 1976 to 1984 and negative from 1984 onwards. The government applied increases to the oil price, which resulted in a decrease in the sale of hydrocarbons, from 14.3 percent of total annual energy sales between 1974 and 1984 down to an average of 2.4 percent over the 1984 to 1989 period.

However, the inclusion of the price variable in the model during the period of the study (1970-1998) did not produce significant result with a low t-test and (p = 0.40) although the result showed a high $R^2$ value and the right sign for a price variable (negative sign). This indicates that price did not have a significant explanatory power in the demand for hydrocarbons by industry. The plot of actual values of hydrocarbons consumption in industrial sector versus the predicted values is shown in Figure 5.2 below.

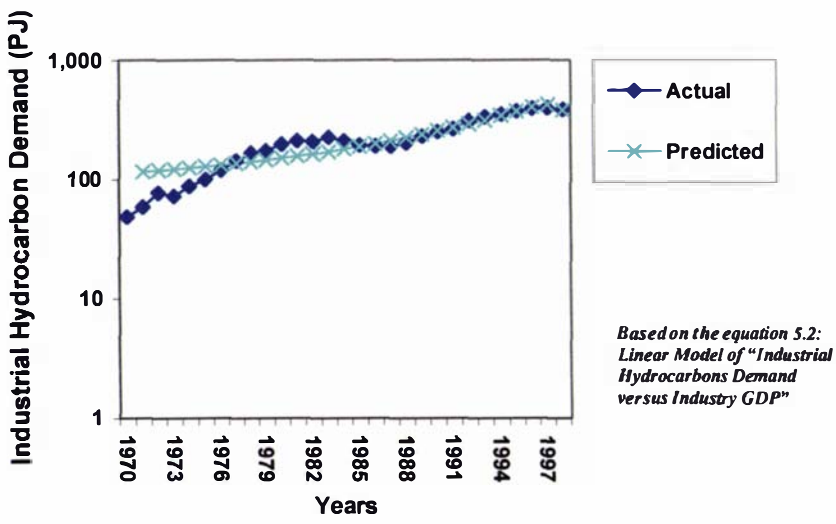



**Figure 5.2a Actual versus Predicted Values for Industrial Hydrocarbons Demand, for Indonesia, 1970 –1998**

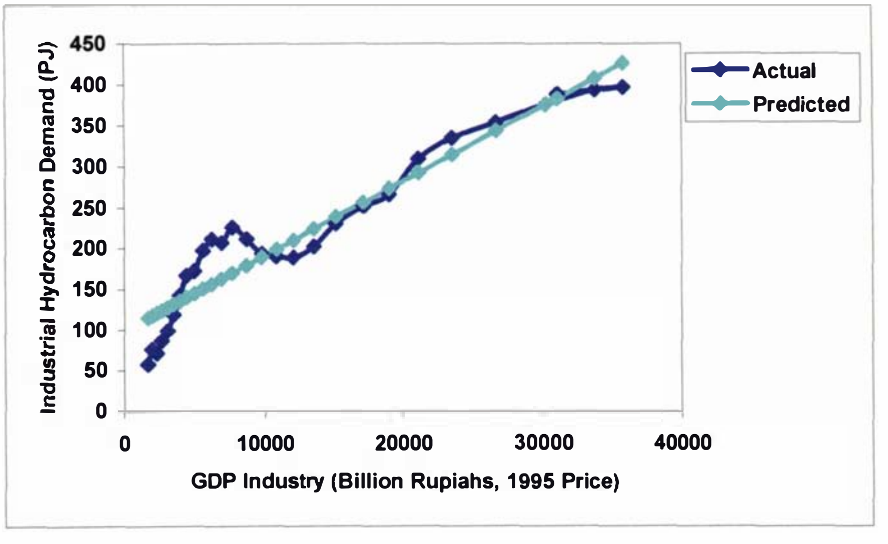



**Figure 5.2b. Actual and Predicted Values versus GDP Industry for Industrial Hydrocarbons Demand, For Indonesia, 1970-1998**

**LPG**

The best regression model was found to be:

$$Log\ LPG\ Demand\ (Industry) = -6.8069 + 1.8036\ Log\ GDP\ (Industry) \qquad (5.3)$$

$R^2 = 0.91$

*F ratio (for Model) = 110.79 (p <0.0001)*

*t ratio (for Log GDP variable) = 14.69 ( p<0.0001)*

The independent variables considered for inclusion in this regression were:

- *LPG Price in Industrial Sector*
- *GDP Industry*

When the regression of GDP industry to LPG demand was done, the relationship (Equation 5.3) was found to be significant with a GDP elasticity of 1.8036 for the LPG demand in the sector (log-model), with a $R^2 = 0.91$ and a relatively high F and t-statistic, and a p value of less than .0001. The plot of actual values versus predicted LPG demand (see Figure 5.3) showed a high positive residual (actual minus predicted) values from 1974 to 1984 and negative values from 1985 up to present except for in 1990. The explanation of this phenomenon may be found from the fact that during 1970 to 1975 efforts to build a gas infrastructure were accelerated to catch up with the rapid growing domestic demand for gas. This rapid growth of domestic gas utilization was motivated by the rise in oil prices in the 1970s, making gas a prospective alternative to oil. In this period, transmission and distribution lines owned by PGN (The State Gas Company) to residential, commercial, and industrial sectors reached 1,528 km (excluding newly constructed pipelines) with a total capacity of 246 Standard Cubic Feet (SCF) per day.

In 1976, total natural gas production reached 312 billion SCF (BSCF), which was three times 1966's production (106 BSCF). An LPG plant constructed in Mundu (East Java), started operatiing in 1976, and this was followed by other LPG plant constructions in various other locations. The rapidly growing domestic market prompted the government to encourage natural gas exploration in Indonesia. In 1990, the residual value showed a substantially high increase with actual consumption significantly higher than the predicted value for that year. This was possibly caused by the government's diversification policy which encouraged the use of LPG. The period between 1989 and 1991 marked the end of town gas utilization in some big cities in Java. The government closed down city gas supply for Bandung, Semarang, Surabaya, and Ujung Pandang, and replaced it with LPG distribution.

In the period of 1990 to 1991, the State Gas Company (PGN) grew rapidly in line with increasing utilisation of natural gas by the industrial, commercial, and household sectors in Indonesia. Management in the gas sector was then improved in 1992 by the government to support the escalating development in the gas sector. The plot of actual values of LPG consumption in industrial sector versus the predicted values is shown in Figure 5.3 below.

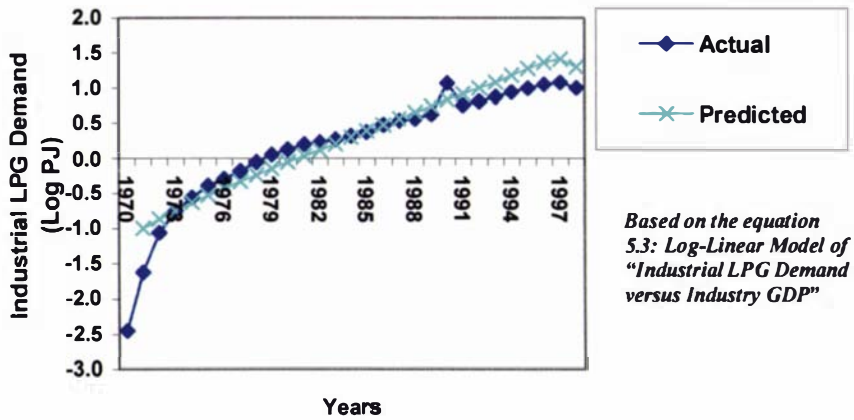



**Figure 5.3a Actual versus Predicted Values for Industrial LPG Demand, for Indonesia, 1970 –1998**

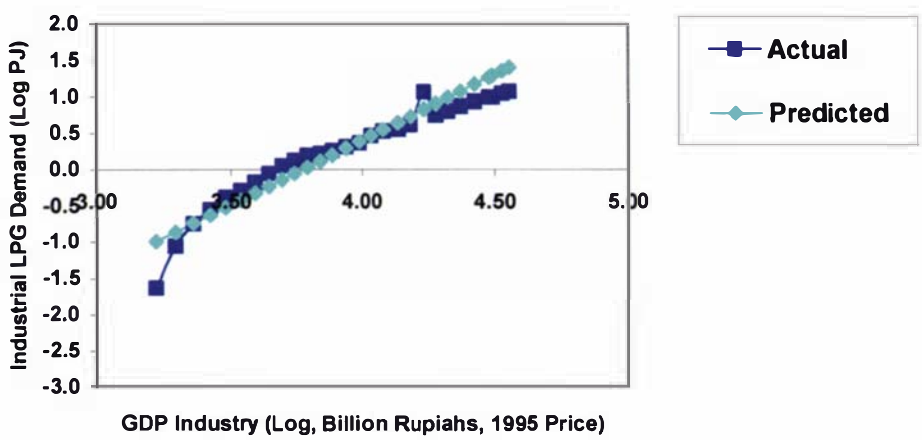



**Figure 5.3b. Actual and Predicted Values versus GDP Industry for Industrial LPG Demand, for Indonesia, 1970-1998**

**Coal**

The best regression model was found to be:

*Log Coal Demand (Industry) = -5.6977 + 1.72 Log GDP (Industry)* (5.4)

$R^2 = 0.98$

*F ratio (for Model) = 529.57 (p < 0.0001)*

*t ratio (for Log GDP variable) = 17.33 (p < 0.0001)*

The independent variables considered for inclusion in this regression were:

- *Coal Price in Industrial Sector*
- *GDP Industry*

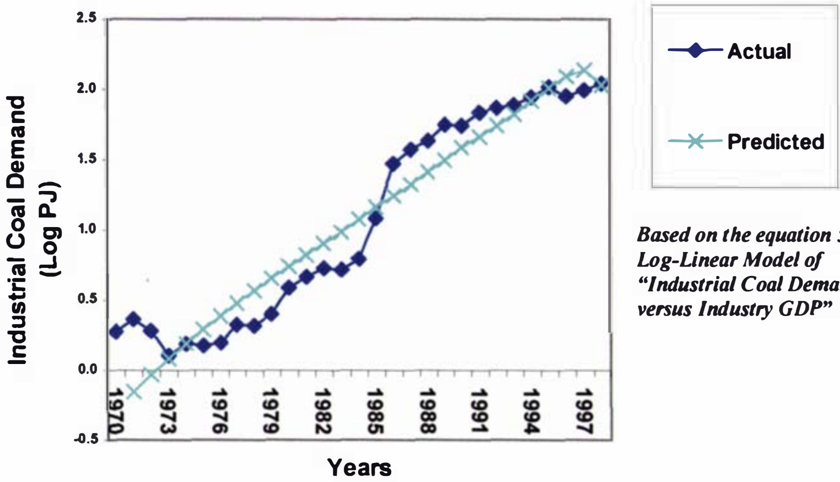
The GDP (Industry) was found to have a significant relationship to the demand for coal in industry. The coefficient of GDP was found to be 1.72 (log-model) for the coal demand in the sector (Equation 5.4). The $R^2 = 0.98$, was also supported with a high F-stat and t-test ($p < 0.0001$), indicating a good for the model. The plot of actual versus predicted values of demand was non-random. With the early years (1971 to 1973) predicting value was much less than the actual. During 1974 to 1985, the values were negative indicating that the actual values were far below the predicted ones. And from 1985 to 1994, residual (actual-predicted) values showed positive signs.

This can be explained as follows. The 1970s brought about a resurgence of interest in coal as an alternative to oil in Indonesia. This was also the case in other coal exporting countries around the world. The 1973 oil embargo by Arab countries also brought about the development of coal industries in Indonesia, as attention from investors was redirected to coal as an alternative to oil. However, coal consumption showed a declining trend during 1974 to 1985. This was possibly caused by inconsistency in the government's energy policy, which hampered coal development for domestic use. On one hand, the government wanted coal to gradually replace oil in the domestic market, but, on the other hand, the domestic oil price was heavily subsidized to boost industrialization. During this period, domestic coal consumption continually dropped as a result of the low oil price.

The higher actual consumption than predicted values (positive residual values) observed during 1985 to 1994 may be attributed to the government's rigorous effort to accelerate coal production and utilization as an alternative to oil during 1976 to 1988. In 1976 with the issuance of the first National Energy Policy, the government started to accelerate coal diversification. An effective way towards acceleration of the domestic coal market began with the initiation of interdepartmental cooperation. In 1977, a Joint Ministerial Decree was issued, followed by the establishment of a Coordination Group on Bukit Asam Coal Development and Transportation (POKKORLAK P4BA), which was aimed at increasing domestic coal utilization. In 1980, the government invited foreign companies to explore and develop potential coal potential in the Indonesian islands. Then, in 1981, the Production Sharing-Contract (PSC) system was started to boost coal production and during the period 1981 to 1984, several coal production sharing contracts were signed between the government and seven foreign coal contractors. Moreover, between the period 1981 to 1987, there were nine foreign, and one local, coal investors in Indonesia.

In 1985, for the purpose of supporting BAKOREN (National Energy Coordinating Board established in 1980) in issuing the coal development policy, the Minister of Mines and Energy established the Coordinating Committee on Coal Development (PANKORBANG BATUBARA), which was chaired by the Director General for Mining. The drive to accelerate the utilization of coal as a substitute for fossil fuel oil in the power generation sector also emerged at the end of 1988. The establishment of the Committee for Coordinating Large Electric Power Plant Installations in Java, i.e. Suralaya (Coal), Gresik (Natural Gas), and Paiton (Coal) then materialized. Quite ambitious targets were set for this program. PLN, the State Utility Company, already generated some 25 percent of its electricity from coal, and 55 percent was set as the target for 1999 and 66 percent by 2004. In 1989, the Suralaya-Steam-Generation Power Plant – Units I, II, III, and IV started their operation with coal supplied from PT Tambang Batubara Bukit Asam.

The lagged model did not show satisfactory results either in the $R^2$ or in the significance of statistical parameters. When a price variable was added to the model, the result was not significant, indicated by ($p = 0.43$) and low t-test (-0.79). The price coefficient was negative, showing the right sign. As was thc case with other fuels, it seems the coal price did not have a significant effect on the demand for coal in the sector, which, perhaps, was due to the still relatively insignificant share of coal in the total domestic energy consumption in the industrial sector (12 percent in 1998). The low saturation level of coal utilization is mainly due to industry not being set up to use coal as an energy source. This condition (a low saturation level) is likely to change in the near future, especially with the fast growth of coal utilization in Indonesia. It was observed that during the last two decades, the growth of domestic coal consumption has averaged approximately 24 percent a year, which is very high compared to the growth of other fossil fuels (DGENE, 1999). The plot of actual values of coal consumption in industrial sector versus the predicted values is shown in Figure 5.4 below.




***Based on the equation 5.4: Log-Linear Model of "Industrial Coal Demand versus Industry GDP"***

**Figure 5.4 Actual versus Predicted Values for Industrial Coal Demand, for Indonesia, 1970 –1998**

**Natural Gas**

The best regression model was found to be:

*Log Natural Gas Demand (Industry) = -3.4435 + 1.3178 Log GDP (Industry)* (5.5)

$R^2 = 0.98$

*F ratio (for Model) = 878.85 (p < 0.0001)*

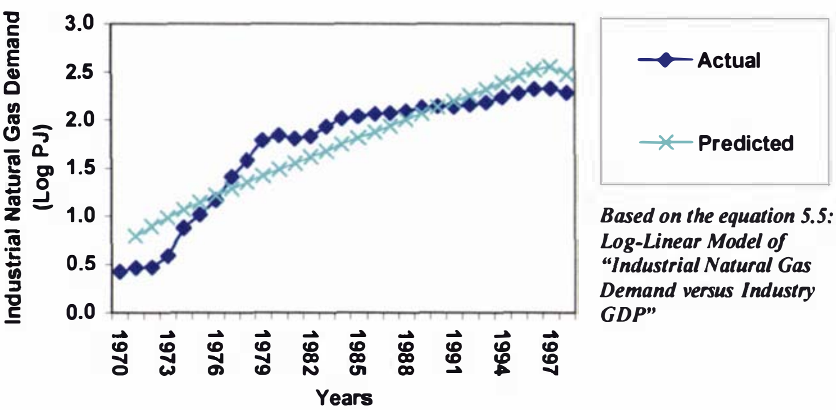
*t ratio (for Log GDP variable) = 12.03 (p< 0.0001)*

The independent variables considered for inclusion in this regression were:

- *Natural Gas Price in Industrial Sector*
- *GDP Industry*

The GDP (Industry) found to have statistically significant explanatory power in the demand for natural gas by the industrial sector (Equation 5.5). The coefficient of GDP has the expected sign and it is significant at 1.3178 to the demand for natural gas in industry (log-model). The $R^2 = 0.98$, with a high F-test and t-test ($p < 0.0001$), indicating the best fit model. The plot actual versus predicted values, however, showed significant negative residual (actual minus predicted) values in the early years, 1971 to 1976, then positive values during 1977 to 1989, and negative patterns again from 1991 up to present (see Figure 5.5). This indicated higher actual demand than the model predicted occurred during the period 1977 to 1989. This was, perhaps caused by the new government policy, which promoted a greater role for natural gas in the industrial sector as a replacement for oil in the early 1970s.

The negative values of residual (actual minuspredicted) during 1991 up to the present time were probably attributed to a drop in the hydrocarbon price and gradual increase in the natural gas price in the industrial sector, which both commenced in 1984, thereby making natural gas less attractive as a substitute for oil. When the price variable was included in the model (the log as well as non-log model), the results were not satisfactory although the $R^2$ were high for both log and non-log models. The sign was found to be wrong for price showing that price was not related to the demand for natural gas in this sector.




***Based on the equation 5.5: Log-Linear Model of "Industrial Natural Gas Demand versus Industry GDP"***

**Figure 5.5 Actual versus Predicted Values for Industrial Natural Gas Demand, for Indonesia, 1970 –1998**

### 5.2.2 Residential and Commercial

**Electricity**

The best regression model was found to be:

*Log Electricity Demand (Res-Com) = -13.6297 + 2.5153 Log Income/Cap* (5.6)

$R^2 = 0.99$

*F ratio (for Model) = 102395.30 (p < 0.0001)*

*t ratio (for Log Income/Cap variable) = 24.02 (p < 0.0001)*

The independent variables considered for inclusion in this regression were:

- *Electricity Price in Res-Com Sector*
- *Income per Capita*

- *Number of Households*
- *Number of Residential Customer (Electricity)*
- *Ratio of Electrification*

In the residential-commercial sector, per capita income is better able to explain per capita electricity demand then GDP variable. When the log regression model was done, elasticity of income per capita to the per capita electricity demand was found to be significant (2.52) with an $R^2 = 0.99$, significant t-test, high F-test ($p < 0.0001$) indicating that it is the best fit model (see Equation 5.6). The plot of actual versus predicted values, showed a random distribution (see Figure 5.6), supporting the above statement. Slightly lower actual electricity consumptions than predicted occurred at the end 1973 to 1978 (negative residuals) and these were probably affected by the increase in electricity prices as a result of the government introducing a new electricity tariff structure (TDL 1973). An exploitation cost (TBE) was added to the tariff as it was considered a dominant/important cost.

The inclusion of price was tried in the regression analysis (log and non-log) but price again failed to show any significant relationship (the sign was found wrongly positive) although $R^2 = 0.98$. This shows that the electricity price did not affect the electricity demand in this sector and this is because of the still relatively low saturation level of electricity demand in the country. In 1998, the electrification ratio was still at the level of 51 percent (CESUI, 2000). The lagged model was also tried for both the log and non-log models but this did not produce any significant improvement as the R-square values were found to be lower and the other statistical parameters were not significant. The plot of actual electricity consumption values in residential-commercial sector versus the predicted values is shown in Figure 5.6 below.

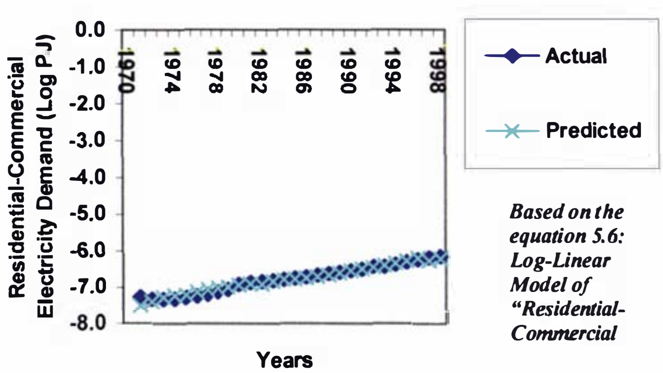



**Figure 5.6 Actual versus Predicted Values for Residential-Commercial Electricity Demand, for Indonesia, 1970 –1998**

**Hydrocarbons**

The best regression model was found to be:

*Log Hydrocarbons Demand (Res-Com) = -7.8007 + 0.7806 Log (Income/Cap) – 0.3147 Log Price Hydrocarbons (Res-Com)* (5.7)

$R^2 = 0.99$

*F ratio (for Model) = 111954.20 (p < 0.0001)*

*t ratio (for Log Income/Cap variable) = 7.22 (p < 0.0001); t ratio (for Log Price Hydrocarbon variable) = -4.75 (p < 0.0001)*

The independent variables considered for inclusion in this regression were:

- *Hydrocarbon Price in Res-Com Sector*
- *Income per Capita*

In order to analyse determinants for *hydrocarbons* demand in the residential-commercial sector, a number of explanatory variables were tried to produce the best-fit model. It was found that two independent variables, income per capita and hydrocarbon price (in this case kerosene) have the greatest explanatory powers for per capita hydrocarbon demand. The multi-variable regression produced an income per capita elasticity of 0.7806 and a price-elasticity of 0.3147 for the log-model (Equation 5.7). The $R^2$ value was very high (= 0.99), the F test and t-test were reasonably good (p<0.0001). The model indicated that higher per capita income per capita increased the per capita hydrocarbon (kerosene) consumption in this sector, perhaps due to the change from wood-fuel (wood-stove) to kerosene (kerosene stove) especially in urban areas.

Unlike the other above-mentioned models, the hydrocarbon price seems to have an influence on the demand for hydrocarbon in the residential-commercial sector, though it was not very significant. A possible explanation is hydrocarbons reaching a saturation levels of utilization in the sector. When the price variable was removed from the model, the results were not significantly better, and the R-square value was reduced to 0.97 and the income per capita variable became insignificance (p=0.0133). The plot of actual and predicted values showed a random distribution of residual (actual minus predicted). Only during 1994 to 1997 was the actual hydrocarbon consumption a bit lower than that predicted by the model. This may be explained by the unavailability of price data from 1994 to 1997 and the need to use proxy data. In this case, the author collected data from other resources, such as APERC, the Central Bureau of Statistic, University of Indonesia, BPPT (The Agency for Research and

Application of Technology), etc. The plot of the actual values of hydrocarbons consumption by the residential-commercial sector versus the predicted values is shown in Figure 5.7.

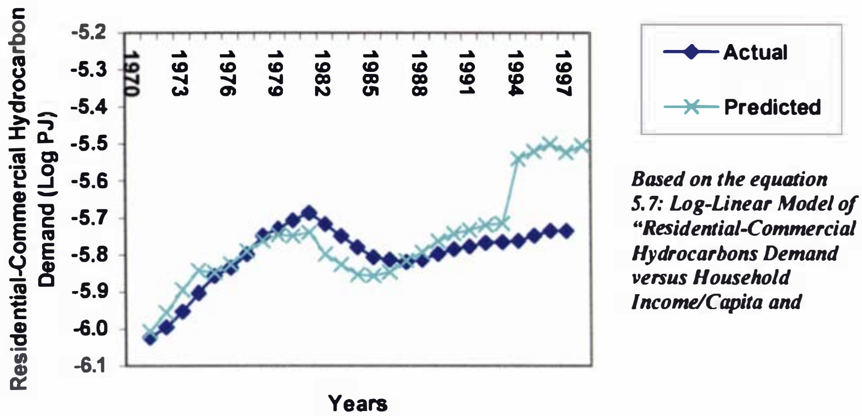



**Figure 5.7 Actual versus Predicted Values for Residential-Commercial Hydrocarbons Demand, for Indonesia, 1970 –1998**

**LPG**

The best regression model was found to be:

*Log LPG Demand (Res-Com) = -14.0879 + 2.9798 Log Income per Capita* *(5.8)*

$R^2 = 0.98$

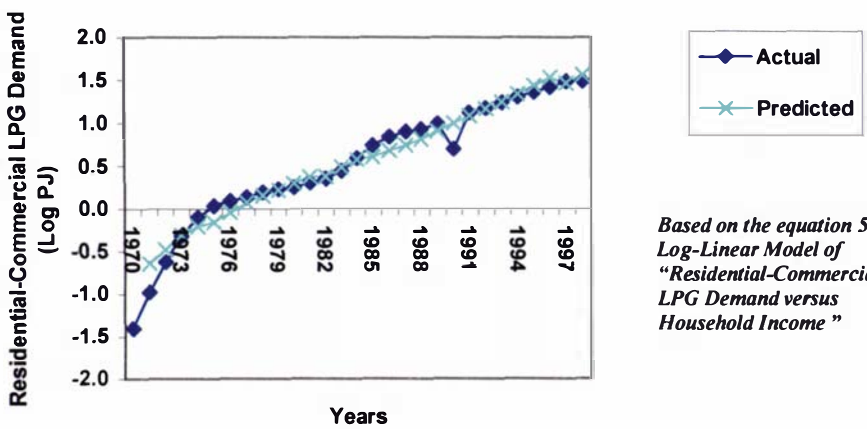
*F ratio (for Log Model) = 619.29 (p < 0.0001)*

*t ratio (for Log Income per Capita variable) = 25.89 (p < 0.0001)*

The independent variables considered for inclusion in this regression were:

- *LPG Price in Res-Com Sector*
- *Income per Capita*

From the regression analysis, the LPG demand in the residential-commercial sector was found to be affected more by household income, rather than income per capita. The regression analysis produced a very high income elasticity of 2.98 for the LPG demand in the sector (log-model), with a $R^2 = 0.98$, high t-test and F-test, ($p<0.0001$) (see Equation 5.8). However, when the price variable was added to the model (non-log), the sign was wrong (positive) indicating that the LPG price was not a significant determinant of LPG demand in this sector. The addition of price variable to the log-model, however, produced the right sign (negative), but unfortunately, the value of p = 0.9698 and the t-test showed the price variable was not statistically significant. The plot of actual versus predicted values showed a non-random distribution of residual (actual minus predicted) see Figure 5.8. There was a fluctuating trend with negative residual values in the early years (1971 to 1972), high positive residual values during 1975-1977 and 1985-1987 respectively, and a very high negative residual value in 1990. The high negative residual value from 1971 to 1972 indicated a lower actual LPG consumption value than predicted, possibly due to the effect of a kerosene price drop in 1971. In contrast, the higher actual LPG consumption than the predicted values that occurred in 1975-1977 and 1985-1987 were probably the results of kerosene price increases that occurred in 1974 and in 1982, 1983, and 1984, stimulating the change from kerosene to LPG stoves. The lagged regression model was tried, but failed to improve the significance of the explanatory variables as well as the $R^2$ value. The plot of actual values of LPG demand in residential-commercial sector versus the predicted values is shown in Figure 5.8 below.




*Based on the equation 5.8: Log-Linear Model of "Residential-Commercial LPG Demand versus Household Income"*

**Figure 5.8 Actual versus Predicted Values for Residential-Commercial LPG Demand, for Indonesia, 1970 –1998**

**Natural Gas**

The best regression model was found to be:

*Log Natural Gas Demand (Res-Com) = -7.3727 + 1.3404 Log Income per Capita* (5.9)

$R^2 = 0.96$

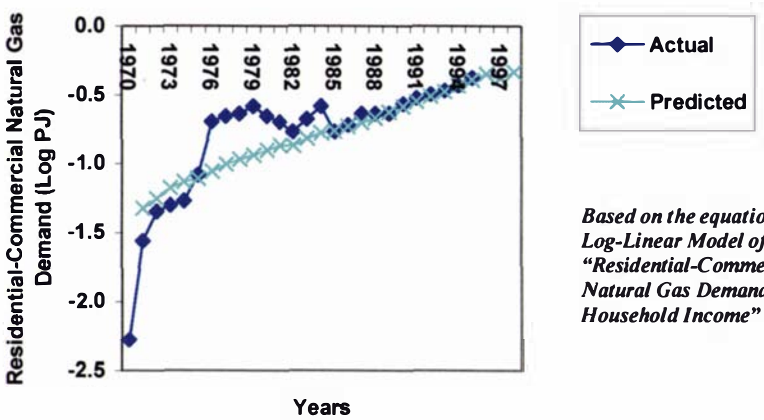
*F ratio (for Model) = 189.43 (p < 0.0001)*

*t ratio (for Log Income per Capita variable) = 4.37 (p< 0.0004)*

The independent variables considered for inclusion in this regression were:

- *Natural Gas Price in Res-Com Sector*
- *Income per Capita*

In the case of natural gas in the residential-commercial sector, it was found that household income was dominant in influencing the demand . The income elasticity in respect of natural gas demand was 1.34 (see Equation 5.9), with a $R^2 = 0.96$, reasonably high F test and t-test ($p < 0.0004$). Income improvement has encouraged the growth in demand for natural gas in the sector during the period and natural gas has been substituted for hydrocarbon fuel (kerosene) and wood in urban areas. The gas-stove is considered a more convenient and energy-efficient appliance by many urban communities, thus, as income increases, the substitution from hydrocarbon and fuel-wood to natural gas is encouraged. When the price variable was included in the model, the regression produced the wrong sign for the variable (positive), indicating that price did not affect the demand for natural gas in this sector. The plot of actual versus predicted natural gas demand showed a non-random distribution of residuals in the beginning period of the study, especially in 1973-78 with negative residual values and in 1979-1984 with positive residual (actual minus predicted) values (see Figure 5.9). The 1973-1978 trend was probably brought about by the subsequent drops in kerosene prices that happened during 1972 and 1979. There were probably three combined reasons that triggered the 1979-1984 positive trend. The first was the kerosene price increases during 1979 to 1984 leading to the change from kerosene to natural gas. The second reason was the result of the gas infrastructure development that started in early 1970 and was completed in 1976. The third was the boom indomestic natural gas production that began in 1976 (almost three-times of 1966's total production). The lagged model did not show an improvement in the significance of the parameters and the fitness of the model. The plot of the actual values of natural gas demand in residential-commercial sector versus the predicted values is shown in Figure 5.9 below.




***Based on the equation 5.9: Log-Linear Model of "Residential-Commercial Natural Gas Demand versus Household Income"***

**Figure 5.9 Actual versus Predicted Values for Residential-Commercial Natural Gas Demand, for Indonesia, 1970 –1998**

### 5.2.3 Transport

**Hydrocarbons**

The best regression model was found to be:

*Log Hydrocarbons Demand (Transport) = -1.8773 + 1.2836 Log GDP (Transport) – 0.3074 Log Price Hydrocarbons (Transport)* (5.10)

$R^2 = 0.99$

*F ratio (for Model) = 35912.75 (p < 0.0001)*

*t ratio (for Log GDP variable) = 28.74 ( p< 0.0001); t ratio (for Log Price Hydrocarbon variable) = -3.52 (p < 0.0001)*

The independent variables considered for inclusion in this regression were:

- *Hydrocarbon Price in Transport Sector*
- *GDP Transport*

During the last three decades, there were two explanatory variables, GDP and hydrocarbon price, that influenced the demand for *hydrocarbons* in the transport sector. The multivariable regression analysis (log-model) showed the significance of the GDP variable, with an elasticity of 1.28, whereas the price variable, though not statistically significant, also affected the demand, with the coefficient of 0.31 (see Equation 5.10). The $R^2 = 0.99$, indicating the best fit model, though the influence of price was only slight. When the price variable was removed, the $R^2$ was slightly reduced with no significant improvement in the parameters. As the GDP increases, the demand for hydrocarbons by this sector also increases given the above elasticity, indicate that more people buy cars/vehicles as GDP increases. The demand was only slightly reduced by the increase in hydrocarbon price. The plot of actual versus predicted demand values, indicated a non-random distribution of residual (actual minus predicted). At the beginning (1971, 1972) there were negative residual values, in the middle study period (1981,1982) positive residual values and at the end period (1994 to 1998) substantial negative residual values. Figure 5.10 shows lower actual hydrocarbon consumptions than those predicted by the model in 1971 and 1972 (negative residuals) despite the drops in hydrocarbon prices during these years. This was possibly caused by the insufficient supply of hydrocarbons by domestic refineries, and in 1970, the government attempted to overcome this by developing more domestic oil refineries. During 1981 and 1982, the residual values shows positive sign indicating higher actual consumptions than predicted ones as shown in Figure 5.10. This was quite possibly the result of the constructions of three refineries (Sungai Pakning, Dumai and Cilacap), in 1980, which were capable of doubling the national production to 800 thousand barrels of oil fuel per day. The plot of the actual values of hydrocarbons consumption by the transport sector versus the predicted values is shown in Figure 5.10 below.

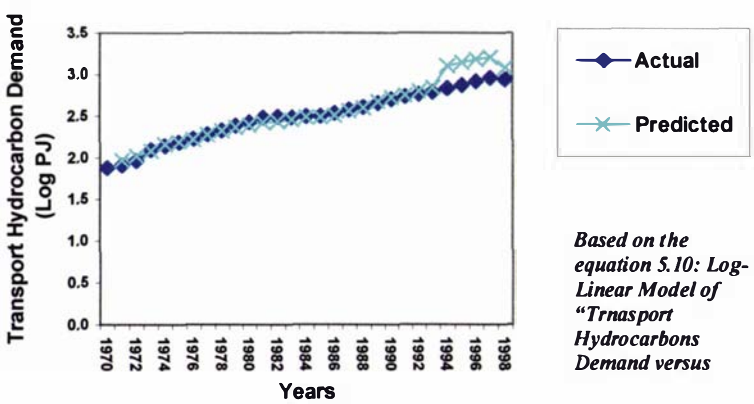



**Figure 5.10 Actual versus Predicted Values for Transport Hydrocarbons Demand, for Indonesia, 1970 –1998**

**Coal**

The best regression model was found to be:

*Coal Demand (Transport) = 1.1747 – 0.0002 GDP (Transport)* *(5.11)*

$R^2 = 0.76$

*F ratio (for Model) = 27.26 (p < 0.0001)*

*t ratio (for GDP variable) = -5.31 (p< 0.0001)*

The independent variables considered for inclusion in this regression were:

- *Coal Price in Transport Sector*
- *GDP Transport*

In the case of coal demand by the transport sector, from the multi-variable regression analysis (log and non-log) models) it can be seen that the explanatory variable, GDP, did not have significant statistical relationships with coal demand. Regression analysis, with the combined variables of GDP and price, showed wrong signs for both explanatory variables (negative for GDP and positive for price). When the price variable was removed, the $R^2$ was further reduced (0.76) and the sign of the GDP coefficient was still negative (see Equation 5.11). This indicates that neither GDP for transport or the coal price had any influence on demand for coal in the transport sector. The explanation of this poor fit may be due to the very small percentage of coal utilization by the transport sector and that small share has been decreasing rapidly since 1978 reaching zero in 1987. Since then coal has not been used. The lagged regression model, as expected, did not produce a better model. The plot of the actual versus predicted values (Figure 5.11) shows a confusing pattern making it difficult to analyse.

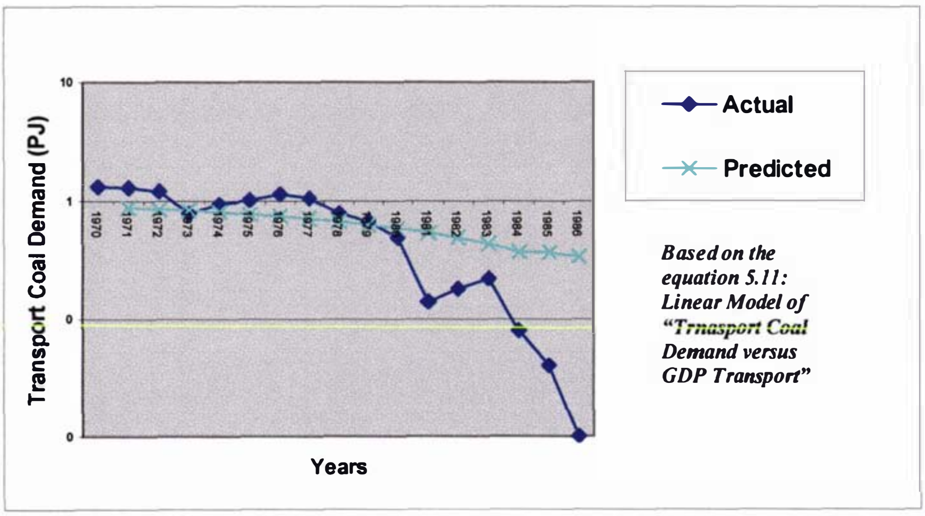



**Figure 5.11 Actual versus Predicted Values for Transport Coal Demand, for Indonesia, 1970 –1987**

**Natural Gas**

The best regression model was found to be:

*Natural Gas Demand (Transport) = -0.3214 + 0.0001 GDP (Transport)* (5.12)

$R^2 = 0.75$

*F ratio (for Model) =* $38.19$ *(*$p < 0.0001$*)*

*t ratio (for GDP variable) =* $7.26$ *(*$p < 0.0001$*)*

The independent variables considered for inclusion in this regression were:

- *Natural Gas Price in Transport Sector*
- *GDP Transport*

As was the case with coal, natural gas demand in the transport sector, was not affected by the GDP of the transport sector or the price of natural gas. The log and non-log models that used the two variables (price and GDP) did not produce significant coefficients and even indicated wrong signs for both variables with a $R^2 = 0.58$. When the price variable was dropped, and the non-log regression analysis was applied, the model produced $R^2 = 0.75$, but with a very low elasticity of GDP (0.0001) (see Equation 5.12), which indicated that both are inelastic to the demand for natural gas in the transport sector. Even the lagged model did not improve the significance of the two variables. The explanation of this poor fit was, perhaps, due to the insignificant share of natural gas in the sector. Natural gas utilization in Indonesia began in 1987 and in 1998 its share was still relatively low (about 0.13 percent to total energy use in the transport sector) (DGEED, 1999). Clearly, a lack of data is also behind this poor result in regression analysis. Like the regression model of coal use in the transport sector, the plot of actual versus predicted values shows a disorganized trend in residuals (actual minus predicted) making it difficult to analyse because of data unreliability and data limitations especially on the price variable. The plot of the actual values of natural gas consumption by the transport sector versus the predicted values is shown in Figure 5.12 below.

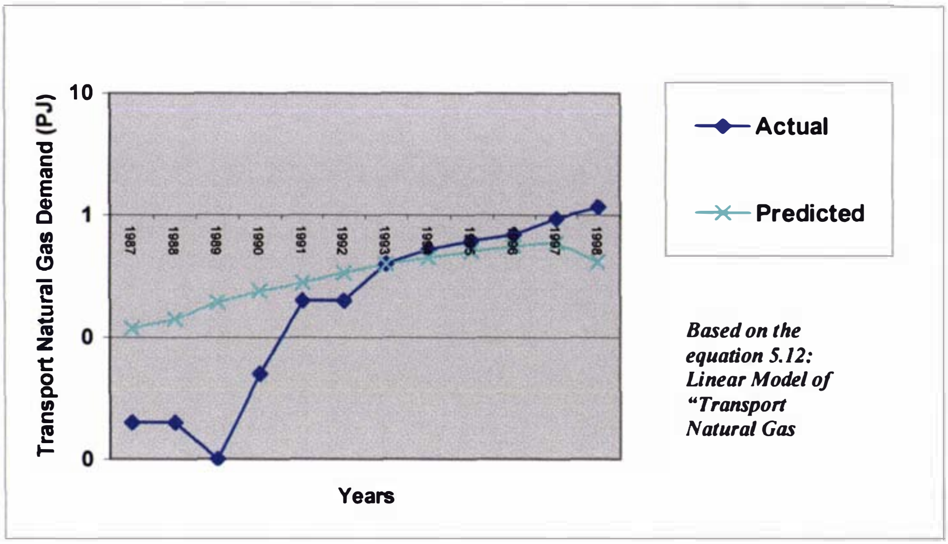



**Figure 5.12 Actual versus Predicted Values for Transport Natural Gas Demand, for Indonesia, 1987 –1998**

## 5.3 Regression Analysis With Sectors and With Fuel Types Combined in One Regression

### 5.3.1. Regression Analysis, by Fuel Type (With Sectors Combined in One Regression)

Section 5.2 analysis determines regression equations that predict demand for a given fuel on a sector by sector basis – ie, a separate regression equation was derived for each fuel type. The Section 5.3.1 analysis goes a step further by, for each given fuel type, deriving a regression equation that covers *all* sectors. For example, in the electricity demand regression equation there is one dummy variable for the industrial and another dummy variable for the residential-commercial sector. The dependent variable records either the electricity demand for the industrial sector or the electricity demand for the residential-commercial sector. Schematically we have:

| *Electricity Demand (PJ)* | *Industrial Sector* | *Res-Com Sector* | *Indonesian GDP** |
|---|---|---|---|
| *For Industrial Sector (1971)* | *1* | *0* | *32590* |
| *For Res-Com Sector (1971)* | *0* | *1* | *32590* |
| *For Industrial Sector (1972)* | *1* | *0* | *36859* |
| *For Res-Com Sector* | *0* | *1* | *36859* |
| . | . | . | . |

** Or some other explanatory variable, such as the sector energy price*

The rationale behind this model formulation is that demand for each sector-energy type combination is driven primarily by the overall growth in the Indonesian economy (or some other explanatory variable), with some distinctive adjustments for each sector.

**Table 5.3.1 Regression Results: Energy Demand (By Type) versus GDP, Price and Sector Dummy Variables, for Indonesia 1970-1998**

| Energy Demand | Regression Coefficients | | | | | |
|---|---|---|---|---|---|---|
| | GDP | Log GDP | Log Price | Industry | Res-Comm | Transport |
| Electricity | - | 22,460 | - | -96,961 | -96,430 | - |
| | - | (35.04)*** | - | (n.a) | (n.a) | - |
| Hydrocarbons | - | 12,184 | -0.3192 | -3.6020 | -3.4467 | -3.2761 |
| | - | (21.15)*** | (-5.39)*** | (n.a) | (n.a) | (n.a) |
| LPG | - | 30,319 | - | -14.6622 | -14.3447 | - |
| | - | (29.39)*** | - | (n.a) | (n.a) | - |
| Coal | - | 22,984 | - | -10.2554 | - | -11.6753 |
| | - | (3.59)** | - | (n.a) | - | (n.a) |
| Natural Gas | 0.0005 | - | - | 44.5950 | -45.3853 | - |
| | (4.77)*** | - | - | (n.a) | (n.a) | - |

*t ratios in brackets,*

***, p > 0.0001
**, p > 0.001
*, p > 0.01
*n.a = not applicable*

The results of the regression analysis of energy demand, explained by GDP, price and sector dummy variables are described by Table 5.3.1. Most of the energy demand (electricity, hydrocarbons, LPG and Coal) in this regression analysis were well explained by GDP or Log GDP and the respective sector dummy variables. Price was only a significant variable in explaining the level of demand for Hydrocarbons, where it had relatively low price elasticity.

### 5.3.2. Regression Analysis, by Sector (With Energy Types Combined in One Regression)

The section 5.3.2. analysis derives in turn a regression equation, for each sector, that combines all fuel types. For example, for the industrial sector we schematically have:

| *Industrial Sector Demand (PJ)* | *Electricity Dummy* | *Nat.gas Dummy* | *Industrial GDP** |
|---|---|---|---|
| *For Electricity (1972)* | *1* | *0* | *23245* |
| *For Natural Gas (1972)* | *0* | *1* | *23245* |
| *For Electricity (1973)* | *1* | *0* | *24566* |
| *For Natural Gas (1973)* | *0* | *1* | *24566* |
| . | . | . | . |
| . | . | . | . |

** Or some other explanatory variable, such as sector-fuel price*

The rationale behind this model formulation is that demand for each fuel type in a given sector is primarily driven by the GDP output (or some other explanatory variable) of that sector, with some adjustments for the fuel type in question.

**Table 5.3.2 Regression Results: Sectors versus Energy Demand (By Sector) versus GDP, Income Per Capita and Energy Type Dummy Variables, For Indonesia 1970-1998**

| Sector | Regression Coefficients | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | GDP Transport | Log GDP | Log Income/Capita | HC Price (Transport) | Electricity | Hydrocarbons | LPG | Coal | Natural Gas |
| Industry | - | 12,972 | - | - | -3.7625 | -2.8339 | -4.8733 | -4.0284 | -3.3619 |
| | - | (-25.93)*** | - | - | (n.a) | (n.a) | (n.a) | (n.a) | (n.a) |
| Transport | 0.0 40 | - | - | -23.4543 | - | 226,040 | - | -151. 63 | -121.296 |
| | (7.12)*** | - | - | (-3.04)** | - | (n.a) | - | (n.a) | (n.a) |
| Res-Comm | - | - | 16,114 | - | -6.5194 | -5.5249 | -7.3396 | - | -8.6836 |
| | - | - | (11.56)*** | - | (n.a) | (n.a) | (n.a) | - | (n.a) |

t ratios in brackets,

*** , $p > 0.0001$
** , $p > 0.001$
* , $p > 0.01$
n.a = not applicable

The results of the regression analysis of sectoral energy demand explained by GDP, price, income per capita and the energy type dummy variables are described by Table 5.3.1. The energy demand in industry (electricity, hydrocarbons, LPG and coal) in this regression analysis were well explained by GDP in Log GDP. The energy demand in transport (hydrocarbons, coal and natural gas) were significantly explained by GDP (Transport only) and hydrocarbon fuel price in transport sector. Unlike, the other two sectors, the demand for energy in residential-commercial sector (electricity, hydrocarbons, LPG and natural gas) was greatly influenced by log income per capita variable.

## 5.4 Regression Analysis, for Transport Sector, Using Other Explanatory Variables

The best regression model was found to be:

*Log Transport Fuel Demand = -3.9017– 0.5517 Log Transport Hydrocarbon Price + 0.9145 Log Numbers Cars Motor Cycles/Cap* (5.13)

$R^2 = 0.99$

*F ratio (for Model) = 27611.440 ($p < 0.0001$)*

*t ratio (for Log Hydrocarbons Price variable) = -6.41 ($p < 0.0001$); t ratio (for Log No. Cars-Motor/Cap variable) = 17.56 ($p < 0.0001$)*

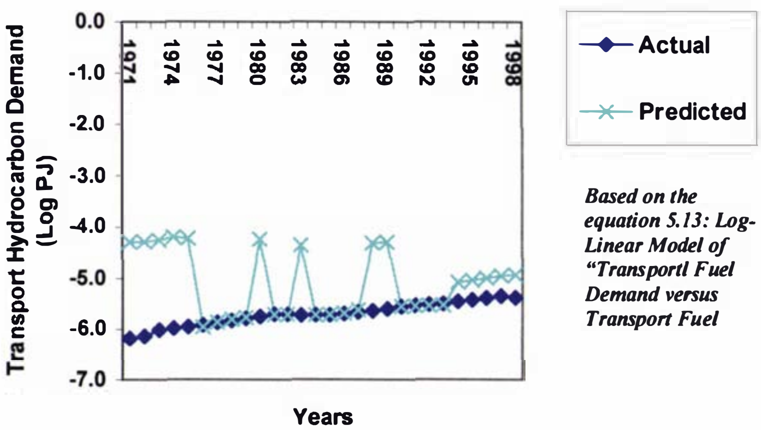
The independent variables considered for inclusion in this regression were:

- *Hydrocarbons Price in Transport Sector*
- *GDP Transport*
- *Number of Cars-Motors Total*
- *Number of Cars-Motors per Capita*
- *Number of passenger-cars*
- *Total Income*

This aspect of the study is limited only to the hydrocarbon demand in the transport sector. The purpose of this study is to find the answer to the questions "what will be the effect, if other variables (beside GDP and price) are included in the model?" and "what is the elasticity of these variables to the demand for hydrocarbons in the transport sector?" Several explanatory variables were applied to the multi-variable regression model to find their relationship to hydrocarbon demand in the transport sector. Basically, there were four approaches that were used to find the answers; 1) the dependent variable of transport hydrocarbon demand was regressed using the independent variables of hydrocarbon price, total income, number of passenger-cars and number of motorcycles; 2) the same as 1) but on a per capita basis; 3) the hydrocarbon demand was regressed using the independent variables; hydrocarbon price, total income and total number of vehicles (cars + motorcycles); and 4) similar to 3, but on a per capita basis. The regressions were done to both log and non-log models. The best fit model was obtained using the log-model, which produced an elasticity of hydrocarbon price of 0.55 and elasticity of total vehicles per capita of 0.9145 to the per capita demand for hydrocarbon in the transport sector (Equation 5.13). The best model produced $R^2 = 0.99$ as shown above.

The plot (Fig 5.13) of predicted versus actual data shows a number of 'spikes', where there is a significant difference between the actual and the predicted values. This is due to incomplete data on the total number of vehicles (data on cars and motorcycles were unavailable). As a result, the log coefficient for this variable in the model was underestimated.

From the regressions using the above four approaches, both total income and income per capita was found to be inelastic to hydrocarbon demand in the sector. Moreover, the first approach, which treated the number of passenger-cars and motorcycles as separate explanatory variables, did not produce a significant relationship to hydrocarbon demand in the transport sector. The plot of the actual values of hydrocarbons consumption versus the predicted values in the transport sector, using other explanatory variables, is shown in Figure 5.13 below.




*Based on the equation 5.13: Log-Linear Model of "Transportl Fuel Demand versus Transport Fuel*

**Figure 5.13 Actual versus Predicted Values for Transport Hydrocarbons Demand, for Indonesia, 1970 –1998**

## 5.5 Conclusion

This study concluded that GDP, as well as income per capita had a significant influence on the demand for energy in Indonesia and that, as a consequence, as GDP and income rise over time, they are likely to exert more than a proportional influence on energy consumption. The effect of fuel price rises, on the other hand, did not exert a significant influence on the demand for energy in the country. From the analyses conducted in this study no clear conclusion can be drawn on the 'price effects', especially when referenced to electricity, coal and natural gas. The effect of a fuel price rise, was significant only when the fuel had reached a saturation level in certain sectors, for example, hydrocarbons in the transport and residential sectors. In the long run, however, beside fuel prices changes, other factors like lifestyles changes and changes of a social or political nature may need to be explored as they may play a more important part. The country must start to research the effects of changes in the social and political environment on its energy demand trends and include these in policy analysis in the near future. These factors were not included in the analysis due to limited data available and lack of accuracy.

Although the results of some equations in this chapter are given in the log-function, when they are applied in the dynamic model, they are all converted into an anti-log function to produce the correct projection figures.

# CHAPTER SIX

# ENERGY DEMAND: TECHNOLOGICAL DETERMINANTS

This chapter focuses on the role that technology has historically played in determining both the patterns and level of energy demand in Indonesia, as well as how new technologies can play such a role in the future. This data and information provides a valuable input into the system dynamics model presented in Chapters 8 and 9.

Section 6.1 describes the application of the Divisia decomposition method which identifies the technical and structural components of changes in consumer (delivered) energy intensity in Indonesia, from 1971 to 1998. The Divisia decomposition method is a powerful method for isolating the technical efficiency improvements from any structural changes that effect the Energy:GDP ratio. The method can be applied at the national level or at the sectoral level depending on the availability of data. Essentially, the application of the method provides useful data on trends in energy efficiency which can then be fed into the system dynamics model (in Chapters 8 and 9).

Section 6.2 provides a broader discussion of the *current and new end-use technologies* used in converting consumer (delivered) energy to end-uses, and the potential they have for reducing energy demand. Accordingly, the *potential energy savings* for each sector, and delivered energy type within each sector, is identified using various literature sources.

## 6.1 Quantifying Changes in Indonesia's Technical Energy Efficiency, By Using Divisia Decomposition

### 6. 1.1 Previous Studies

The method employed in this section is an extension of the decomposition method developed by Ang and Choi (1997), which is decomposition with no residual term (residual free decomposition). The changes in energy intensity will be decomposed into structural and technical changes only and do not take into account the energy quality effect addressed by other authors such as Jollands and Lermit (2002). Traditional energy (combustible renewables and waste) will be included in the calculation of final energy consumption due to its relatively high share (more than 40 percent) of the current total energy input.

To date this type of analysis has not been conducted for Indonesia. The past energy intensity analyses carried out by the Ministry of Mines and Energy in Indonesia only dealt with the basic ratio of total primary energy equivalent (measured in barrels of oil equivalent) to GDP (measured in rupiahs, at certain prices). The intensity was then broken-down into sectoral energy intensity for more detailed analysis. The use of this simple Energy: GDP ratio for Indonesia was mainly due to the lack of disaggregation information on sectoral final energy consumption by energy types and sectoral industrial outputs (GDP) (BAKOREN, 1995).

The International Energy Agency (IEA) conducted a sectoral energy analysis for developing countries, which included Indonesia, in the Low to Middle Income East Asia category. It employed a relatively simple descriptive analysis of the Energy: GDP ratio which is defined as the ratio of TPES (Total Primary Energy Supply) to GDP at US$ 1987 prices and purchasing power parities (IEA, 1994). Goldenberg (1996), employing the same simple method of energy intensity analysis, also presented a study of energy intensity in developing countries, which included Indonesia. Recently, the Asia Pacific Energy Research Centre (APERC, 1998) started to study the energy intensity of APEC member countries, including Indonesia. This may employ more recent decomposition methods. The results of the IEA's Energy: GDP study (1994) for the industrial sector in Asian countries during 1971 to 1991 showed a declining trend for countries like Hong Kong, South Korea, Taiwan, Philippines, Thailand, and India over the study period. Indonesia's industrial energy intensity showed a slightly increasing trend during 1975 to 1986, but then declined after 1986. Interestingly, unlike the other Asian countries mentioned above, Singapore's industrial energy intensity showed an increasing pattern over the period, and a substantial increase between 1983 and 1985 was observed. This IEA study, however, provides a relatively poor basis for comparing intensity trends between the countries due to the simplicity of the IEA's Energy: GDP ratio method (IEA, 1994).

Some Energy: GDP case studies for other Asian countries have been carried out intensively using more advanced decomposition methods in the past 10 years. The more comprehensive decomposition (energy and environment) studies in Asian countries have so far involved only Singapore, Taiwan, China, South Korea, Thailand, India and Japan (Ang & Zhang, 2000). For example, the case studies by Ang and Choi (1997) for South Korean industry, which employs a refined Divisia index method; by Liu, Ang and Ong (1992) for Taiwan, which decomposes the change in energy consumption into four components, isolating the effect of interfuel substitution, by Ang (1995) for Singaporean industry, which applies multilevel decomposition of industrial energy consumption, by Liu, Ang and Ong (1992) for Singapore Industry, which uses the divisia index for the decomposition of changes, by Ang and Lee (1994) for Singaporean and Taiwanese industry, which applies two general parametric Divisia index methods and five specific decomposition methods, by Ang (1994) for Singaporean and Taiwanese industry, which deals with the decomposition technique using the energy intensity approach; by Chung and Rhee (2001) for Korean Industry, which employs a residual-free decomposition of the sources of carbon dioxide emissions and by Garbaccio and Ho (1999) for China, which decomposes overall changes in energy intensity into structural and technical change. The latest version of Divisia method by Ang (2005) discussing 'the LMDI approach' to decomposition analysis for energy policy analysis is also a very important approach that needs to be further researched for future development of the system dynamics energy model of Indonesia. However, most of the above case studies were carried out for the advancement of decomposition methods rather than for more comprehensive analyses of energy intensity and possible factors that affect energy efficiency in a country. The objectives of the case studies were to point out the strengths and weaknesses of each methods by comparing the results utilising the data of each country.

### 6.1.2 Methodology

The change in the Energy:GDP ratio in this study is decomposed into two components, technical effect and structural effect. The main reason for not taking into account the energy quality effect is the relatively small percentage of hydro energy in Indonesia's energy input mix (less than one per cent) and the small impact it has. Moreover, the role of hydro has not significantly developed during the last 10 years, and in 1995, was only about 0.7 % of the total energy input mix. Therefore there is no need for decomposing the intensity effect into technical and quality effect. The decomposition method applied in this study is described in the following diagram:

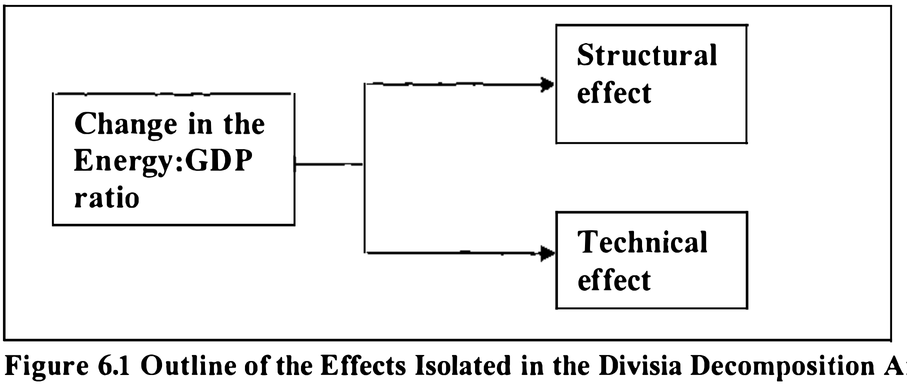



**Figure 6.1 Outline of the Effects Isolated in the Divisia Decomposition Analysis of Indonesia's Energy:GDP Ratio**

The method developed for this analysis is an extension of Ang and Choi's (1997) approach which proposes decomposition with no residual term. The decomposition technique is described as follows:

1) The economy is divided into a number of sectors *(j)*, which are taken as homogeneous. 2) The GDP and final energy consumption are measured for each sector for each year over the period of the study. 3) The types of energy consumed in each sector *(i)* are also used, as the energy mix may vary over time. The aim of the method used in this study is to decompose the effects of the Energy: GDP ratio into a structural effect and an intensity or technical effect for each individual sector.

Following are the definitions for each variable and the decomposition formulae for the two effects, technical and structural.

- $E$: Total enthalphic energy
- $E_{i,j}$ Energy use measured in joules for the $i^{th}$ energy type in sector $j$
- $Y$: Total Economic Output, in constant Rp. (1995 price)
- $Y_j$ : Value added or GDP from the sector $j$
- $y_j$ : Production share of the $j^{th}$ sector $(= Y_j/Y)$
- $I$ : Energy Intensity of the whole economy $(= E/Y)$
- $I_j$ : Enthalphic energy intensity of the $j^{th}$ sector $(= E_j/Y_j)$
- $w_{ij}$ : Energy share of the $i^{th}$ energy type in the $j^{th}$ sector $(= E_{ij}/E)$

All variables are continuous, but are typically observed only at certain points of time, and are usually aggregated annually. Let $t = 0$ and $t = \mathrm{T}$ be two such times, in which the change in energy use over this interval is measured. The above variables are intended to capture the two main factors affecting changes in the Energy: GDP ratio. These are:

- The *technical effect* – which reflects the contribution made by the changing energy efficiency of machinery through the replacement of old technology and the retrofitting of existing equipment. The technical effect also accounts for energy efficiency changes as a result of different levels of energy management.
- The *structural effect* – measures the changes in the Energy : GDP ratio due to the changes in the relative size of energy intensive sectors. For example, an increase in the proportion of GDP derived from an energy intensive sector would cause a positive sectoral mix effect.

The Energy: GDP Components can be described as follows:

The energy intensity of the whole economy can be broken down into individual sectors, weighted by the production share of each sector:

$$I = \frac{E}{Y} = \sum_j \frac{Y_j}{Y}\frac{E_j}{Y_j}$$

The energy used in each sector can be further broken down into individual energy types (electricity, gas, coal, oil, renewables, etc.).

$$E_j = \sum_i E_{ij}$$

We wish to calculate the changes in energy intensity due to :

- changes in technical intensity ( $I_{ij}$ )
- changes in economic structure ( $y_j$ )

First consider the rate of change of the logarithm of intensity. The reason for choosing the logarithm is that *d* ln *(I)* = *d I/I*, so that the derivative represents the *relative* change in the growth rate of intensity.

$$\frac{d\ln(I)}{dt} = \frac{1}{I}\frac{dI}{dt} \tag{6.1}$$

$$= \frac{1}{I}\frac{d}{dt}\sum_j \frac{Y_j}{Y}\frac{E_j}{Y_j} = \frac{1}{I}\frac{d}{dt}\sum_j I_j y_j \tag{6.2}$$

$$= \frac{1}{I}\left[\sum_j (y_j)\frac{dI_j}{dt} + \sum_j (I_{ij})\frac{dy_j}{dt}\right] \tag{6.3}$$

Remembering that the general rule of :

$$d(\ln y_j) = \frac{1}{y_j}\,d\,y_j$$

Now convert (6.3) back to log form

$$\frac{d\ln(I)}{dt} = \frac{1}{I}\left[\sum_j I_j \frac{y_j d(\ln y_j)}{dt} + \sum_j y_j \frac{I_j d(\ln I_j)}{dt}\right] \tag{6.4}$$

$$= \frac{1}{I}\left[\sum_j I_j y_j \frac{d(\ln y_j)}{dt} + \sum_j y_j I_j \frac{d(\ln I_j)}{dt}\right] \tag{6.5}$$

$$= \left[\sum_j \frac{I_j y_j}{I}\frac{d(\ln y_j)}{dt} + \sum_j \frac{y_j I_j}{I}\frac{d(\ln I_j)}{dt}\right] \tag{6.6}$$

$$= \sum_j \frac{I_j y_j}{I}\left[\frac{d(\ln y_j)}{dt} + \frac{d(\ln I_j)}{dt}\right] \tag{6.7}$$

Note that,

$$\frac{I_{ij} y_j}{I} = \frac{E_{ij}}{y_j}\frac{y_j}{Y} \Big/ \frac{E}{Y} = \frac{E_{ij}}{E} = w_{ij}$$

$$\frac{d\ln(I)}{dt} = \sum_j w_j \left[\frac{d\ln(I_j)}{dt} + \frac{d\ln(y_j)}{dt}\right] \tag{6.8}$$

Integrating (6.8) over time interval 0 to 1 →

$$(\ln I_T - \ln I_0) = \ln(I_T / I_0) = \int_0^T \sum_j (w_j) \frac{d\ln(I_j)}{dt} dt + \int_0^T \sum_j (w_j) \frac{d\ln(y_j)}{dt} dt \tag{6.9}$$

Expressing this in multiplicative form via exponentials,

$$
\begin{aligned}
D_{tot} &= D_{str} \times D_{tech} = e^{(\vartheta)} \times e^{(-)} \\
D_{tot} &= \exp\left[ \ln(\frac{I_T}{I_0}) \right] = \frac{I_T}{I_0} \\
D_{str} &= \exp\left[ \int_0^T \sum_j (w_j) \frac{d\ln(y_j)}{dt} dt \right] \\
D_{tech} &= \exp\left[ \int_0^T \sum_j (w_j) \frac{d\ln(I_j)}{dt} dt \right]
\end{aligned}
\tag{6.10}
$$

Deriving the weights,

$$
\begin{aligned}
D_{str} &= \exp\left[\sum_j w_j^{\bullet} \ln(y_{j,T}/y_{j,0})\right] \\
D_{tech} &= \exp\left[\sum_j w_j^{\bullet} \ln(I_{j,T}/I_{j,0})\right]
\end{aligned}
\tag{6.10a}
$$

Where $w_j^{\bullet}$ = undefined but $\sum_i w_i^{\bullet} = 1$, because $w_i^{\bullet}$ is a share of total energy

$\approx \frac{E_i}{E} \rightarrow \sum_i \frac{E_i}{E} = 1$

Thus $D_{tot} = \frac{I_T}{I_0} = \exp\left[ \ln \frac{(\sum_j y_{j,T} I_{j,T})}{\sum_j y_{j,0} I_{j,0}} \right]$ (6.10b)

And,

$$
D_{str} X D_{tech} = \exp\left[ \sum_j w_j^{\bullet} \ln\left( {}^{y_{j,T}}\!\!\big/_{y_{j,0}} \right) \right] X \exp\left[ \sum_j w_j^{\bullet} \ln\left( {}^{I_{j,T}}\!\!\big/_{I_{j,0}} \right) \right] \tag{6.10c}
$$

$$
D_{str} X D_{tech} = \exp\left[ \left[ \sum_j w_j^{\bullet} \ln\left( {}^{y_{j,T}}\!\!\big/_{y_{j,0}} \right) \right] + \left[ \sum_j w_j^{\bullet} \ln\left( {}^{I_{j,T}}\!\!\big/_{I_{j,0}} \right) \right] \right] \tag{6.11}
$$

$$
= \exp\left[ \sum_j w_j^{\bullet} \left[ \ln y_{j,T} - \ln y_{j,0} \right] + \left[ \ln I_{j,T} - \ln I_{j,0} \right] \right] \tag{6.12}
$$

$$= \exp\left[\sum_j w_j^* \left[\ln y_{j,T} + \ln I_{j,T}\right] - \left[\ln y_{j,0} + \ln I_{j,0}\right]\right] \quad (6.13)$$

$$= \exp\left[\sum_j w_j^* \ln \frac{y_{j,T} \cdot I_{j,T}}{y_{j,0} \cdot I_{j,0}}\right] \quad (6.14)$$

For zero residual, $D_{tot}$ must equal $D_{str} X D_{tech}$, taking logarithms, let $\Delta$ be the difference between them,

$$\Delta = D_{str} X D_{tech} - D_{tot} = 0$$

$$\Delta = \sum_j w_j^* \ln\left[\frac{y_{j,T} I_{j,T}}{y_{j,0} I_{j,0}}\right] - \ln\left[\frac{\sum_k y_{k,T} I_{k,T}}{\sum_k y_{k,0} I_{k,0}}\right] \quad (6.15)$$

Simplify terms and insert → $\sum_j w_j^* = 1$, k = sector

$$\Delta = \sum_j w_j^* \ln \frac{E_{j,T}}{E_{j,0}} - \sum_j w_j^* \ln \frac{\sum_k E_{k,T}}{\sum_k E_{k,0}} \quad (6.16)$$

Collect the terms (i.e. $w_j^*$ )

$$\Delta = \sum_j w_j^* \left[\left(\ln E_{j,T} - \ln E_{j,0}\right) - \left(\ln \sum_k E_{k,T} - \ln \sum_k E_{k,0}\right)\right] \quad (6.17)$$

$$= \sum_j w_j^* \left[\ln E_{j,T} - \ln \sum_k E_{k,T} - \ln E_{j,0} + \ln \sum_k E_{k,0}\right] \quad (6.18)$$

$$= \sum_j w_j^* \left[\ln\left(\frac{E_{j,T}}{\sum_k E_{k,T}}\right) - \ln\left(\frac{E_{j,0}}{\sum_k E_{k,0}}\right)\right] \quad (6.19)$$

and since $w_j = \frac{E_j}{\sum_j E_j}$

$$\Delta = \sum_j w_j^* \ln\left( {w_{j,T}}/{w_{j,0}} \right) \quad (6.20)$$

Now, a choice of weights needs to be made so that this expression equals zero.

Define the logarithmic mean:

$$L(x,y) = \frac{y - x}{\ln(y / x)} \tag{6.21}$$

So that,

$$L(w_{j,0}, w_{j,T}) = \frac{w_{j,T} - w_{j,0}}{\ln\left( w_{j,T} / w_{j,0} \right)} \tag{6.22}$$

And define the weight $\dot{w}_j$ as

$$\dot{w}_j = \frac{L(w_{j,0}, w_{j,T})}{\sum_k L(w_{k,0}, w_{k,T})}$$

$$\text{because} \quad \dot{w}_j = \frac{E_j}{\sum_j E_j} = \frac{\left( \frac{E_j}{\sum_j E_j} \right)}{\sum_j \left( \frac{E_j}{\sum_j E_j} \right)} = \frac{w_j}{\sum_j w_j} \tag{6.23}$$

Because $\dot{w}_j$ is an energy share, and equation (6.23) is the (logarithmic) average energy share.

Now substitute equation (6.23) into (6.20) and $\Delta$ the error term becomes;

$$\Delta = \sum_j \frac{L(w_{j,0}, w_{j,k})}{\sum_k L(w_{k,0}, w_{k,T})} \ln\left( w_{j,T} / w_{j,0} \right) \tag{6.24}$$

Substitute (6.22) into (6.24)

$$\Delta = \frac{\sum_j \dfrac{w_{j,T} - w_{j,0}}{\ln\left( w_{j,T} / w_{j,0} \right)} \ln\left( w_{j,T} / w_{j,0} \right)}{\sum_k L\left(w_{k,0}, w_{k,T}\right)}$$

$$= \frac{\sum_j w_{j,T} - w_{j,0}}{\sum_k L\left(w_{k,0}, w_{k,T}\right)} = 0$$

Since $\sum_j w_{j,T} = \sum_j w_{j,0} = 1$

The equations used for calculating technical and structural effects are given in equations 6.10a. ($D_{str}$ *and* $D_{tech}$).

### 6.1.3 Results: Description of Changes in the Energy:GDP Ratio, 1971-1998

The Energy: GDP ratio of Indonesia has declined since 1971 at an average rate of almost two percent annually (see Figure 6.2). Against this trend, there was an increase of approximately 6.2 percent in 1989 and, quite significantly, an increase of about 16 percent in 1998. The latter was caused by the Asian crisis that occurred in late 1997. Almost all economic sectors during the crisis declined with the average rate reaching -14 percent in 1998. The impact of the crisis is still being felt as the economy is growing slowly at the rate of only three to four percent, far below the last 20 years when it reached six to seven percent annually. However, current final energy consumption is growing at the rate of five percent for petroleum, and about 13 percent for electricity. For this reason, it is predicted that in the next four to five years, Indonesia's Energy: GDP trend will still follow the escalating trend as the result of the crisis.

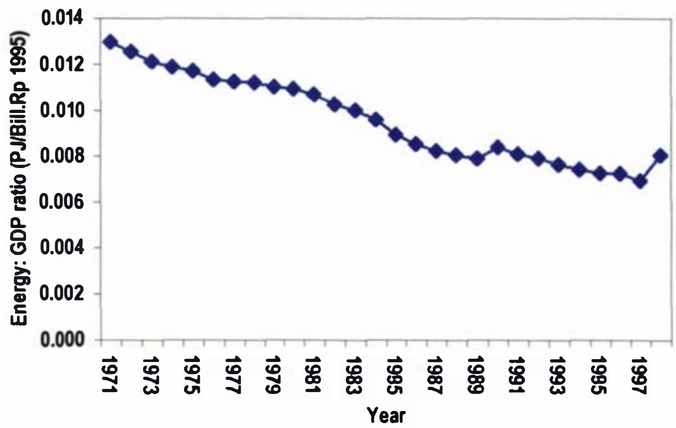



**Figure 6.2 Energy: GDP Ratio ( PJ/Billion Rupiah, 1995's** constant price) **for Indonesia, 1971-1998**

Figure 6.3 shows cumulative energy intensity (Energy: GDP ratio) from 1971 to 1998. The graph shows a significant decrease (about a 44.4 %) throughout the 1971/72 to 1997/1998 period. This is quite surprising and a significant improvement for a developing and oil exporting country like Indonesia. Structural change and efficiency improvements have both played a part in the declining energy intensity of the country.

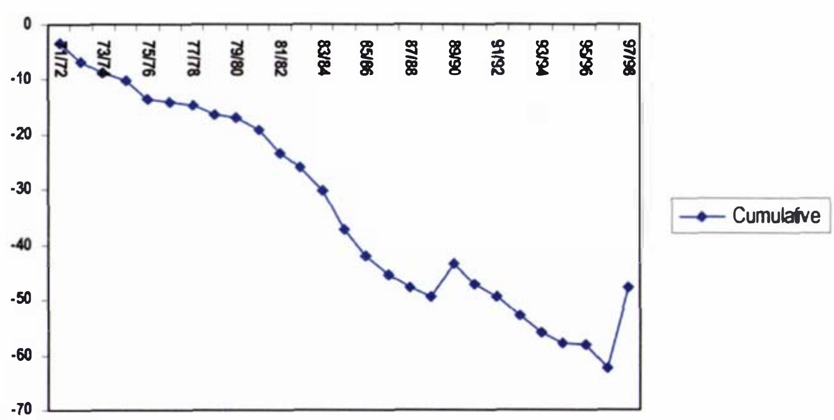



**Figure 6.3 Cumulative Decreases (%) in Indonesia's Energy: GDP Ratio, 1971-1998**

Analysis on a sectoral basis isolating both the structural and technical effects will be required to fully understand the reasons for the improved efficiency. The next section will describe the result and the analysis of the decomposition of the Energy: GDP ratio into two of its components; structural and technical effects.

### 6.1.4 Results: Structural Changes, 1971 - 1998

Figure 6.4. clearly shows that structural effects have become a less important factor in the intensity improvement in Indonesia since 1971/72. Its positive influence has steadily decreased and in 1997/98 it had a negative impact. However, the smooth trend looks suspicious and was probably due to inaccurate historical data used by IEA on combustible renewable and waste energy consumed in the residential sector, (IEA, 2000).

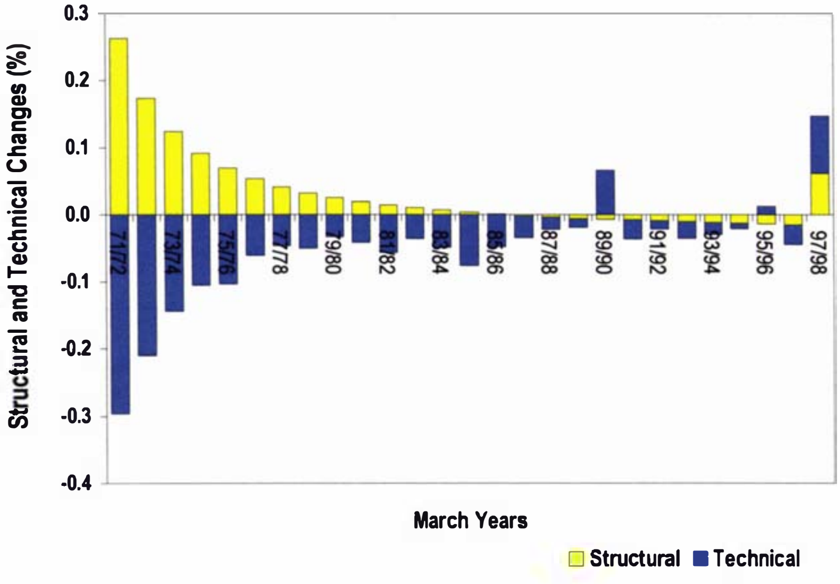



**Figure 6.4 Structural and Technical Changes (%), in Indonesia's Energy: GDP Ratio, 1971-1998**

Out of the economic sectors considered, the residential sector contributed significantly to the negative contribution of the structural changes in energy intensity in Indonesia. Figure 6.5. shows the continuous drop in the residential sector's contribution to structural efficiency and how it swamps changes in all the other sections. This shows that the residential sector is getting more inefficient and more consumptive in consuming energy.

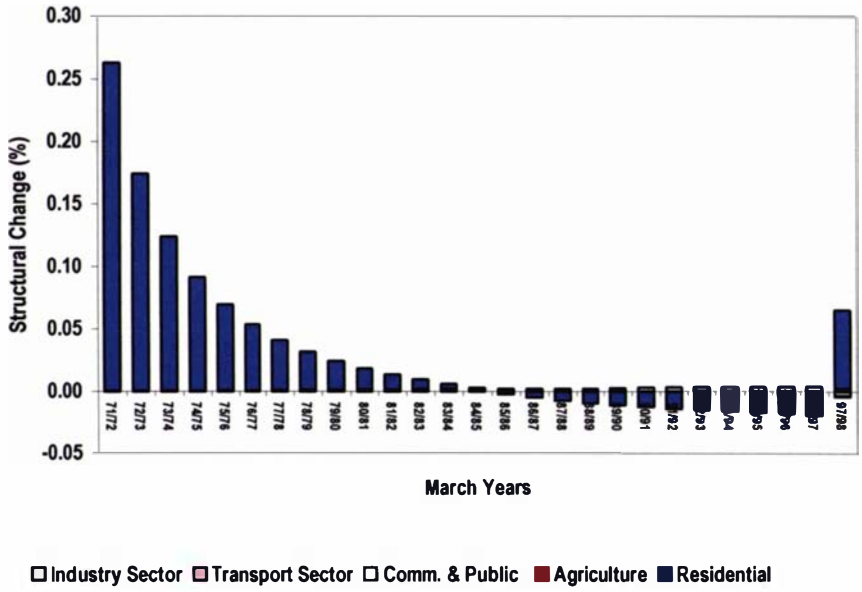



**Figure 6.5 Structural Changes (%) in Indonesia's Energy: GDP Ratio, 1971-1998 (including the residential sector)**

To enable a more accurate analysis of the behaviour of other sectors, the residential sector is excluded in Figure 6.6. In this way, structural changes the other sectors can be seen more clearly.

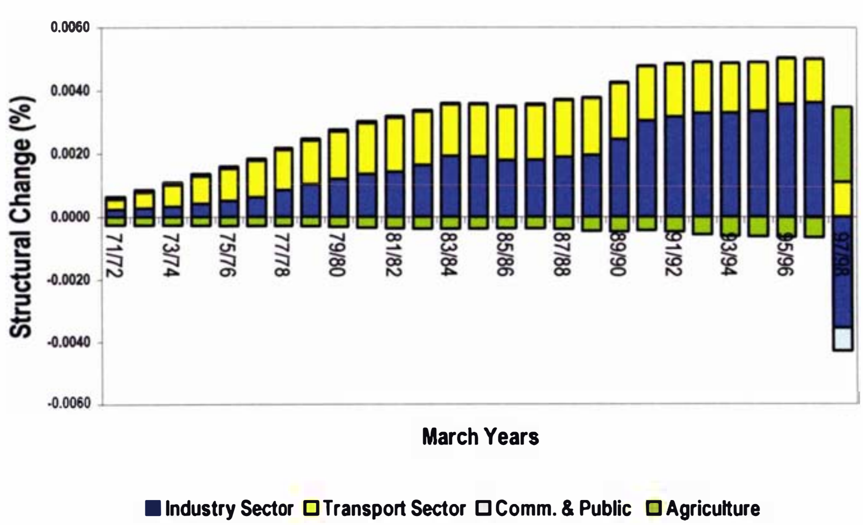



**Figure 6.6 Structural Changes (%) in Indonesia's Energy: GDP Ratio, 1971 – 1998 (excluding the residential sector)**

Structural changes in both the industrial and transport sectors though very slightly accounted for the decrease in the Energy:GDP ratio and these changes tended to escalate over the period 1971/72 to 1996/97 (see Figure 6.6). This was probably due to the shift of the industrial structure from less efficient or old industries toward more energy efficient modern industries. For example, new technology and machinery replaced old machinery in the sugar industry. In the last 10 years, many newly built industries have began operation in Indonesia using new and more efficient equipment and machinery imported from developed countries. In 1997/98, during the Asian crisis, the industrial and commercial sectors had a negative impact on the improvement of aggregated energy intensity, whereas the agriculture and transport sectors, had positive effects. Over the period 1971/72 to 1996/97, the agriculture sector, steadily made a negative contribution (though not very significant) to the improvement in overall energy intensity in the country. In 1997/98 during the Asian crisis, this sector had a significant positive effect on the overall intensity improvement, which offset the decline in the Energy:GDP ratio in the industrial sector.

### 6.1.5 Results: Technical Efficiency Changes by Sector, 1971-98

In contrast, the technical effect contribution to intensity improvement increased quite dramatically from 1971/72 to 1980/1981. After 1981/82 it started to have a negative contribution, but increased again in 1985/86 and even significantly increased its contribution in 1989/90 and 1997/98. The main reasons for the declines between 1981/82 and 1985/86 were the escalating use of non-productive electric appliances, such as televisions and radios in the residential sector, and the increased use of imported goods and machinery in the industrial sector. Moreover, the figure shows clearly that the economic crisis of 1997/98 had a positive impact on technical efficiency, as the contribution of technical efficiency escalated, increasing about 12 percent in only a year (1997 to 1998). More discussion on the causes of the negative trend of the technical effect for each sector will be discussed later.

Between 1971/72 and 1980/81, technical change in the residential sector explained most of the decrease in the Energy: GDP ratio. However, from 1981/82 to 1985/86, the opposite effect was recorded, but the positive effect continued again from 1985/86 until 1989/90 (see Fig. 6.7). In 1996/97, a year before the crisis, it even accounted for most of the decrease in the energy: GDP ratio. The technical change in the industrial sector, on the other hand, provided a more erratic pattern as shown in Figure 6.7. In 1976 to 1978 it produced a positive effects but in 1985/86 it gave negative effect, whereas in 1989/90 the effect was positive, significantly decreasing the energy:GDP ratio by more than five percent compared to the previous year. In 1997/78, during the crisis, the positive effect of the technical change in the industrial sector was again recorded. During the crisis in 1997/98, the technical effects in the three sectors, industrial, residential and transport, have almost equally shared the responsibility for the decrease in the energy:GDP ratio.

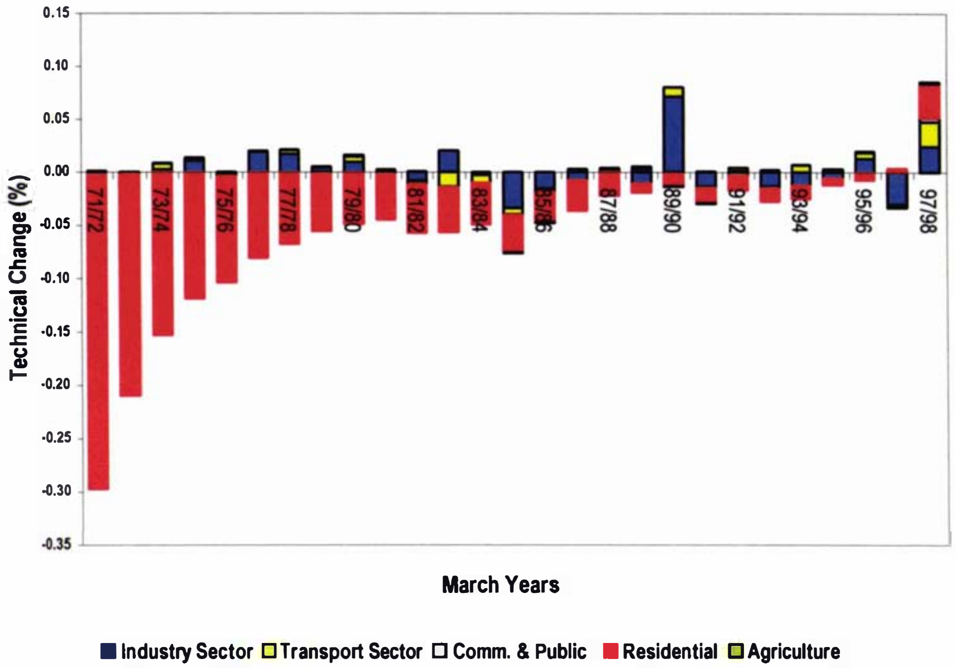
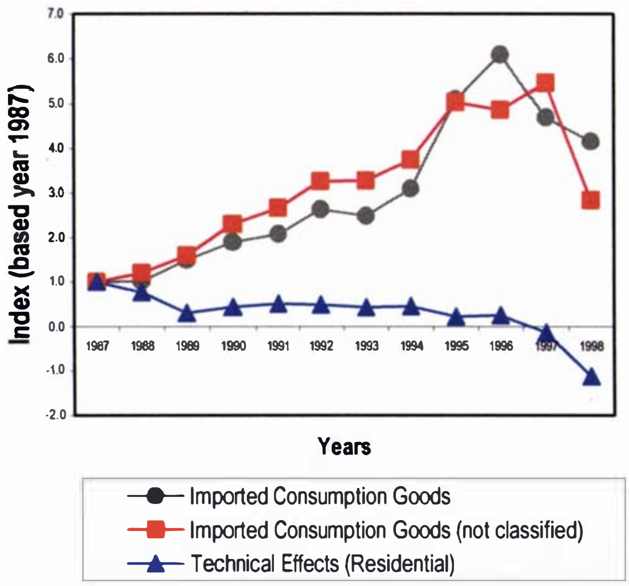



**Figure 6.7 Technical Changes (%), by Sector, in Indonesia's Energy: GDP Ratio, 1971-1998**

### 6.1.5.1 Residential Sector

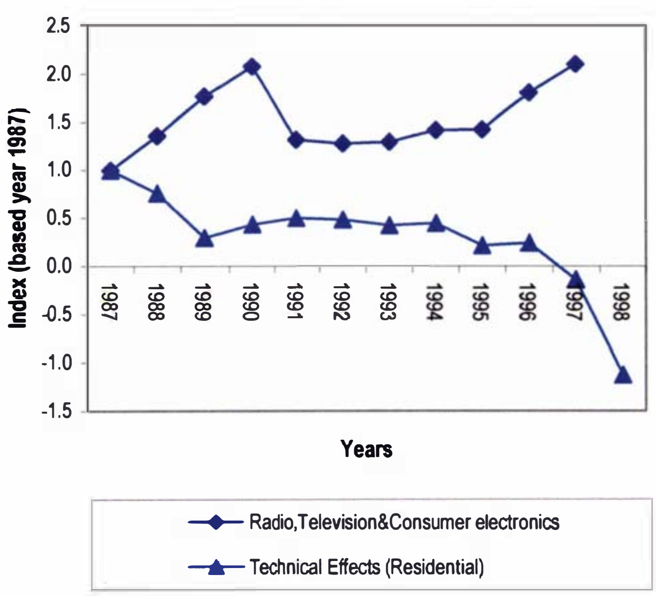
In order to understand what caused the technical changes that occurred in the residential sector, the percentage change in the technical effects was correlated with imported goods (consumption goods), as shown in Figure 6.8. The correlation shows negative correlation between imported consumption goods as well as non-classified imported goods and technical changes. More specifically, Figure 6.9 also shows the negative correlation between the technical changes and the demand for radios, televisions and other consumer electronics in the residential sector. The correlations show that as more goods imported and more electronic appliances used in the residential sector, the index of technical change declined (or efficiency increased) compared to the base year 1987. New and more efficient imported electronic appliance technologies may have contributed to improvements in the technical change index in the sector.




Correlations:
(1) Negative correlation between imported consumption goods and technical effect

(2) Negative correlation between imported consumption goods (not classified) and technical effect

**Figure 6.8 Correlation between Imported Goods and the Technical Change Effect in the Residential Sector, 1987-1998**

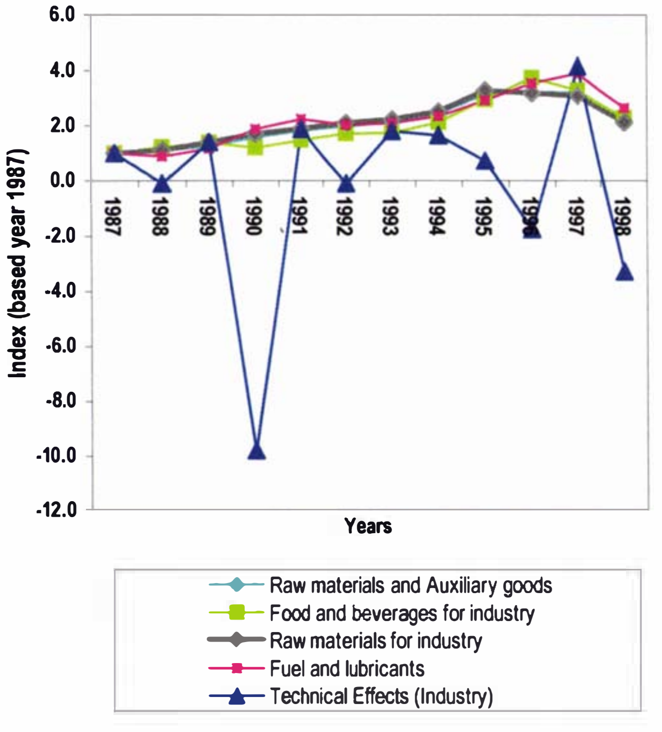



Correlation:
Negative correlation between "demand for radio, television & consumer electronics" and technical effects

**Figure 6.9 Correlation between Demand for Consumer Electronic Goods and the Technical Change Effects in the Residential Sector, 1987 - 1998**

#### 6.1.5.2 Industrial Sector

The correlations between technical effects in industrial sector and the imported goods for industry (raw materials & auxiliary goods, food and beverages and fuel and lubricants) were also plotted, as shown in Figures 6.10 and 6.11. Unlike the residential sector, the correlations between the technical effects and the number of imported goods (raw materials, fuel and lubricants, etc) for industrial purposes were negatively weak, though the patterns were quite similar. The total technical effects tended to decrease (become more efficient) with the increasing amount of imported transport equipment for industry. This indicated that the technical efficiency of imported transport equipment for industry was increasing per year during the period. Overal number of imported goods showed a poor correlation with the technical change effects in the sector.




Correlations:

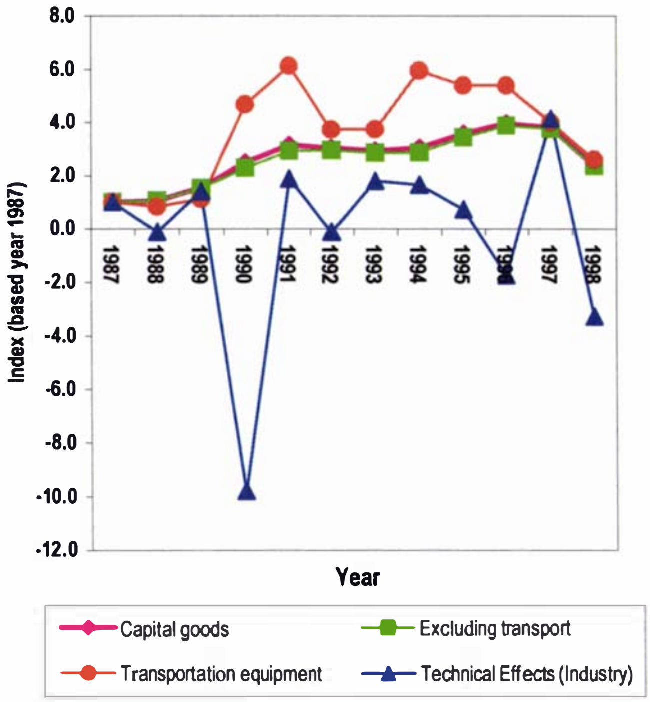
(1) Weak negative correlation between "imported raw materials" and technical effect

(2) Weak negative correlation between "imported raw materials" and technical effect

(3) Weak negative correlation between "imported food & beverages" and technical effect

(4) Weak negative correlation between "imported fuel & lubricants" and technical effect

**Figure 6.10 Correlation between Imported Goods and the Technical Change Effects in Industrial Sector, 1987 - 1998**

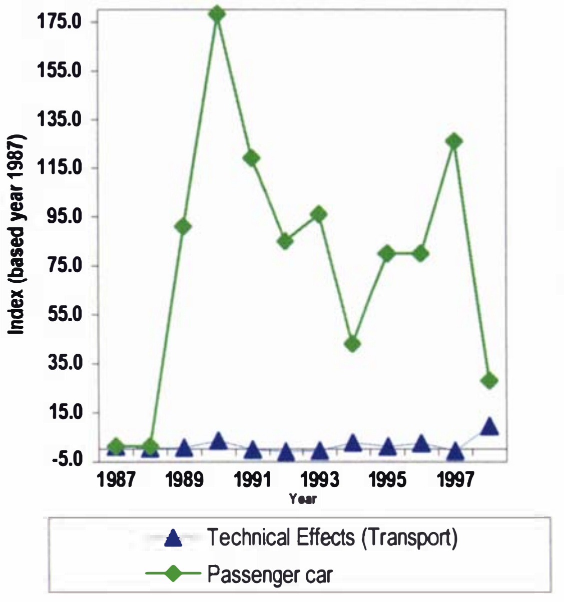



Correlation:
No correlation between "capital goods, transportation equipment and excluding transport equipments" and technical effects

**Figure 6.11 Correlation between Imported Goods and the Technical Effects in Industrial Sector, 1987 - 1998**

### 6.1.5.3 Transport Sector

The correlation between technical effects and the number of imported passenger cars is given in Figure 6.12 below. There is no correlation between the variables investigated. Although the number of imported passenger cars fluctuated significantly over the period, the technical effect of the transport sector was almost constant throughout the period. The technical effects of this sector did not greatly influence the overall technical effects, and produced an irregular pattern over the period. During the Asian crisis (1997/98), there was a positive effect resulting in an almost 15 percent decrease in the Energy: GDP ratio.




Correlation:
No correlation between "imported passenger cars" and technical effects

**Figure 6. 12 Correlation between Imported Passenger Cars and the Technical Effects in Transport Sector, 1987 – 1998**

There are no linkages between the technical effects over the period 1987/88 and 1994/95 and the state budget allocated for transport during the period (as a proportion to the total state budget) as can be seen in Figure 6.13. In 1988/89, the state budget for transport was increased to approximately 19 percent of the 1987/88's level and stay almost constant until 1994/95 (Kim and Knaap, 1992). However, technical effect patterns of the transport sector did not followed the same trend. The technical changes of the sector (transport) stay almost constant up to 1994/95. Most of the state budget for transport was used for the development of transport infrastructure (road development). This implied that road development does not influence Energy:GDP ratio of the transport sector.

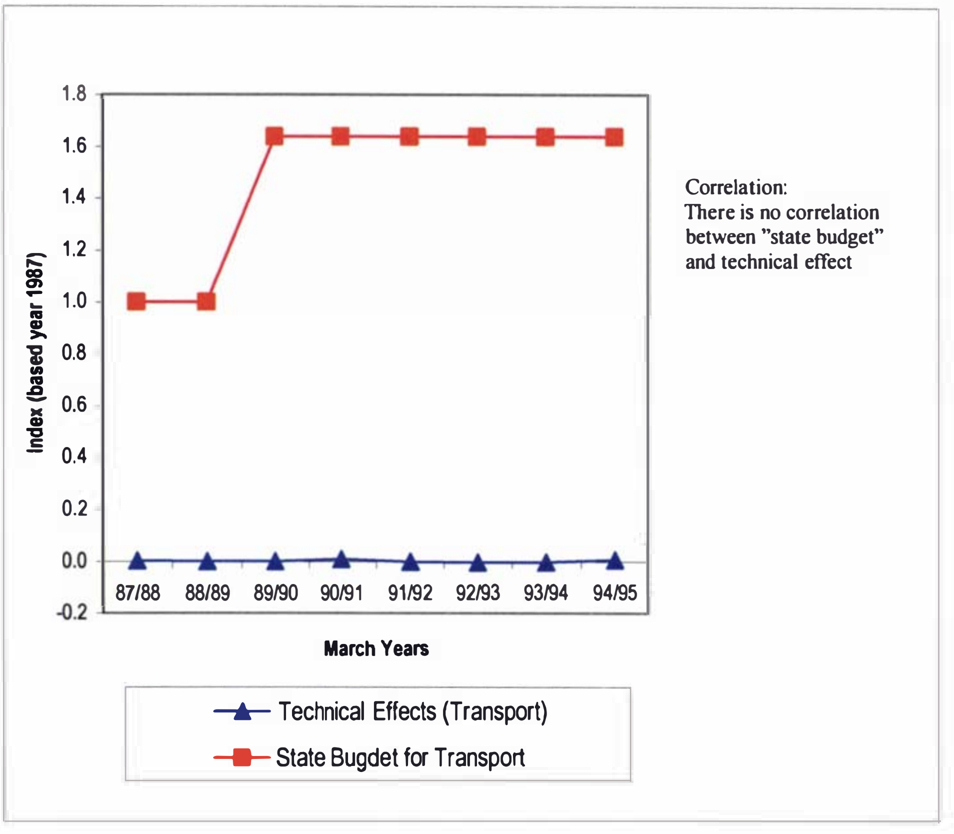



**Figure 6.13 Correlation between State Budget for Transport Sector and Technical Effect for Transport, 1971-1998.**

## 6.2 End-Use Energy Technologies and Their Penetration Rates

This section will discuss the current status of new energy technologies and the average technical efficiencies of the demand sectors, namely the household-commercial sector, the industrial or manufacturing sector, and the transport sectors.

### 6.2.1 Current and New End-Use Energy Technologies

Because of the limited of data available, the discussion in this section will focus on the international current status of new end-use energy technologies rather than Indonesia's. However, when reviewing the potential sectoral efficiency gains, consideration of the current status of potential energy savings in Indonesia will be integrated into the analysis.

**Current Status of Household-Commercial Energy Technologies**

The status of demand side energy technologies in the household-commercial sector was summarized by the office of Technological Assessment in 1997 (OTA, 1997). The status of building energy management and control systems are mostly commercial, and some technologies are improved. These management and control system technologies offer the greatest potential for savings in the commercial sector and improvements in these technologies are continuing. Technology developed to improve lighting technologies is currently either commercial, nearly commercial or still in research and development phase. Research and development is progressing to improve phosphors. Various combinations of lighting technical options can cut energy consumption significantly. More efficient fluorescents, compact fluorescent lamps, and electronic ballasts are already available in the market place. Refrigerator insulation also provides great potential for appliance efficiency improvements. Potential products incorporating more efficient technology according to OTA (1997) include vacuum insulation, compact vacuum insulation and soft vacuum insulation, but these are still in the research and development stage.

**Current Status of Industrial/Manufacturing Energy Technologies**

Followings are some important energy saving technologies in this sector identified by the Office of Technology Assessment (OTA, 1997). Improved electric motor technology is already commercial. The adjustable-speed drive and new high-efficiency motors account for approximately 50 percent of the total potential savings in the industrial/manufacturing sector. The advanced turbine STIG (Steam Injected Gas Turbine) is already available in the market, but some refinements are not yet fully commercial. However, the inter-cooling STIG (better suited for utility applications), which has the potential to increase efficiency by about 50% percent is nearly commercial or at the pilot plant stage. The industrial computer control and sensors, which can improve monitoring and control optimised conversion and the distribution of energy, are either commercially available or close to this point. The potential savings from such computer control technology can range from 5 to 20 percent. The status of technology of to improve catalytic reaction, which reduces heating and compression requirements, is grouped into three categories; commercial, nearly commercial and research project stages. The technological status of improved separation technology is also either commercial, nearly commercial or still at the research stage.

**Current Status of Transportation Energy Technologies**

The current status of new developments in demand side energy technologies for the transportation sector according to OTA (1997) are as follows. In new car technology, the use of ultra-high bypass engines can increase efficiency by about 20 percent but the costs are twice that of current generation bypass engines. Direct injection or adiabatic diesels are already at the commercial stage, with some still at the research and development stages. In Europe, a limited number of passenger cars already use this technology. It offers significant efficiency improvements for both light-duty vehicles and heavy trucks. However, questions remain on meeting more stringent emission standards. The status of 2-stroke engine technology is still at the research and development stage. The technology is promising for the long term. However, the ability of the engine to comply with emission standards is still being questioned. The status of alternative fuels such as alcohol fuels are that some already commercial, some are nearly commercial, but some are still at the research and development stages. The use of methanol and ethanol can result in greater engine-efficiency. However, the costs of the fuel are higher. Electric transportation is still at the research and development stage, but it offers a big greenhouse advantage if the electricity used is derived from nuclear or solar energy.

### 6.2.2 Potential of Savings from New Technologies and Improved Practice

**Overall Situation**

Energy saving potential refers to the possible savings that can be realised from conducting energy saving measures or activities, either from retrofitting, housekeeping (maintenance) or from investment in more energy efficient equipment or appliances.

According to a study conducted by the Ministry of Mines and Energy and the Energy Conservation Consulting Company (PT. KONEBA) over the period 1985 to 1995. There are a number of potential energy savings (percent of energy saving from the total consumption) in the household-commercial, industry and transportation sectors (MME, 1995). The industrial sector offers the largest saving potential, 15 to 30 percent annually, followed by the household and commercial sectors, 10 to 30 percent annually. The potential saving in the transportation sector is about 10 to 25 percent annually. The potential savings of industrial sector were calculated by comparing the efficiency of the existing equipments and processes in hundreds of energy intensive industries (e.g. textiles, cement, steel, pulp and paper, sugar industries) with the best available energy efficient technologies and processes in 1995. The savings were assumed to be achieved with and without investment. The calculation of potential savings in the other sectors (household-commercial and transport) also employed similar method. The calculation of the household-commercial sector potential savings included private sector buildings/offices, hospitals and hotels, while estimates for the transport sector included public and private buses, freight transport as well as passenger cars though excluded sea transport.

**Table 6.1. Average Potential of Savings in The Demand Sectors in Indonesia**

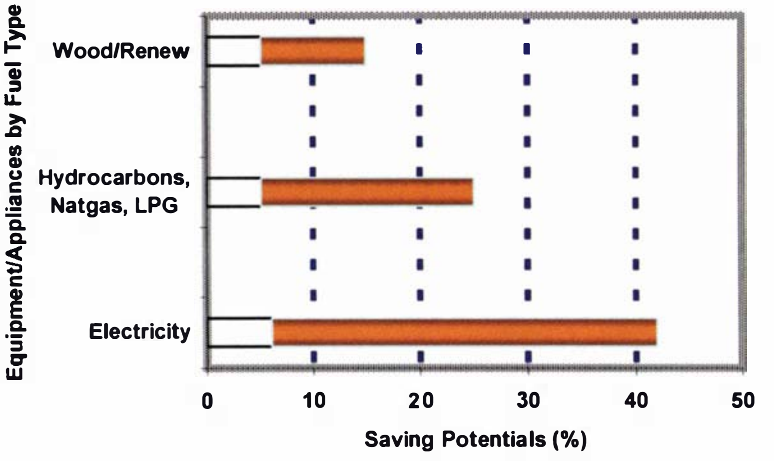
| Sector | Potential Savings (%) |
|---|---|
| *Household-Commercial* | *10 – 30 %* |
| *Industrial/Manufacturing* | *15 – 30 %* |
| *Transportation* | *10 – 25 %* |
| ***Total*** | *10 – 30 %* |

Source: Ministry of Mines and Energy (1995)

It is difficult to estimate the potential savings of an energy consuming sector in Indonesia especially based on the type of fuel used, due to lack of data. Estimates for each sector discussed in the following sections are based on data on Indonesian experiences obtained from PT. KONEBA, the Energy Conservation Consulting Company (Ministry of Mines and Energy, 1995), information from the OTA (1997) and surveys conducted by the Working Group on the IPCC (1995). The estimates are expressed as percentage scope for improvement from the base year of 1995. The calculated potential saving by fuel type for each sector are used later in the modeling.

**Household and Commercial Sectors**

Figure 6.14 shows the potential energy savings by fuel type that can be obtained from equipment and appliances, that are used in the household and commercial sectors. For example, using wood or renewable energy as fuels, the saving potentials range between 5 to 15 percent; for hydrocarbons, natural gas and LPG, the potential savings are between 5 to 25 percent; whereas for appliances that use electricity, the potential of savings range between 5 to 42 percent.

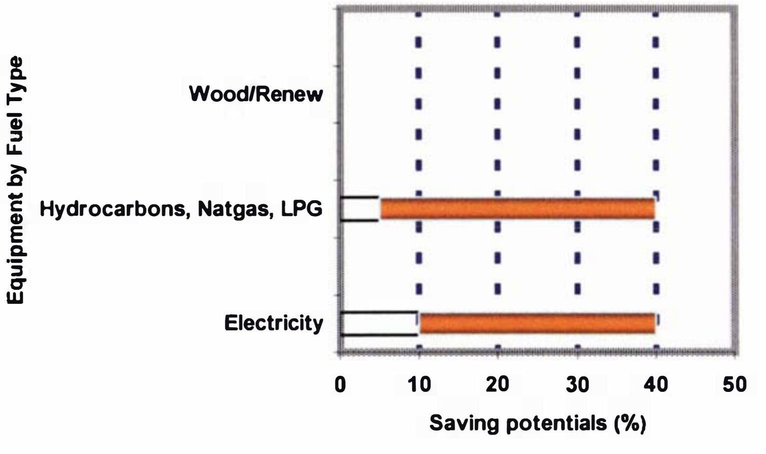



*Source: OTA (1997), EWG-IPCC (1995) and MME (1995)*

**Figure 6.14 Potential Energy Savings in the Household-Commercial Sector (percentage), from a base year of 1995 by fuel types.**

### Industrial/Manufacturing Sectors

The industrial potential for savings of hydrocarbons, natural gas and LPG are around 5 to 40 percent per year, while the electricity potential for savings ranges between 10 to 40 percent annually (see Figure 6.15).

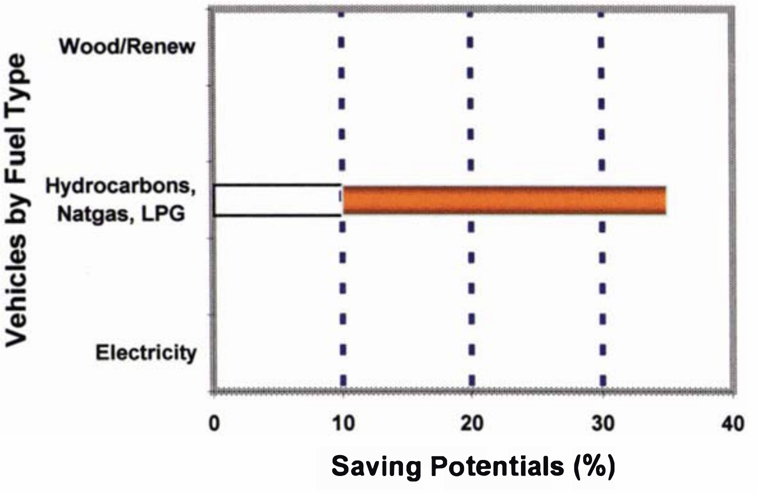



Source: OTA (1997), EWG-IPCC (1995) and MME (1995)

**Figure 6.15 Percentage Potential of Savings in Industry/Manufacturing Sectors, in Indonesia, from a base year of 1995**

**Transportation Sector**

For hydrocarbons, natural gas and LPG fuels, the potential savings are estimated at about 10 percent (minimum) and about 35 percent (maximum) of the total fuel consumed in this sector annually.




Source: OTA (1997), EWG-IPCC (1995) and MME (1995)

**Figure 6.16 Potential Energy Savings in the Transport Sector, from a base year of 1995**

### 6.2.3 Penetration Rates of End-Use Energy Technologies in Indonesia

The penetration rates of innovative end-use energy technologies in Indonesia are greatly affected not only by technology advances (domestic or international) but also by government policies, especially fiscal and non-fiscal energy conservation policies. An energy conservation policy started was introduced following the Energy Conservation Symposium held in 1979. The government realised that energy saving implementation and technological penetrations would depend on energy efficiency regulations and measures. It took almost three years after the symposium for the government to enact a new regulation to encourage energy conservation implementation. In 1982, Presidential Instruction No. 9/1982 was issued. This Decree stipulates the need for conducting energy conservation implementation in state-owned buildings and vehicles. This was aimed at setting an example to the public and increasing energy conservation awareness so that the market penetration of energy efficient technologies would increase. However, the implementation of this decree was unsuccessful due to complicated reporting procedures (bottom up and cumulative reporting) from the lowest government echelon to the highest echelon.

Realising that the up take of energy conservation technologies, especially in the industrial and commercial sectors, would require technical skill knowledge of energy efficiency techniques and management, the government established an energy conservation consulting company. In 1987, the first state-owned energy conservation company PT KONEBA (Energy Conservation Consulting Company) was established. Its tasks cover the promotion, training, consultancy, and services to assist the implementation of the energy conservation program. However, only a few industries and commercial building owners used PT KONEBA due to lack of interest concerning efficiency implementation and insufficient financial incentives, with the relatively cheap price of energy (oil, gas, coal, and electricity).

Efforts have been made to encourage the penetration of energy conservation technologies in the industrial and commercial sectors, with the introduction of incentive packages (share savings, free preliminary audits, free tax on imported energy-efficient appliances, loan etc.), but to no avail. Some effort was also made to make energy conservation implementation, compulsory in the Ministry of Mines and Energy owned buildings and facilities. In 1993, the government issued Ministerial Decree No. 43/1993, regarding energy conservation implementation in the mining and energy sector. The decree required that all state owned companies under the Ministry of Mines and Energy implement energy saving measures utilising the services of PT KONEBA (Persero) through energy auditing and energy saving actions. This policy also did not work well. In 1990, the National Energy Conservation Team was established by the Minister of Mines and Energy (Ministerial Decree No. 0604K/702/MPE/1990, to promote the implementation of the National Energy Conservation Program. The team established national energy efficiency awareness programs, including public campaigns (television, radio, newspapers, bill-boards, leaflets, booklets etc.), efficiency competitions, and award programs. In 1991, the government issued another decree to promote energy conservation implementation by energy users and the energy consuming sectors through Presidential Instruction No. 43/1991. The implementation of the decree was not satisfactory, probably because it was not a mandatory action and did not include comprehensive guidelines.

Another government effort was launched in 1992, in considering that energy conservation is a vital element in reducing the rapidly increasing domestic energy demand, the President of Indonesia appealed for more efficient and wise use of energy. On this occasion he also introduced The "Public Awareness and Action on Energy Conservation" program (BAKOREN, 1995). Following the President's appeal for more efficient use of energy, energy conservation became a national concern and on the national agenda. An energy conservation program was included (stated explicitly) in the 1993 State Guidelines. The

State Guidelines stipulated the national target for energy saving in 1999 and 2000 as 15 percent and 17 percent, respectively. In 1994, a Master Plan of National Energy Conservation was formulated and was used as the guideline for government institutions, state-owned companies, and the private sector for a implementing energy conservation. The Master Plan also included efficiency targets and guidelines for implementing energy efficiency measures in their respective institutions (BAKOREN, 1995). By issuing the national targets, the government hoped that more energy efficient technologies would be implemented.

Energy pricing policy, especially that which has been recently enacted in the country with the removal of hydrocarbon and electricity subsidies, is expected to increase the penetration of end-use energy efficiency technologies in all energy demand sectors. The market penetration of more efficient appliance technology and more efficient vehicles/passenger cars is expected to grow with higher prices for electricity and hydrocarbons. However, the price of many energy efficient appliances is still high, for instance, the price of efficient fluorescent lamps can be three times as high as incandescent lamps. Many other efficient electrical appliances, like energy efficient refrigerators are still expensive and less than 10 percent of urban households can afford to buy them. Incentives measures, for instance, tax exemptions for energy efficient products would be useful to curb imported inefficient electrical appliances or vehicles. In the transport sector, progressive taxes based on age have been implemented to reduce the number of old inefficient road vehicles (passenger cars) and increase the use of more efficient cars.

In the commercial building sector, the absence of building codes has hampered the market penetration of energy efficient appliances/equipment/materials. However, many commercial buildings like hotels and commercial offices in Jakarta and other big cities in the country have installed more energy efficient lighting and air conditioning systems, and opted for more energy efficient building designs. The government has carried out free energy audits in several commercial building/offices including hotels to promote energy efficiency implementation in the commercial sector. In a similar effort to promote energy efficiency implementation, free preliminary energy audits have been carried out in several energy intensive industries, like sugar, textiles and cement factories.

Another way to increase the market penetration of energy efficient equipments/appliances is by enforcing mandatory energy labelling and standards/certification programs. This has been started with government to government cooperation between the Indonesian government and the Dutch government outlining voluntary labelling and standards programs for lighting and refrigerators. This effort will gradually move to mandatory labelling/standards/certification programs for energy efficient products and appliances. If the government wants to further encourage market penetration of energy efficient products or appliances, an environmentally benign policy objective must also be promoted. More efficient energy appliances/equipment will reduce energy consumption, and pollutant emissions such as $CO_2$ which cause global warming and other environmental problems. The introduction of carbon taxes could be initiated with the long-term target of promoting market penetration of energy efficient appliances.

## 6.3 Conclusion

The analysis of Indonesia's Energy:GDP ratio showed a quite significant decrease (about a 44 percent) throughout the 1971/72 to 1998/1999 period. The Divisia decomposition demonstrated that of the two types of changes the *technical* change gives a greater contribution to energy efficiency improvements in Indonesia, than structural change. Structural changes especially in the residential sector contribute negatively to the Energy:GDP ratio of the country. The industrial and transport sectors, made a small positive contribution, offsetting the negative effect of residential structural change.

Further analysis of technical change, revealed that technical change in the residential sector seems to play an important role in the improvement of energy efficiency compared to the other sectors transportation and industry. More efficient electrical appliances have contributed significantly to efficiency improvement in the residential sector. In addition transport equipment used by industry has moderately, contributed to improvements in technical efficiency in the industrial sector. In the transportation sector, no technical efficiency improvements were observed. The increasing number of new imported cars and vehicles, during the period, did not bring a positive impact to efficiency improvements in the transport sector.

There are potential energy saving that can be made in the household/commercial, industrial manufacturing and transport sectors. The government of Indonesia has made efforts to implement energy conservation policy in almost all energy consuming sectors. It has encouraged the penetration of energy conservation technologies through several measures including awareness campaigns and information, training, regulation, incentive packages, standards and labelling. However, so far the efforts have not given satisfactory results.

# CHAPTER SEVEN

# ENERGY SUPPLY: TECHNOLOGICAL, ECONOMIC AND POLICY DETERMINANTS

This chapter discusses the dynamics and determinants of energy supply. It is important to understand this for several reasons; *first,* by understanding the determinants of energy supply, one will be better able to foresee what the likely future pattern of energy supply mix will be in Indonesia and identify the types of energy that may dominate the future domestic energy supply mix. *Second,* knowledge of the energy supply dynamics and determinants will enable the evaluation of certain government policy impacts on the energy supply patterns and allow appropriate policy responses. *Third,* information on the determinants of energy supply can help taylor the future supply pattern to meet the social, environmental and economic policy objectives. This chapter addresses three important determinants of energy supply; the impact of government policy on energy supply patterns; the status of technology and its influence on energy supply patterns; and the effect of economic factors on energy supply patterns.

## 7.1 Impact of Government Policy on Energy Supply Patterns

The first determinant considered an important influence on energy supply patterns is government policy. This is regarded as a critical element of the supply patterns because government actions have been shown to have a significant impact on the country's energy availability. Inappropriate energy policies can cause problems for the domestic energy supply mix and security. This section will briefly discuss examples of government policies that have impacts on energy supply patterns.

*First,* it can be argued that the problem of electricity supply in some regions was mainly caused by ineffective policy interventions in the electricity sector. For example, many households in some regions have not been able to have electricity installed because of conflicting policy directions. The capability of PLN to respond to increasing demand in remote or rural areas has been hampered by some inappropriate policies in the electricity sector. Government still requires PLN to carry out social objectives (eg, rural electrification) as well as its function as a profit oriented State Owned Company. This has caused the rural electrification program to be neglected because the company is more willing to focus on its business/commercial activity rather than carrying out its social responsibilities. The government's ability to finance electricity developments in many regions in the country has also been affected by lack of funds. According to RUKN (General Electricity Planning Program), huge investment, amounting to US$ 30 billion, is required to install additional power generation capacity (cumulative 23,443 MW) up to 2013. The government is capable only of financing US$ 7 billions, and the rest (US$ 23 billions) has to be made available through domestic and foreign investment (MEMR, 2004). Despite this problem, there is no effective operating policies or regulations that encourage more private sector participation in the investment and development of electric power projects in Indonesia. Some policies and regulations, such as electricity policy, financing policy, fiscal and income tax duties, incentives, etc have been criticised as inconsistent and ineffective by many domestic and foreign investors (MES, 2004). Moreover, the electricity tariff is still under the economic price which is not conducive to investment. Some tariff structures such as low income households, are still subsidised.

*Second,* many important energy decisions, like nuclear installations have been suspended because government policy favours public opinion rather than economic or national interest (Study Report, 2001). The government intended to build the first nuclear plant on Mount Muria, 440 km east of Java in 1998. This plan was based on a thorough long-term study involving domestic and foreign experts from the IEA (MME, 1995). The plan, however, has provoked severe public debate because of the plant location and its waste sites. There had been something of a stop-go policy on the nuclear project, which was associated with the influence of environmentalists and some elite politicians. The government decisions to delay the nuclear power installation in 1998 and to see nuclear power as the last option to other energy alternatives has effectively cancelled the nuclear project in central Java and affected energy supply pattern. The above policies have caused set-backs to the energy supply systems output.

*Third,* is the problem of economic inefficiencies and the waste of resources as a result of unwise investment decisions in primary energy projects. Many energy supply and investment decisions were driven by political interests rather than being designed by respected energy institutions (Prawiro, 1998). Most energy projects, like new refineries and power-plant installations in the country, were the results of government decisions that were made without a comprehensive and integrated plan involving related energy installations. Lack of economic considerations in the project analysis and heavy political influence isions have characterised decisions on project installations leading to further ineffectiveness in Indonesia's economic performance (Hill, 1996). As a result, there was no comprehensive and integrated analysis on the balance between supply and demand causing economic inefficiencies and the waste of resources. The huge national debt, amounting to trillions of US dollars accrued by the electricity sector, was one of the reasons for the economic crisis the country faced from 1997 to the present.

*Fourth,* inconsistent energy pricing policies have caused additional burdens on government funding for energy subsidies. The pricing policies for hydrocarbons (gasoline, diesel and kerosene) were set in 1998 to gradually increase prices to remove subsidies by 2004. This policy is aimed at reducing the government's energy subsidies and encouraging energy efficiency, especially in the industry and transport sectors. However, implementation of the pricing policies has stalled due to social and political barriers. Some decisions affecting the pricing of electricity and gasoline, for example, have been reconsidered and have not been fully adopted in accordance to the plan. As a result, the government is still heavily burdened by increasing spending on energy subsidies.

*Fifth,* the government policy of still favouring the export of oil and gas for foreign income earning has caused further depletion of scarce resources and affected the security of the domestic supply of oil and gas resources. Despite the fact that oil and gas reserves are facing rapid depletion (see the discussion in Sections 4.3. and 4.5 of Chapter 4), the past policy of utilising oil and gas resources for foreign income purposes is still being continued. Many energy analysts have warned about the possible change in Indonesia's status to an oil importing country in six to eight years from 1998 (ARCO, 1998 and BAKOREN, 1995 and 1998). However, the government is still implementing a 'resource based policy' which encourages the export of oil and gas for foreign exchange earning to aid economic development. The spirit of using oil and gas earnings as the main source of income for economic development can be observed in the new oil and gas law which has issued by Parliament in 2003 (MME, 2003). The new oil and gas policy encourages private or foreign oil companies to participate in development of oil and gas exploration and exploitation for domestic and export purposes. The finding of new oil and gas reserves in the last decade has shown very slow progress (see discussion in Sections 4.3 and 4.5 of Chapter 4). This phenomenon will surely affect the security of the country's energy supply in the not too distant future if there are no new major oil and gas reserve findings.

For the above reasons, there is an urgent need to rigorously assess the role of government in planning and designing energy supply policies. There should be a separation of function between energy producers, suppliers and decision or policy makers. There should also be a separation of role of the energy industry in social and commercial functions. In the case of the nuclear power project cancellation, for example, the policy option to embark on a nuclear power plan needs to be rigorously assessed and analysed using energy modelling and policy analyses before they are issued and implemented. A comprehensive approach to energy policy decision-making and analysis that includes the element of decisions on new energy project installations is the appropriate way to deal with the problem of inefficiency in energy investments. Government energy policies, such as energy pricing, the diversification of energy mix, energy conservation, energy imports and exports, and intensification of energy exploration and exploitation, are important elements in affecting the domestic energy supply patterns. Therefore, those important elements should be integrated in energy modelling to achieve comprehensive energy policy analysis.

## 7.2 Impact of Technology on Current and Future Supply Patterns

Although some of the literature (eg, OTA, 1997) identifies technology as being an important long-term determinant of Indonesia's energy supply patterns, it can be argued that technological developments *only have a small impact especially in the short-term.* In other words, the country's current energy supply trends will not undergo significant changes throughout the next 20 to 30 years. This argument is supported by studies conducted by BATAN (Study Report, 2001), Ministry of Mines and Energy (MME, 1999) and the Indonesian University (Study Report, 2000) and is based on the following considerations:

1. The current mix of primary energy supply technology employes the *best available* or the least cost technology in accordance with international standards. The current technologies used for primary energy supply of oil, coal, and natural gas, for example, are commercially competitive and close to international 'best practice'.

2. Based on past experience in Indonesia, the development of new energy supply technologies requires a considerable lead-in time, usually more than a 10-year period.

Therefore, the development status of energy supply technology in Indonesia can be expected to be similar to that of international development levels, even with a 20 year time horizon.

### 7.2.1 Fossil Fuels

*Oil technology*: Most of the developments in exploration and production technologies have been adopted by oil companies operating in Indonesia. Currently, there are some new developments in exploration technology particularly in the selection of favourable drill sites using a new prospecting technique that was initially developed to record earthquakes, called seismography. It is now used to provide a direct means of obtaining sub-surface structural information without drilling wells. Also, advances in computer and electronic technology have made it possible to analyse larger geographical areas more easily and to explain data more precisely (OTA, 1997). All of these recent developments in exploration technology have been taken up and implemented by oil companies in Indonesia. The new oil production technologies, like infill drilling, horizontal drilling techniques, (which could improve oil recovery), deep-water and enhanced oil recovery techniques (using thermal recovery for example) have all been applied in Indonesia (MME, 1997).

*Natural gas technology:* New developments in gas production technology, in particular improvements in recovery efficiency, have been adopted in Indonesia. Recovery efficiency, currently lower than 80%, can now be improved with, for example, the commercial hydraulic fracturing technique (MME, 1997).

*Coal and peat technology:* Most power plants and industries in the world, including Indonesia's still burn coal in pulverized coal-fired boiler furnaces. With gradual improvements in combustion technology, higher efficiencies can be achieved. Large coal power plants now operate more efficiently at higher temperatures and pressures (OTA, 1997). However, its is argued that further efficiency improvements to the combustion process are likely to be incremental, which has been the case for Indonesia's coal technology. Much effort is currently being focused on improving the environmental performance of coal burning, particularly emission reduction. Currently, the utilisation of peat as an energy source has not reached a commercial stage (Working Group on IPCC, 1995). Indonesia is planning to build large scale peat power plants (feasibility study is in progress) at Pekanbaru (Riau) and Pangkoh (South Kalimantan) (MME, 1997).

### 7.2.2 Nuclear

Indonesia has not yet embarked on nuclear utilisation and therefore, has no experience with this technology. Nuclear technology is regarded as mostly, though not completely, mature. Some improvements are still to be made in reactor technology and management to make it more commercially competitive. The Advanced Light Water Reactor (LWR) has reached the stage of commercial application, while the MHTGR (Modular High-Temperature Gas Reactor) has advanced nearly to the commercial stage. Presently, if agreed on construction could start with an essentially complete design. Advanced designs are currently being completed incorporating safety and reliability features that could possibly solve many of the past problems (OTA, 1997). The Indonesian government has committed on utilising nuclear energy by 2016 at the latest (Study Report, 2001) and has plans to use the once-through pressurized water nuclear technology that is currently being used by South Korea and Pakistan.

### 7.2.3 Electricity

The electric power supply technology that Indonesia is currently using is similar to that used in developed countries (MME, 1997). Nowadays, there are a number of new promising technologies for electric power generation. New turbine technologies and advanced materials allow higher combustion temperatures, thus higher efficiency. Combined Cycle (CC) technology has greatly improved combustion efficiency, and this technology has reached commercialisation. Many of the advances in design and high temperature materials for turbines result from military research and development for improved jet engines. The inter-cooling Steam Injected Gas Turbine (ISTIG) is still being developed to fully reach commercial application (Working Group on IPCC, 1995).

### 7.2.4 Biomass

Biomass is already a significant source of renewable energy, especially in Indonesia. Currently there are various biomass energy technologies around the world, which are grouped into two categories, thermal conversion and biological conversion technology. Both thermal conversion technology and biological conversion technology for biomass are currently being implemented and developed in Indonesia, for example, biogas production by anaerobic digestion (MME, 1997). Some of the thermal technologies, however, for example, steam/oxygen gasification and liquefaction are still at the research and development stage, whereas others are at semi-commercial and commercial stages. For households and small-scale industries in Indonesia, efforts to increase the efficiency of solid biomass have been through research into the use of efficient stoves. These have been developed by government institutions. Research and development programs on gasification technology in Indonesia began in 1976 and are carried out by ITB and BPPT. Presently, there are several other government and non-government institutions that are actively conducting research and development, demonstration projects, and implementation of biomass technology in the country. Most gasification units installed in Indonesia are of a fixed bed type technology and many Indonesian are experienced and skilled in this type of technology.

### 7.2.5 Geothermal

Worldwide, the development of geothermal technology considers safety and environment factors. The current status of exploration technology has reached a commercial stage in Indonesia as well as in the rest of the world. However, some of the technologies are still in the research and development stage, for example; Hot Dry Rock (HDR), a technology for increasing geothermal energy recovery. Drilling techniques for geothermal energy are being developed with improvements in oil drilling techniques. Technology developments basically cover; a) the development of drilling equipment for high temperatures and pressures, b) the development of high quality materials for pipeline isolation, distribution pipelines for high temperatures and high pressure and that are also corrosion resistant, c) development of drilling equipment and techniques, like Steering Tool, Oriented Coring and Directional Survey. The development of conversion technology at the moment is focused more on the effort to lower the generation cost, and increase efficiency in electricity generation. At present, some of the conversion technologies, either nationally or internationally, have reached the commercial stage. The conversion system technologies of geothermal power plants being operated at present are; a) dry steam geothermal plants, b) separated steam plants, c) separated steam/hot water flash plants, d) separated steam/multi-flash plants, e) binary cycle plant with secondary working fluid, f) single flash steam plants with pumped wells, g) double flash steam plant with pumped wells, h) combined flash/binary plants. Plants with technologies a) to f) have currently been commercially operating in various countries, whereas plants with technologies g) and h) are still in the research and development stage (MME, 1997). Geothermal energy utilisation in Indonesia uses the current commercially available exploitation and conversion technologies described above.

### 7.2.6 Other Renewables

*Solar technology:* the application of solar technology in Indonesia is grouped into two categories, solar cell and solar thermal. The devclopment of solar cell technology in Indonesia has focused on two types of PV modular systems; the concentrator system and the flat-plate collector. The aim of research and development programs at the moment is to develop concentrators that minimise optical losses and maintain focused radiation on cells through wind stress, and thermal cycling and tracking. The application of solar-cell technology in Indonesia is mainly in rural or remote areas where the national electricity-grids are unavailable. The technology is commonly used for water-pumps, public television, telecommunication, and refrigeration in rural health clinics. In some developed countries, the application of this technology has been more for commercial electricity generation in urban areas and for demonstration solar cars. Traditionally, the application of solar-thermal in Indonesia is for drying purposes. The technology developed with energy conversion technology. Current applications of the technology in Indonesia can be successfully implemented because of government subsidy. Research and development on solar-thermal technology is being carried out by BPPT, LIPI and other government institutions.

*Wind power technology:* Current improvements in this technology are achieved with more sophisticated turbines that can adjust to the changing speed and direction of the wind, thus help provide steadier power supply to a utility. Horizontal axis technology has been commercially applied internationally, though nationally it is still at the demonstration stage. The application of vertical axis technology is now commercial (OTA, 1997). Wind energy in Indonesia is an energy alternative for lighting in households, water irrigation systems, and telecommunication systems. Some efforts have been made to improve its distribution efficiency by making raw materials available that are relatively cheap and affordable price to consumers (MME, 1997).

*Ocean technology:* This technology has not been utilised in Indonesia and is still in the research stage (MME, 1997). Generally, the barrier to developing this technology is the economic cost, due to problems with the efficiency of pumps, corrosion suitable materials for cooling water pipelines and bio-fouling. In addition, there is limited information, knowledge, and studies on the development of this technology. According to OTA (1997), there are no commercial OTEC plants developed, but under some conditions, OTEC-derived electricity may be competitive in the next five to 10 years for small and remote islands, where national electricity grids are not available and power from diesel generators is very expensive.

*Tidal technology:* Indonesia, which is comprised of thousands of islands surrounded by ocean, bays, peninsulas, and straits, has enormous potential for tidal energy. However, the technology has not been utilised in the country. There are several areas well suited to tidal energy generation in Indonesia, that is, Bagan Siapi-api, Palu Bay, Bima Bay in Sumbawa (West Nusa-Tenggara), West Kalimantan, Irian Jaya, and the southern coasts of Java island (MME, 1997). Research and development into tidal technology has been carried out in some countries, like France, Russian, USA, and Canada since 1920.

*Wave technology:* Though the technology is considered expensive and not yet commercially applicable, many developed countries are interested in this technology like Finland, USA, UK, Japan and Netherlands (OTA, 1997). Wave energy has the potential to be developed in some areas in Indonesia like in the South-Java and Sumatra seas. BPPT has tried to utilise wave energy in Baron, south of Yogyakarta (MME, 1997).

### 7.2.7 Municipal Wastes

Although the municipal waste (MSW) potential in Indonesia is significant, the technology is still at a research and development stage. A MSW plant has been installed for research and development purpose in Jakarta (MME, 1997). Currently, efforts to improve technology are concentrated on reducing the costs of electric power generation and better emission control. New techniques are required to dispose of dioxins, nitrogen oxides, chlorinated gases, solid residues, and ash. Automatic trash sorting to remove glass, plastics, and other recyclicables would help improve MSW combustion and reduce disposal problems (OTA, 1997).

### 7.2.8 Technical Efficiency Improvements in Energy Supply

Although it is argued that energy technology developments will have no significant impact on the short-term future supply mix (as discussed above), it appears that improvements gained from ‘energy efficient technologies’ can have significant impacts. In this regard the analysis by the IPCC (1995), as set on Table 7.1 shows that future efficiency improvements in secondary energy supply technologies such as electric power plants, the transformation sector, and energy distribution technology offer considerable potential for energy supply savings. These projections show that significant efficiency improvements can be realised. For example, the technical efficiency of hydrocarbon power plants can increase from 0.310 to 0.450 and coal power plant efficiency can increase from only 0.245 in 2000 to 0.400 in 2020. In the transformation sector, LNG plant efficiency can be improved from 0.815 to 0.970 in 20 years. In the distribution sector, the efficiency of hydrocarbon distribution losses can be improved from 0.145 to 0.050. These efficiency improvements will likely affect the amount of energy supply needed in the future. Efficiency improvements of energy supply will, gain greater consideration as concerns over the environmental impacts of fossil fuel burning increases.

**Table 7.1 The Average Technical Efficiency (current and projected) of Energy Supply Sectors (National, from 2000 to 2020)**

| No. | Energy Supply Technologies | *Technical Efficiency** | |
|---|---|---|---|
| | | 2000 | 2020 |
| 1 | **Electric Power Plants** | | |
| | Hydrocarbons Power Plant | 0.310 | 0.450 |
| | Coal Power Plant | 0.245 | 0.400 |
| | Nuclear Power Plant | 0.305 | 0.360 |
| | LNG Power Plant | 0.310 | 0.500 |
| | Hydro Power Plant | 0.785 | 0.800 |
| | Micro-Hydro Power Plant | 0.735 | 0.790 |
| | Geothermal Power Plant | 0.790 | 0.800 |
| | Biomass/Combustion Wood Power Plant | 0.150 | 0.295 |
| 2 | **Transformation Sector** | | |
| | LPG Plant | 0.880 | 0.940 |
| | Oil-Refinery Plant | 0.815 | 0.970 |
| | LNG Plant | 0.855 | 0.935 |
| | CNG Plant | 0.920 | 0.945 |
| | Coal Plant | 0.810 | 0.900 |
| | Combust. Renew./Biomass | 0.490 | 0.550 |
| 3 | **Distribution Losses (**)** | | |
| | LPG Distribution | 0.095 | 0.050 |
| | Hydrocarbon Distribution | 0.145 | 0.050 |
| | Coal Distribution | 0.105 | 0.050 |
| | LNG Distribution | 0.100 | 0.050 |
| | Combust.Renew. Distribution | 0.165 | 0.075 |
| | Electricity Distribution | 0.190 | 0.130 |

Source : Working Group II on IPCC (1995)

(*Technical efficiency is defined as energy outputs per energy inputs and is estimated and measured based on the information on the current and projected future energy supply technologies and their efficiencies. Whereas distribution losses ** is the amount of energy losses per unit of output. The above figures are obtained from The Technical Inventory Book of IPCC Working Group (1995) and some are estimated).*

### 7.2.9 Summary of The Technological Status of Future Energy Supply Options

The status of development of major energy supply technologies for primary and secondary energy supply as well as energy conversion are summarised in Table 7.2. The technologies are grouped into four categories, i.e. research and development (R&D), demonstration, semi-commercial, and commercial stage. The status of development for some technologies is given for Indonesia (national) and at the international level.

**Table 7.2 The Current Status of Major Energy Technologies For Energy Supply and Conversion**

| No. | Energy Supply Technologies | R & D | Demonstration Project | Semi-Commercial | Commercial |
|---|---|---|---|---|---|
| **1** | **Oil Technology** | | | | |
| | Deepwater/Arctic technologies | v | | | v |
| | Enhanced Oil Recovery Techniques | v | | | v |
| | Therrnal Recovery | v | | | |
| | Miscible Flooding | v | | v | |
| | Chemical Flooding | | | | v |
| **2** | **Coal Technology** | | | | |
| | Atmospheric Fluidized-Bed Combustion (AFBC) | v | | v | |
| | Pressurized Fluidized-Bed Combustion (PFBC) | | v | | |
| | Integrated Gasification Combined Cycle (IGCC) | | | v | |
| | Flue-Gas Desulfurization (FGD) | | | | v |
| | Sorbent Injection | | | v | v |
| | Staged Combustion | v | | | |
| **3** | **Natural Gas Technology** | | | | |
| | Hydraulic Fracturing | | | | v |
| **4** | **Nuclear Technology** | | | | |
| | Advanced Light Water Reactor | | | | v |
| | Modular High-Temperature Gas Reactor (MHTGR) | v | | v | |
| | Power Reactor Inherently Safe Module (PRISM) | v | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **5** | **Electricity Technology** | | | | | |
| | Combined Cycle Gas Turbine (CCGT) | | | | | v |
| | Intercooling Steam Injected Gas Turbine (ISTIG) | | | | v | |
| | Fuel Cells | v | | | | |
| | Magnetohydrodynamics (MHD) | v | | | | |
| | Advanced Batteries | v | | | | |
| | Compressed Air Energy Storage (CAES) | | | | | v |
| **6** | **Geothermal Energy Technology** | | | | | |
| | Conversion Technology (National) | | | | | v |
| | Conversion Technology (International) | | | | | v |
| | Reservoir Technology (National) | | | | v | v |
| | Reservoir Technology (International) | | | | v | v |
| | Exploitation Technology (National) | | | | v | v |
| | Exploitation Technology (International) | | | | | v |
| | Exploration Technology (National) | | | | v | v |
| | Exploration Technology (International) | | | | | v |
| **7** | **Micro-Hydro Energy Technology** | | | | | |
| | Component of MH.Tech. (National) | | | ' | | v |
| | Component of MH.Tech. (International) | | | | | v |
| | Micro-Hydro PP. (National) | | v | | | |
| | Micro-Hydro PP. (International) | | | | | v |
| **8** | **Solar Energy Technology** | | | | | |
| | Solar Thermal Technology (National) | | | | | v |
| | Solar Thermal Technology (International) | | | | | v |
| | Solar Cell Technology (National) | | | | v | |
| | Solar Cell Technology (International) | | | | | v |
| **9** | **Wind Energy Technology** | | | | | |
| | Vertical Axis Technology (National) | v | | | | |
| | Vertical Axis Technology (International) | | | | v | |
| | Horizontal Axis Technology (National) | | v | | | |
| | Horizontal Axis Technology (International) | | | | | v |
| **10** | **Biomass Energy Technology** | | | | | |
| | Thermal Use (International) | | | | | v |
| | Aerobic Gasifc. Technology (National) | | | | | v |
| | Aerobic Gasifc. Technology (International) | | | | | v |
| | Steam/Ox Gasifc.Technology (National) | v | | | | |
| | Steam/Ox Gasifc. Technology (International) | v | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | Liquefaction Technology (National) | v | | | |
| | Liquefaction Technology (International) | v | | | v |
| | Pyrolysis Technology (National) | | | | v |
| | Pyrolysis Technology (International) | | | | v |
| | Direct Combustion (National) | | | | v |
| | Direct Combustion (International) | | | | v |
| | Densification (National) | | v | | |
| | Densification (International) | | | | v |
| **11** | **Peat Energy Technology** | | | | |
| | Small-Scale Peat-PP Technology (25kW) | | v | | |
| | Briquette. Technology | | | v | |
| | Peat-Charcoal Technology | | v | | |
| | Peat-Drying Technology | | v | | |
| | Peat-Stove Technology | | v | | |
| | Peat-Pyrolysis --> Liquid Product for Industry | v | | | |
| | Carbon Active Utilization | v | | | |
| **12** | **OTEC Technology** | | | | |
| | Permanent-Floating Tech. (National) | v | | | |
| | Permanent-Floating Tech. (International) | v | | | |
| | Floating Plat-Form Technology (National) | v | | | |
| | Floating Plat-Form Technology (International) | | v | | |
| | Coastal Land Technology (National) | v | | | |
| | Coastal Land Technology (International) | | v | | |
| **13** | **Tidal Energy Technology** | | | | |
| | Dual-Pool Technology (National) | v | | | |
| | Dual-Pool Technology (International) | | | v | |
| | Single-Pool (National) | v | | | |
| | Single-Pool (International) | | | v | |
| **14** | **Wave Energy Technology** | | | | |
| | Tube System Technology (International) | | v | | |
| | Tube System Technology (National) | v | | | |
| | Assembly System Technology (International) | | v | | |
| | Assembly System Technology (National) | v | | | |
| **15** | **Fuel-Cell Energy Technology** | | | | |
| | Solid Polymer Elect. Technology (National) | v | | | |
| | Solid Polymer Elect. Technology (International) | | v | | |
| | Molten Carbonate Technology (National) | v | | | |

| | | | | | |
|---|---|---|---|---|---|
| | Molten Carbonate Technology (International) | | v | | |
| | Solid Oxide Technology (National) | v | | | |
| | Solid Oxide Technology (International) | | v | | |
| | Phosphoric Acid Technology (National) | v | | | |
| | Phosphoric Acid Technology (International) | | | v | |
| **16** | **Storage Energy Technology** | | | | |
| | Supercondct. Magnet. Techn. (National) | v | | | |
| | Supercondct. Magnet. Techn. (International) | | | v | |
| | Fly Wheels Technology (National) | v | | | |
| | Fly Wheels Technology (International) | | v | | |
| | Battery Technology (National) | v | | | |
| | Battery Technology (International) | | | v | |
| | Compress. Air Storage Techn. (National) | v | | | |
| | Compress. Air Storage Techn. (International) | | | | v |
| | Pumped Hydro Storage (National) | v | | | |
| | Pumped Hydro Storage (International) | | | | v |

Source : OTA (1997) & MME (1997)

## 7.3 Economics of Energy Supply

The discussion in this section aims to provide information on the current economic status of primary energy and secondary energy, including renewable sources of energy, to determine the relative influence of different energy types in the future energy supply mix.

### 7.3.1 Economics of Conventional Energy Sources

It can be argued that the economics of primary energy supply in the future will not greatly influence the future patterns of the energy supply mix. The study conducted by BATAN-IEA (Study Report, 2001) showed that the costs of some primary energy supply, especially for natural gas and coal, still continues the same, though for oil, it experiences a change, which being slightly more expensive than the current cost. To support this argument, the following sections discuss the economics of some primary and secondary energy supply sources in the next 25 years (Study Report, 2001; JICA, 2002; PLN, 2002)

#### 7.3.1.1 Economics of Oil, Natural Gas and Coal Production

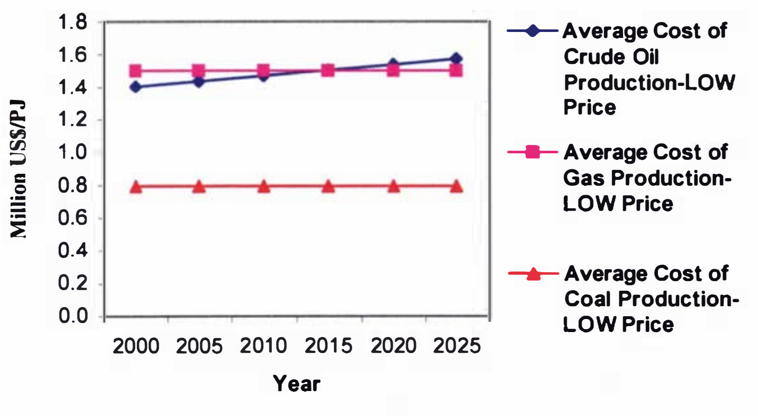
Two reports have looked at the average oil, natural gas and coal production costs. These have projected different future costs. According to the Study Report (2001) prepared by the Indonesian Nuclear Energy Agency (BATAN) and teams from energy related institutions including the IEA, average crude oil production costs are projected to increase slightly from 1.4026 to 1.5724 million US$/P-Joule by 2025. The projected production costs for natural gas (1.502 million US$/P-Joule) and coal (0.7935 million US$/P-Joule) between 2000 to 2025 are flat. These projections are set out in Table 7.3.

**Table 7.3 Average Oil, Natural Gas and Coal Production Costs in Indonesia: Low Price (Million US$/P-Joule), Current and Projected.**

| Year | Average Oil Production Cost – Low Price | Average Natural Gas Production Cost – Low Price | Average Coal Production Cost – Low Price |
|---|---|---|---|
| **2000** | 1.4026 | 1.502 | 0.7935 |
| **2005** | 1.4366 | 1.502 | 0.7935 |
| **2010** | 1.4706 | 1.502 | 0.7935 |
| **2015** | 1.5042 | 1.502 | 0.7935 |
| **2020** | 1.5384 | 1.502 | 0.7935 |
| **2025** | 1.5724 | 1.502 | 0.7935 |

Source: Study Report (2001), price base year 1997

The highest production cost of the three fuels at present is natural gas production cost at 1.502 million US$/P-Joule, followed by oil with 1.4706 million US$/P-Joule and coal 0.7935 million US$/P-Joule. However, from 2015, the projected oil production cost becomes the most expensive among the three fuels, with the cost increasing to 1.5724 million US$/P-Joule in 2025. The increasing projected price of oil is attributable to depleting world-wide oil reserves and, environmental concerns regarding oil utilisation. The projected production cost changes are graphed in Figure 7.1.




Source: Study Report (2001)

**Figure 7.1 Indonesian Average Cost of Oil, Natural Gas and Coal Production-Low Price (Million US$/P-Joule) in Indonesia, Current and Projected.**

However, the IEA version of oil, natural gas and coal production costs is substantially different from the BATAN Study Report. Natural gas production costs remain the highest among the three fuels throughout the period 2000-2025, with a cost of 1.413 million US$/Peta-Joule at present, and a projected increase to 1.666 million US$/Peta-Joule in 2025. Oil production costs also increase from 1.3616 million US$/Peta-Joule in 2000 to 1.6484 million US$/Peta-Joule in 2025. Coal is the lowest among the three with the average production cost of 0.7935 million US$/Peta-Joule (in 2000) which is projected to increase to 0.8740 million US$/Peta-Joule in 2025 (IEA, 2000).

The dynamic energy simulation modelling, has used this IEA projected data for oil, natural gas and coal production costs for projecting the total costs of primary energy supply. The methodology for doing this is discussed in Chapter 9 of this thesis.

#### 7.3.1.2 Economics of Electricity Production

Though the average cost of electricity production in the country is projected to increase significantly in the next 20 years, the electricity supply pattern will not be affected to a great extent for several reasons; 1) the level of demand in the household sector in the next 10 to 20 years will not reach saturation level. In other words, the electricity demand per capita is low so the annual consumption rate will still increase even though the price is higher; 2) the electrification ratio is currently considered low (about 52-60 percent) (MME, 1997), and many remote areas in the country are not yet electrified. Therefore, the electricity price increases will not affect the total domestic consumption and supply pattern. Table 7.5 provides the estimate cost of electricity production from the various primary energy sources in Indonesia.

**Table 7.5 The Average Costs of Electricity Production from Primary Energy Sources in Indonesia (Million US $/P-Joule), Current and Projected**

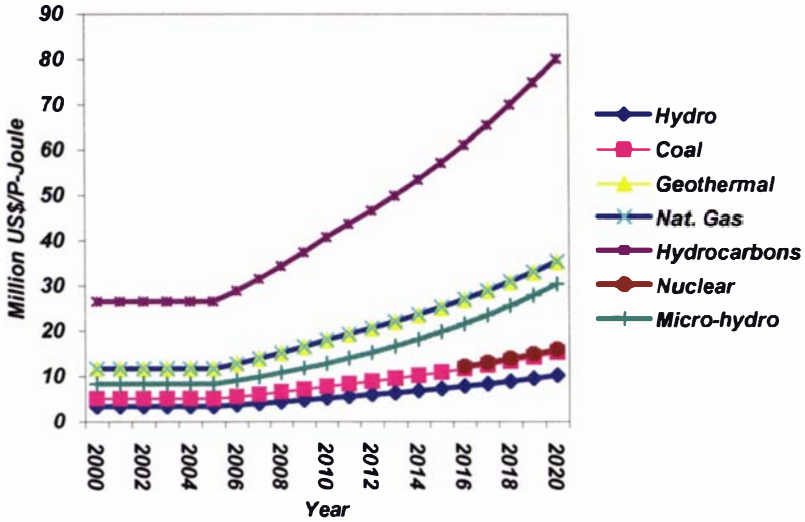
| Year | Hydro | Coal | Geothermal | Nat. Gas | Hydrocarbons | Nuclear | Micro-hydro |
|---|---|---|---|---|---|---|---|
| 2000 | 3.371 | 5.036 | 11.633 | 11.676 | 26.470 | | 8.330 |
| 2001 | 3.371 | 5.036 | 11.633 | 11.676 | 26.470 | | 8.330 |
| 2002 | 3.371 | 5.036 | 11.633 | 11.676 | 26.470 | | 8.330 |
| 2003 | 3.371 | 5.036 | 11.633 | 11.676 | 26.470 | | 8.330 |
| 2004 | 3.371 | 5.036 | 11.633 | 11.676 | 26.470 | | 8.330 |
| 2005 | 3.371 | 5.036 | 11.633 | 11.676 | 26.470 | | 8.330 |
| 2006 | 3.670 | 5.490 | 12.680 | 12.730 | 28.850 | | 9.080 |
| 2007 | 4.000 | 5.980 | 13.820 | 13.870 | 31.450 | | 9.900 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2008 | 4.360 | 6.520 | 15.060 | 15.120 | 34.280 | | 10.790 |
| 2009 | 4.760 | 7.110 | 16.420 | 16.480 | 37.360 | | 11.760 |
| 2010 | 5.190 | 7.750 | 17.900 | 17.960 | 40.730 | | 12.820 |
| 2011 | 5.550 | 8.290 | 19.150 | 19.220 | 43.580 | | 13.980 |
| 2012 | 5.940 | 8.870 | 20.490 | 20.570 | 46.630 | | 15.230 |
| 2013 | 6.350 | 9.490 | 21.930 | 22.010 | 49.890 | | 16.610 |
| 2014 | 6.800 | 10.160 | 23.460 | 23.550 | 53.390 | | 18.100 |
| 2015 | 7.270 | 10.870 | 25.100 | 25.200 | 57.120 | | 19.730 |
| 2016 | 7.780 | 11.630 | 26.860 | 26.960 | 61.120 | 12.160 | 21.510 |
| 2017 | 8.330 | 12.440 | 28.850 | 28.850 | 65.400 | 13.010 | 23.440 |
| 2018 | 8.910 | 13.310 | 30.750 | 30.870 | 69.980 | 13.920 | 25.550 |
| 2019 | 9.530 | 14.240 | 32.900 | 33.030 | 74.880 | 14.890 | 27.850 |
| 2020 | 10.200 | 15.240 | 35.210 | 35.340 | 80.120 | 15.940 | 30.360 |

Source: Study Report (2001, JICA (2002) and MME (1997)

Electricity production in Indonesia is currently generated by hydro, coal, geothermal, natural gas, micro-hydro and hydrocarbon fuels. A nuclear power plant has not been installed and currently its viability, in terms of economics, technology and social and environmental aspects, is still being researched by the National Nuclear Energy Agency (Study Report, 2001). The agency has, however, predicted that a nuclear power plant will be built in year 2016. The projected generating cost for electricity to 2020 from the various energy sources are shown are graphed in Figure 7.2. The average current (2000-2005) electricity generating costs calculations are based on the existing plants operated in Indonesia and future extension plans, including committed projects planned by utility companies and the government. The projected cost figures from 2005 to 2020 assume that the inflation rate from 2006 to 2007 grows at the rate of 9 percent, 2008 at 8.5 percent, 2009 to 2010 at 8 percent, and from 2011 to 2020 at a flat rate of 7 percent (JICA, 2002).

The average generating cost between 2000-2005 is cheapest for hydro electricity at 3.371 million US$/P-Joule, followed by coal at 5.036 million US$/P-Joule. The most expensive generating cost are hydrocarbon power plants with an average cost of 26.470 million US$/P-Joule. The generating cost of a natural gas power plant is 11.676 million US$/P-Joule on average during 2000-2005. In 2020, the generating cost of a hydrocarbon power plant could reach 80.12 million US$/P-Joule and the hydro-electricity plant's generating costs also increase to 10.2 million US$/P-Joule, but this is still the cheapest power plant in 2020. The second cheapest source in 2020 is still coal power plants with 15.24 million US$/P-joule. The nuclear power plant, which is assumed to be operational in 2016, by 2020 has a projected cost of 12.157 million US$/P-Joule and the cost will increase to 15.94 million US$/P-Joule. According to the study conducted by BATAN, nuclear electricity generating costs vary depending on the technology used by each power plant. For example, for Plant 1 (Pakistan) the cost is about 16.072 million US$/P-Joule, plant 2 (Korea) 13.734 million US$/P-Joule, Generic I (Nukem) 10.381 million US$/P-Joule, Generic II (Nukem) 11.863 million US$/P-Joule, Generic III (PMBR) is 8.735 million US$/P-Joule (Study Report, 2001).




*Source: Study Report (2001), JICA (2002) and MME (1997)*

**Figure 7.2 The Costs of Electricity Production from Primary Energy Sources in Indonesia (Million US $/P-Joule), Current and Projected.**

### 7.3.2 Economics of New and Renewable Sources of Energy (NRSE)

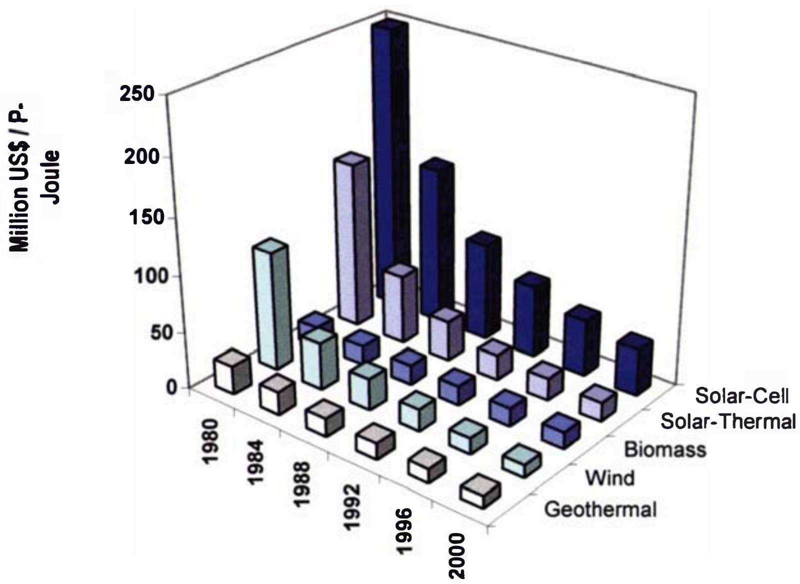
It can be argued that the economics of NRSE will not significantly change the future pattern of the energy supply mix in Indonesia for several reasons. First, the current cost of renewables is considered noncompetitive compared with the primary fuels. Although in the near future it may become competitive, resource like strong winds and water for micro hydro are scattered and only good for small scale applications. Second, the status of technology development for most NRSE in the country is still at the research and demonstration stage, and Thirdly, there are still many technical, financial and institutional barriers to the development of NRSE utilisation in Indonesia. However, if the government attempts to promote NRSE utilisation for environmental or self-sufficiency considerations, its share can be rapidly increased, for example by using biomass and wind energy. The following discussion covers the above mentioned aspects and the prospects for NRSE developments.

#### 7.3.2.1 Costs of Electricity Production from NRSE

Due to limitated Indonesian data, the discussion in this section will refer to NRSE international prices rather than domestic or local NRSE prices. From 1980 to 2000, NRSE prices covering solar-cell, solar-thermal, and wind energy have decreased significantly due mainly to increased demand and technological development. The price of solar-cell energy which was about 250 million US$/P-Joule decreased significantly to 41.7 million US$/P-Joule in 2000. Solar-thermal energy which was 147.2 million US$/P-Joule in 1980, dropped to 16.7 million US$/P-Joule in 2000. Meanwhile, the wind energy price also declined substantially from 105.6 million US$/P-Joule in 1980 to only 11.1 million US $/P-Joule in 2000. Other NRSE like geothermal and biomass energy also decreased but only slightly. Geothermal energy which was 25 million US$/P-Joule in 1980, has dropped to 10.6 million US$/P-Joule in 2000. Biomass energy, which was 17.8 million US$/P-Joule in 1980 declined slightly to 14.4 million US$/P-Joule in 2000. Of the five types of NRSE (solar-cell, solar thermal, wind, geothermal and biomass), the price of solar-PV is the highest and the lowest is geothermal energy. Table 7.6 and Figure 7.3 shows how the cost of each NRSE has changed from 1980 to 2000.

**Table 7.6 The Price of Electricity Production from NRSE (International) in Million US$/P-Joule (1980 – 2000)**

| NRSE type | 1980 | 1984 | 1988 | 1992 | 1996 | 2000 |
|---|---|---|---|---|---|---|
| *Geothermal* | 25.0 | 20.6 | 16.1 | 14.2 | 12.5 | 10.6 |
| *Wind* | 105.6 | 41.7 | 27.8 | 19.4 | 13.9 | 11.1 |
| *Biomass* | 17.8 | 17.5 | 17.2 | 16.9 | 16.1 | 14.4 |
| *Solar-Thermal* | 147.2 | 61.1 | 36.1 | 22.2 | 19.4 | 16.7 |
| *Solar-Cell* | 250.0 | 138.9 | 86.1 | 63.9 | 50.0 | 41.7 |




Source : Ministry of Mines and Energy (1997)

**Figure 7.3 The Energy Prices of NRSE (International) in Million US$/P-Joule from 1980 to 2000**

### 7.3.2.2 Non-Economic Aspects of NRSE Development in Indonesia

*Rural Electrification:* As already discussed above, the NRSE development policy in the country is more directed at fulfilling the energy needs of people in rural or remote areas where the electricity grids from national utilities are unavailable. Therefore, the NRSE development in Indonesia will be very much influenced by rural development. Based on the study conducted by the Ministry of Mines and Energy (1997), many rural and remote areas in the country have not been electrified, which provides a great potential or opportunity for NRSE development. Although the total percentage of rural villages electrified has reached 52 percent, the household electrification ratio is currently only 29 percent.

The electricity consumption per household in rural areas is still very low, due to either the limited capability of rural people to pay electricity bills or the limited availability of power capacity to provide it to them. In line with the growth of population, future projections of the number of households in rural areas is projected to increase, leading to a future higher demand for electricity than the current level. If the electricity consumption level of rural households also increase, the demand in the future will be still higher. This is a normal phenomenon in line with rural development progress. The demand expressed in term of power capacity (MW), is substantial. Socio-economic analysis needs to be carried out to determine the opportunities for developing NRSE in rural areas. Also attention needs to be given to the capability of rural people to pay for electricity supplied to their villages, so commercial utilisations of NRSEs can be implemented. In terms of economic factors, NRSE prices are not yet competitive with the electricity prices generated by conventional sources of energy.

*Greenhouse gas reduction:* Emerging global environmental concerns, especially in respect to increase to $CO_2$ emissions caused by fossil fuel burnings, the role of environmentally benign NRSEs becomes more important. It is not however significant part of the country's total energy supply mix. In a global attempt to curb greenhouse gases emissions into the atmosphere, the Earth Convention in Rio de Janeiro, Brazil in 1992 produced The United Framework Convention on Climate Change (UNFCCC). It has been signed by the majority of the countries in the world, including Indonesia. The ultimate objective of this convention is to stabilise greenhouse gases in the atmosphere to ensure a stable global climate. As a tropical country with the second largest tropical rain forest and an archipelagic country with a very large ocean that could function as an emission sinks, Indonesia has a strategic role in shaping the global climate structure. To contribute to this goal, Indonesia has issued Law no. 6, 1994 regarding the ratification of the United Nations Framework Convention on Climate Change. Although Indonesia is not the member of annex 1 parties, currently the government has also been actively promoting Clean Development Mechanism (CDM) implementation to contribute to the reduction of green house gases reduction as mandated by the Kyoto Protocol.

## 7.4 Conclusion

There are three important factors determinants that need to be assessed to determine the future energy supply of Indonesia:

*First,* government policy which impact on the energy supply patterns. The government policies on energy matters are regarded as a critical element of the supply patterns and therefore, they should be integrated. This can be achieved by designing energy modells for comprehensive energy policy analysis which accomodate these policy variables in the modelling structures.

*Second,* the status of energy supply technology development for conventional will also be important determinant for a country's energy supply system performance. This chapter, however argues that the current status of energy supply technologies (international and domestic) will not significantly influence energy supply in Indonesia in the short-term. In other words, the country's current conventional energy supply trends will not undergo significant changes through the next 20 to 30 years.

*Third,* the economics of and penetration rate for conventional and renewable energy will also be important determinants of future energy supply pattern. The chapter argues that the economics of primary energy supply (natural gas, oil and coal) in the future will not greatly influence the future patterns of the energy supply mix. Moreover, the electricity supply pattern will not be affected to a great extent by the costs of electricity supply. The reasons for this are electricity demand in the household sector in the next 10 to 20 years will not reach saturation level and the electrification ratio is currently low, as many remote areas in the country do not have access to electricity. The section also concludes that Indonesia's energy supply mix will not, even in the long term, undergo a dramatic shift from conventional primary energy supply to more environmentally benign energy supply sources by utilising more environmentally benign NRSE technology. This is mainly due to barrier associated with NRSE technology costs and NRSE market penetration.

# CHAPTER EIGHT

# SYSTEM DYNAMICS MODEL OF THE INDONESIAN ENERGY SYSTEM

## 8.1 Introduction

The purpose of this chapter is to specify the structure of the Indonesian energy model. In addition, the chapter discusses the rationale behind the selection of the modelling approach, the structure and specification of the system dynamics model. Most of the endogenous and exogenous inputs (variables) that contribute to the model structures outlined in this chapter are the results of insights discussed and analysed in previous chapters. This chapter is the core of this thesis describing what and how all the policy variables (quantitative and qualitative variables) are processed through mathematical modelling of energy-economic-environment systems simulation. The insights and lessons from chapter 2 to chapter 7 that are integrated in this chapter are summarised as outline below.

The *history* from the colonial to the post-independence eras discussed in Chapter 2 shows that the political and economic objectives of the governments have a significant influence on the energy policy of Indonesia. In particular, there are two important influences that can be argued to have significant impacts on the energy policy. They, therefore, need to be considered in designing the future policy variables of Indonesia.

First, the excessive exploitation approach inherited from the colonial era has continued up to the present policy and brought about rapid depletion of natural resources and caused environmental problems. The colonial eras characterised by the excessive exploitation of mineral resources for the benefit of the colonial governments disregarding the environment impacts and the sustainability of future energy supply, especially oil and gas.

Second, during the Sukarno's and Soeharto's eras, it also became evident that heavy reliance on one revenue stream for the government is imprudent. Specifically, when a government places its heavy reliance on mineral resource' export earnings to finance economic development, it could cause economic troubles. The heavy reliance on oil and gas revenues and imprudent government spending of oil and gas windfalls have caused severe economic problems like inflation and devaluation. Future policy should consider lowering dependence on oil and gas as export earnings and utilize them more for meeting domestic energy need especially when Indonesia is faced with the possible changing status as a net energy importing country.

Chapter 3 provided arguments for the need to consider some emergent policy objectives that should be investigated to understand the implications of meeting the future increasing demand. In principle, 3 key policy objectives need to be addressed by the model; economic efficiency, environmentally beneficial future ($CO_2$ emission reduction), self sufficiency. All of these policy objectives are represented in the form of model scenarios.

All of the insights and lessons learned in chapter 4 are very important ingredients in developing the model. Chapter 4 discusses the historical trends of the country's energy demand and supply in the past 20 years from 1980 to 1998. The patterns of consumption growth and the possible causes of the escalating increase and the implications if the growth continues are discussed in the chapter. In addition to that, chapter 4 provides a discussion about the potential of indigenous energy resources in the country which will be required in evaluating the future policy alternatives for domestic energy mix.

Chapter 5 takes the historical data and information on energy demand presented in chapter 4, and analyses them using a multi-variable regression method to determine the numerical relationship between two or more related independent variables. The relative degree of influences obtained is then used for forecasting the future demand for energy. The correlation between the trends and various exogenous factors such as prices, population and other economic-demographic variables are needed for building mathematical equations of the demand module. This chapter is therefore considered as the essence of the energy demand module, because it provides guidance on likely future demand patterns.

The current and future status of end-use energy technologies discussed in chapter 6 will be useful to provide the pictures about the current and likely future technical efficiency of some energy technologies in accordance to energy type as well as energy using sectors. The data will then be used in the model to forecast the energy savings that can be obtained from the systems if energy efficiency efforts are applied. In addition to this, section 2 of the chapter (decomposition analysis) also provides insights into the factors that affect energy efficiency in Indonesia, be that structural factor or technical factor. This is very important as it will enable the modeller to predict the potential future developments and derive the appropriate policy responses to emerging trends.

Chapter 7 discusses the current and future status of the supply side energy technologies. The data and information on the current and possible future technical efficiencies of the supply sides are very important to help analyse and estimate the future amount of energy actually supplied to or needed by the systems. The information such as power plant efficiencies, transformation sector efficiencies, and distribution losses are required in the power generation and primary energy supply modules.

A flow diagram describing the contribution of the findings in previous chapters to chapter 8 is shown in figure 8.1.

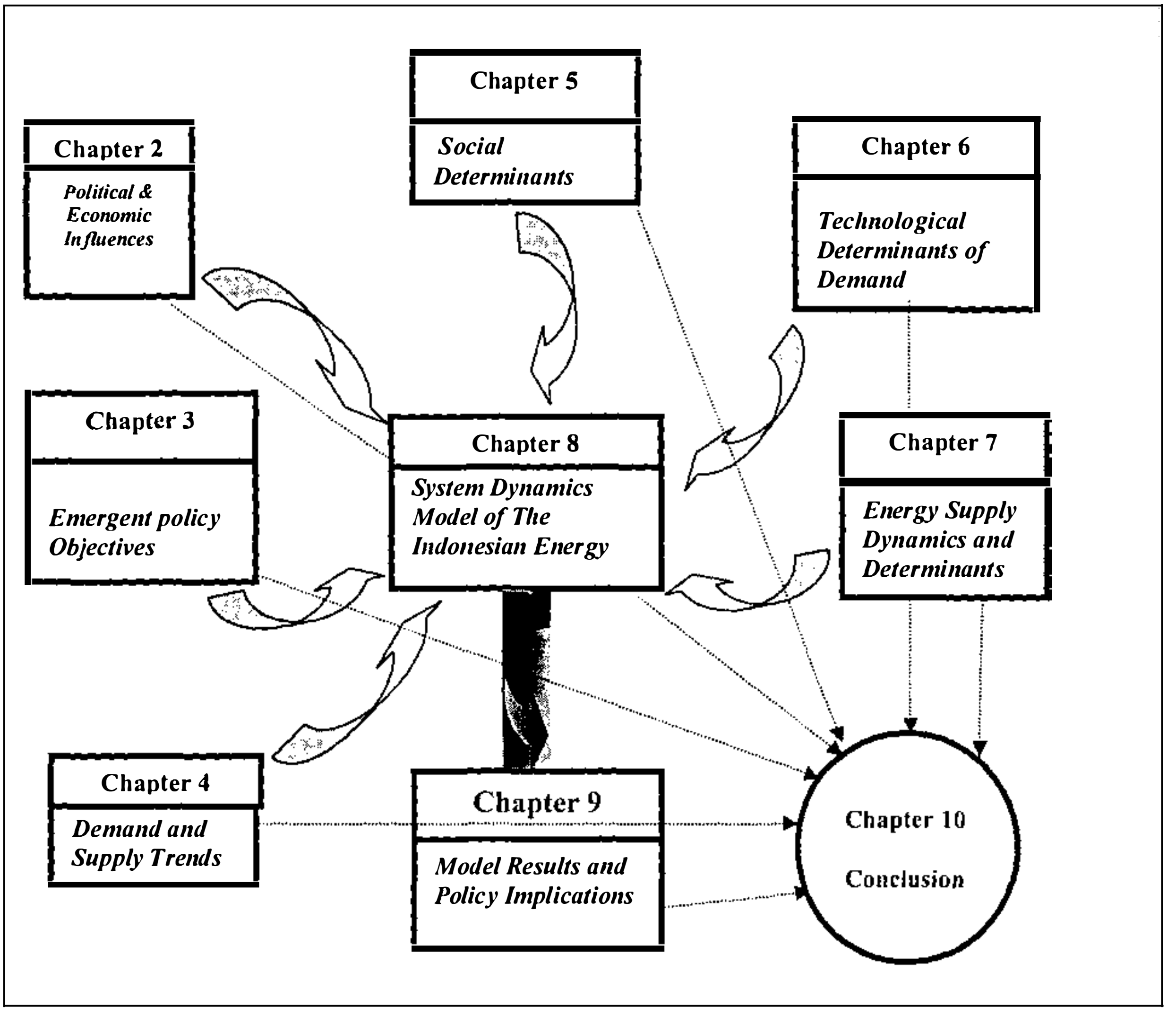



**Figure 8.1 Interrelationships of the Thesis Chapters**

## 8.2 Principles of System Dynamic Modelling

This section is aimed at providing an understanding of the system dynamics approach and the fundamental theory on which it is based. System dynamic modelling approach rests strongly on system theory. The theory about system and systems boundary, stock and flows and other principles that are given in the following sections will therefore help provide a better understanding about system dynamics.

### 8.2.1 Systems Theory

**What is a System?**

Banks & Carson (1984) defines a system as some regular interactions or interdependence of a group of objects that are linked together to achieve some goals. Ljung and Glad (1994) defines a system as an object or a group of objects whose properties are studied. Frederick and Close (1978), define a system as a group of interacting elements or variables which have cause and effect relationships. Drawing on these definitions, this thesis defines a system as dynamic and complex interaction among elements that creates an integrated behaviour representing all elements' behaviours as a whole.

Peet (1992) argued that a system is made up of inseparable elements and cannot be independently divided. He emphasised, in system modelling and analysis, there is the need to take into account the interactions that occur among variables, rather than treating each element or variable independently. Frederick and Close (1978) said that in a model there can be more than one system that can be grouped based on the types of equations used in their mathematical models.

**System Boundary**

Understanding the concept of system boundary is also important because it is an integral part of a system. A system doesn't exist by itself and there are elements outside the system that directly or indirectly influence the behaviour of the system. The changes, which occur outside the system (system environment), which often influence the system need to be treated separately from a system, and the line that provides an explicit demarcation between the system and its environment is called as *a system boundary.* A system boundary is usually defined in accordance to the objective of the study carried out (Banks, 1984). Because of its important role, the system boundary needs to be defined by the modeller before building a model.

**Stocks and Flows**

The structure of a model consists of causal links between circular variables (feed-back loops). There are in principle, two variables that represent these activities within the structures of a model, which are called *level (stock) and rate (flow). Level* is the result of accumulation within the system, whereas *rate* is the activity of the system. *Rate* is the only variable that influences *level*. It is very important to differentiate these two variables in building system dynamics model, because stock or level relates to one point in time, whereas flow or rate relates to a stretch of time. These flow (rate) and stock (level) occur in the real system have to be represented in the model.

**Other Principles**

There are several other important principles that need to be understood in building system dynamic modelling, i.e. systems hierarchy, communication and control, and the type of a system. They are important elements in a system modelling that need to be understood by the modeller, because they will enable the modeller to handle the complexity of the system being modelled and its surrounding. Moreover, they help not only the analyst, but also the users or decision makers to understand the link between variables or elements in a system.

*The first* is the hierarchy of a system. Any system can be arranged in a hierarchical order, in accordance to the level of complexity. This is called the sub-system, which is grouped into one system because it has its own characteristic or specification, which possess the same level of complexity.

The *second* principle is linkages and feedback loops in a system. A system, which is characterised as a network of elements has linkages between all elements within a system. These linkages are represented by feedback lops that channel information. The feedback loops can be positive or negative. Positive feedbacks reinforce the main driving force, whereas, negative feedback loops oppose the main driving force.

*The third* is about the type of a system, an open versus closed system. Open systems are open to their environments while closed systems do not exchange flows of materials or information with their environments. Open systems are very rarely exist in real world.

### 8.2.2 System Dynamics

System dynamics is a modelling approach that attempts to account for the dynamic nature of systems. Wolstenholme (1985) defines system dynamics as a systematic approach for problem detection, system description, qualitative modelling and analysis of change in complex systems.

The systems dynamics society defines system dynamics as a method that uses a viewpoint based on information feedback and mutual causality to learn the dynamic of complex systems and the dynamic causality patterns can be studied using computer simulation. The information feedback and causalities in the system dynamic are represented in the form of mathematical expressions and based on the postulated causal relations, which exist in the systems being studied.

However, Ackerman (1963) stressed that system dynamics is not merely a computer simulation, but more than that. It is a method that applies 'systems thinking', to the vast interconnecting system comprising all humanity and its natural environment. The computer simulation is only helpful to assist the modeller in comparing the model structures and their behavioural patterns with the behaviours of the real system, which will improve our confidence of the model validity.

**The implementation of system dynamics approach for policy analysis and design**

The use of system dynamic approach in simulation computer modelling for policy analysis is very useful. It can be argued that only this type of modelling approach can be used as a tool to deal with the complexity of the behavioural patterns of a system in the real world. The application of the system dynamic approach is especially useful for improving the understanding how the behavioural pattern emerges from the policy structure within the system. The system dynamic approach assumes that the phenomenon in the decision making process consists of an assembly of causal loop structures. The structures are the logical consequences of physical constraints and social goals, rewards and pressures, which cause people to behave and create dominant cumulative dynamic patterns of the total system. However, because of the complexity of the real world, it is understood that not all of the information of the mental model can be explicitly put in the model structure and therefore they need to be selected in accordance to the level of priority based on the phenomenon being studied. The selected information is then integrated in the module structures together in accordance to specific rules.

## 8.3 Rationale for the System Dynamics Approach for Modelling the Indonesian Energy System

### 8.3.1 Previous Approaches to Energy Modelling in Indonesia

It can perhaps be argued that the development of Indonesian energy modelling in the past was very limited and has not accommodated a dynamic approach to policy and environmental changes. In principle, there are three categories of model that have been developed or being developed in Indonesia so far.

*The First category* is a simple regression and forecasting method for developing energy demand and supply analysis. The simple regression method of GDP and population as independent variables to energy demand has been used since 1970s even up to now, to forecast future demand for energy in which the supply side is then determined from the level of demand patterns. There are many limitations with this type of modelling approach as it just totally relies on the past trends and doesn't consider any possible future changes of the significant variables. The significant variables in the future are the same as those of the past. The future trends are merely the continuation of the past trends. The modelling approach disregards the influence some important policy interventions in the future that most probably affect the level or type of variables. Some institutions that used and are still using this simple approach is the Ministry of Energy and Mineral Resources, the utility company like PLN (National Electricity Company), and BAPPENAS (National Development Planning Agency).

*The Second category* is a static and deterministic simulation modelling approach. It is a better approach for energy demand and supply forecast than the first. It is called a static forecasting simulation model because it represents a system at a particular point of time. There are direct, instantaneous links between the variables which contains no random variables. That is why it is classified as deterministic. The models have a known set of inputs, which result in a unique set of outputs. The model works with an exact relationship between measurable and derived variables and expresses itself without uncertainty. The limitation with the model is that there is no room for accommodating the variables that change with time and only have a set of inputs and outputs, whereas, the world is in fact full of uncertainties and probabilities. Examples of this type of modelling approach are a recent study by the Directorate General for Electricity and Energy Development about 'Energy Supply and Demand Projection for 2020' and a study by University of Indonesia entitled "Indonesia 2000; Energy Outlook and Statistics".

*The Third* category of modelling approach that is currently being developed in Indonesia is an optimisation modelling approach. MARKAL (market allocation) model uses this approach. In Indonesia, MARKAL is first developed by BPPT (The Agency of Assessment and Application of Technology) with the help of Germany government. The problem with this optimisation approach is the assumption that every scenario approach applied in the model is at an optimal condition or 'an ideal' state, for example least cost planning, optimal $CO_2$ reduction scenario, optimal energy efficiency scenario, optimal energy mix scenario. Some of these optimal conditions are often not applicable or do not exist in the 'real' world. As a result, when it comes to the policy implementation, all the recommendations of this modelling approach cannot be applied, as only part of the optimal conditions can be met. Not surprisingly, many of the results and policy recommendations of this optimisation approach are only put in the shelves and unlikely to be implemented. Other institutions that conducted this type of study is PLN (the National Electricity Company), with the help of JICA (Japan International Cooperation Agency). The study was entitled "The Optimal Electric Power Development and Operation in Indonesia". Another institution, like The National Nuclear Energy Agency, also uses this optimisation method entitled "Comparative Assessment of Different Energy Sources for Electricity Generation in Indonesia". This new study employs a combination two sub-system modules (optimisation approach), MAED (Model for Analysis of Energy Demand, for energy demand analysis) and MARKAL (Market Allocation, for energy supply analysis).

It is argued in this thesis that the above three categories of modelling approaches that the national institutions are developing are considered as inadequate. This is mainly because of the reason that the country's energy problems are getting more complex and difficult to manage. Many emerging energy issues such as depleting energy resources, environmental issues notably $CO_2$ and $SO_2$ emissions, the security of supply or energy self sufficiency, and economic efficiency are becoming more critical to be address without delay. The popular prediction that the country will become a net energy importer in the not too distant future has further forced the government to use a more sophisticated modelling approach for a better future energy-environment planning.

Faced with the increasingly complex emerging energy issues domestic and internationally, it is timely now that Indonesia embarks on a sophisticated modelling approach that will enable her to deal with difficult and challenging energy problems in the future. System dynamics modelling approach seems a sensible answer to the future energy policy formulations and planning problems of Indonesia. The method helps the policy analyst to understand the complexity of dynamic systems and their behavioural patterns, which are changing with passing time and provides a range of possible solutions to deal with the future emerging problems. The system dynamic methodology recognizes and takes into account the changing behavioural pattern emerges from the policy structure within the system and this is very important for an effective policy planning.

### 8.3.2 Advantages of Using the System Dynamics Approach in Indonesia

This section provides arguments that system dynamics simulation modelling approach offers more advantages to Indonesia than other modelling approaches. In principle, there are several advantages of using the system dynamic approach over other modelling approaches.

Dynamic simulation model allows the users to study and to conduct experiments about the internal interactions of a complex system and or its subsystems. This is particularly important for Indonesia as the policy objectives are undergoing dynamic changes at present and the data or information availability are still developing in a gradual basis. For example, the prices of electricity and hydrocarbons have changed significantly in the last 2 years as part of government efforts to gradually remove subsidies. Data and information availability is still very poor in Indonesia and the efforts to build more accurate data and information especially in economic matters are being more intensively pursued by the Central Bureau of Statistic Office.

With the dynamic simulation model all the informational, organisational, environmental (policy and regulation) changes can be altered and simulated and the effects of these changes on the model's behaviour can be observed and studied. With the dynamic simulation model we can examine or try new designs or policies prior to implementation, and to predict what may happen which allow the analyst to prepare for the possible upcoming problems.

It is very flexible and convenient approach in terms of time scale selection for policy study, which is of great importance for Indonesia with its lack of experience in determining appropriate time-frame for policy analysis. Kelton & Law (1991) said dynamic simulation model allows us to investigate a system with a long term time frame, in compressed time, or detailed working of a system in expanded time at any time we want. As a developing country with relatively political and economical instabilities, Indonesia is facing dynamic changes of energy and economic problem, system dynamic simulation approach is perhaps the only appropriate method of drawing solutions from its economic and energy problems.

The following is a further explanation why the system dynamic modelling approach is considered as more advantageous than the other modelling approaches to Indonesia.

**Powerful Tool for Policy Analysis in More Than One Sector**

The system dynamic energy simulation modelling is a valuable and powerful tool for policy analysis not only in the energy sector, but also in economic and environment sector because it could accommodate more than one system. The consistency of whole properties or variables (exogenous and endogenous) including its sectoral production plan in the economic-energy-environment systems allows the analyst to study the implications of inter-sectoral policy interventions and recommend integrated policy recommendations. The model that represents the links between the three sectors is a realistic to the extent that the logical flows, mathematical correlations and the results can be adequately interpreted, analysed and easily understood by various points of view. The simulation model allows users or policy analysts to alter variables, obtain, and examine the impacts of the implementation of certain energy-economic-environment policy objectives or combination of those policy objectives, and therefore, enable the users develop appropriate recommendations in response to some future expected economy-energy-environment conditions.

**It Is Not a Black Box Policy Analysis Tool**

The model is not a black box, it is relatively easy to understand, and is a user friendly, a flexible tool to adopt any changes in policy designs. This makes it easier for decision makers in economy-energy and environment matters to understand and examine the model results. The model combines economic sector with energy demand and supply sectors and aggregates the Indonesian economy into main consuming sectors, this will provide a precise picture of the consumer and primary energy demand as well as the environment implications. This will ensure consistency of the results can be traced through out the whole economy-energy and environment system.

**It Can Accommodate a Broad Range of Supply-Demand Technologies and Flexible Scenario Approaches and Results Analysis**

The model is able to cover all sources of energy and wide ranges of energy technologies for supply and demand sides, which will allow an examination of competing options under equal conditions. The model possesses the ability to accommodate flexible economy-energy-environment scenario approaches needs and can be easily adjusted (when it is needed) to the Indonesian Government requirements thus provides the opportunity to explore all possible future scenarios, thus save economic, financial and energy resources. The comparison of any given scenario or policy objectives can be seen in the simulation model and the results from sectoral energy demand, sectoral energy efficiency, primary energy supply needs, sectoral CO2 emissions can also be produced in either tabular or graphical forms. The methodology and approaches are very accommodating, changes in energy-economic and environment policy objectives represented by quantitative variables embedded the policy scenarios can be simulated in the model and the results or impacts can be examined in a much shorter time than the traditional method like forcasting or econometric model.

**Suitable for Managing Complex Energy Planning Tasks, Not Only for Energy Institutions But Also for Non-Energy Institutions**

This dynamic simulation model, which integrates almost all energy-economic and environment variables is very comprehensive and a strategic tool for policy analysis and is very suitable for managing complex energy planning tasks either at a national, sectoral or even at state owned company level in Indonesia. The simulation model which also apply an integrated sectoral approach and combined sectoral economic input-outputs, energy demand and supply structures as well as efficiency, financial, technological and environmental aspects of energy utilisation are of great values not only to energy institutions, but also beneficially support the works of other non-energy institutions such as financial and environment related institutions (government and non-government).

### 8.3.3 Limitations of Using the System Dynamics Approach for Modelling in Indonesia

Despite its various advantages, there are also some limitations of this dynamic simulation modelling approach that need to be addressed. The limitations can be categorized into three groups; theoretical, practical and data limitations. Followings are the limitations on the three aspects and some future works required;

**Theoretical Limitations**

There are three main theoretical limitations. *First,* as with many modelling approaches this simulation model projects the future based on the coefficients and correlations obtained from historical data/correlation (of past trends) GDP, population, prices etc. These correlations may change in the future. For example price variables, which in the past 30 years influenced transport demand and not household and industrial energy demand may change in the future.

*Second,* the world may change in an unexpected way and something new may come up in the future. Although, systems dynamic approach allows exploration of unexpected future changes be accommodated in the model structures, these changes may not be immediately accommodated in the model leading to inaccuracy of the model's results, unless the correlations be updated regularly. For example, the equations or correlations that compute sectoral energy demand are dependent on the dynamic economic, demographic and life style changes.

*Third,* when dealing with a complex model of a system, Frenkiel and Goodall (1976) suggest that it is necessary to see whether the modelling objectives require an aggregate macro simulation of the system or whether more detailed micro information is requested. In building the model, the aggregation was done by sectoral basis on energy demand as well as of energy type in accordance to the data availability. It is difficult to produce a model with a more disaggregation as model for Indonesian-energy system should be, again for the reason of data shortages. This level of aggregation may not be suitable to decision maker's needs or may not be appropriate for the Indonesian energy system. This type of limitation also characterised other modelling approaches.

*Fourth,* in many energy-environment simulation models, most of the system variables vary in time scale over the period under consideration. A choice of time-scale on this model has to be made and there is inadequate information available to guide this preference. It is possible that if this choice of time-scale is inappropriate, it may lead to important points being missed in term of the requirements for policy-making analysis. Frenkiel and Goodall (1976) emphasised the need to define the time scale cautiously depending on the construction of models that may hold a mixture of behavioural fluctuations with widely inconsistent natural frequencies. And the selection of the time-scale also depends on the nature of the simulation modelling objectives. For future works, refinements on the time-scale need to be done based on well-defined objectives involving the views of related decision-makers of the system or sub-systems under study.

**Practical Limitations**

The systems dynamic model utilised in this thesis is based on input-output description of the Indonesian economy. There are some important analytical limitations which influence the I-O energy model results, 1) the assumption of *fixed coefficients* of the I-O matrix, and 2) the demand orientation of Input-Output model in which the energy supply side is inadequately considered. The future works should therefore include revising the old I-O matrix coefficient with the new one as the new publication is available, and linking more of policy variables (investments, labours) with the supply side sub-models.

Another practical limitation is a special problem to Indonesia as a developing country. Frenkiel and Goodall (1976) discussed that there is a lack of expertise and technical staff capable of developing and implementing modelling projects in many developing countries. Understanding complex systems, and defining their behavioural pattern of interactions and correlations are very difficult tasks. It requires a capable team works from many disciplines related to the systems being modelled and developing countries are generally lack of these expertises. Another problem is inadequacy of computer facilities. It should be emphasised, however, that lack of capable staff and facilities is not a sound reason for postponing the development and application of the simulation model.

**Data Shortages**

One of the main issues to be resolved in using this I-O energy simulation model is the problem of data. Some data cannot be readily used for the specific modelling needs like the data for building the supply curves for various fuels. A lot of data on electricity generation costs and investments are available in the country but most of it has little relevance to the modelling needs and modelling problems at hand. The problem with data collection in Indonesia includes the lack of sufficient measurement techniques, instruments and resources, which make it difficult to get all the required data. As a consequence, in building the model we were sometimes tempted to proceed without satisfactory data or procedures; this may lead to imperfect models. And the dangerous thing with this situation according to Frenkiel and Goodall (1976) is that the modeller has a tendency to consider the model as the real system itself, rather than as mathematical representation subject to uncertainty. To deal with the problems of data, it is suggested that the processes of model building and data gathering should interact iteratively.

## 8.4 Overall Framework of the Indonesian System Dynamics Energy Model

This section explains the overall framework of the Indonesian System Dynamics Energy Model. The overall framework consists of the main modules (6 modules) and the sub-modules of some main modules. There are some important arguments why the model needs to be divided into main modules and sub-modules.

*First,* modelling a combination of integrated complex systems such as energy-economic and environmental system is a very difficult task for the modellers. In an attempt to make the system dynamics simulation model easier to handle (e.g. for validation purpose), it is necessary to develop the model by decomposing it into a group of interconnected main-modules arranged in an hierarchical order, each of which is easier to control than the overall model. Each of the main-modules can be fairly simply connected with the other sub-modules if necessary through easily definable interfaces with consistent inputs and outputs.

*Second,* the arrangement of the whole model into main modules and sub-modules enables the users or decision makers to understand the whole structures and operation of the model. It is hard for the users or to the decision makers who want to experiment with the model. As Frenkiel and Goodall (1976) said that it can be more helpful and instructive for decision-makers to consider the disaggregated sub-models in terms of a hierarchy of different levels, with the upper levels linking with the lower levels, and with possible links or coordination between sub-systems at the same level, rather than having a large complex model which tend to be more confusing for them.

*Third,* by grouping the model structures into main modules and sub-modules, the analysts or users can produce, examine, analyse of any module or sub-module separately or even compare the results in either tabular or graphical forms.

### 8.4.1 Main Modules, Sub-Modules and Their Inter-Relationships

The overall model, which consists of main modules and sub-modules, describes physical, technical interactions in the economy--energy-environment sector of which each has its own boundary and as a whole it is represented by endogenous and exogenous energy-economic and environment variables.

The model provides the physical structure of the whole systems (the stock and flow networks of goods, population, energy, labours, money, pollutant, efficiency etc.), including the decision making structure of the various players in the system (the decision flows, impacts and information sources for decisions). In this way, the model will mostly be well suited for examining the quantitative dynamic effects of policy initiatives.

The Overall Structure represents the national economy, energy and environment systems, consists of 6 main Modules i.e. Indonesian Economy (I-O) Module, Energy Demand Module, Electricity Generation Module, Heat and Transport Fuel Module, Primary Energy Supply Module, and Environment Module. In addition to that, the Dynamics Model also consists of 5 sub-modules i.e. Technical Efficiency Scenario Sub-Module, Electricity Generation Scenario Sub-Module, Electricity Generation Costs Sub-Module, Heat and Transport Fuel Scenario Sub-Module, and Primary Energy Cost Sub-Module.

The overall frameworks of the modules, sub-modules and their relationship are given in Appendix E.

**Inter-Relationships**

The inter-relationships or process flow of the overall system dynamics model of the Indonesian Energy System are briefly described as follows; The Economic Module produces the GDP for each economic sector (17 sectors) from an Input-Output economic process, which represents the network of intermediate transactions in the economy. The sector growth scalar representing the economic activity of each sector drives the sectoral GDP. From the results of sectoral GDP produced by this economic module, together with other independent variables such as energy prices, population growth, numbers of vehicles (transport) and technical efficiency, then the projected final demand of energy in the respected sector can be calculated using multi-variable regression analysis for determining the numerical relationship between two or more related independent variables. This final energy demand forecast is obtained in the Energy Demand Module. The module calculates final energy demand utilizing the relationship between GDP of a particular sector (industry, transport, residential-commercial) or total GDP and other explanatory variables that influence the demand for energy such as the price of fuel, income per capita, number of households, number of residential customers, electrification ratio, number of passenger cars etc. The model then projects the demand for electricity which takes into account the technical efficiency of each type of the power plants, which is then further analysed in the Electricity Generation Module, to determine the type of energy source used to the generate the electricity in accordance to the assumptions designed for each scenario applied to the model. The other energy types of final demand (coal, hydrocarbons, LPG, wood/biomass, and natural gas) are grouped into two categories of use, i.e. heat and transport fuels for further analysis in the Primary Energy Supply Module. In the Primary Energy Supply Module, the data of heat and transport fuels, as well as the data of energy used to generate electricity (by energy type), are then further analysed (in accordance to the assumptions made for each scenario applied, including the technical efficiency of the energy supply system) to determine the total primary energy supply by energy type. The forecast for indigenous production for each energy type (coal, crude oil, and natural gas) is done based on the trends obtain from historical time series data. Imports and exports of energy are then determined from the information/data on the primary energy supply needs and indigenous energy productions. The final step is the Environment Module, which forecasts emissions of pollutants ($CO_2$, CO, $NO_x$, $SO_2$, Particulates and HC) based on the data of primary energy supply by energy type (in accordance to the scenario applied) obtained from the Primary Energy Supply Module.

**Common Notation of Overall Modules**

This section discusses the common notations of the overall modules in the system dynamics model of the Indonesian energy system. The notations that are specifically owned by each module are given below following the description on each module. The common notations can be summarised as follow;

| | |
|---|---|
| *CSt* | = Commodity Stock (Billion Rupiahs, 1995 Constant Price) |
| *CIn* | = Commodity Input (Billion Rupiahs, 1995 Constant Price) |
| *ImC* | = Import Commodity (Billion Rupiahs, 1995 Constant Price) |
| *COut* | = Commodity Output (Billion Rupiahs, 1995 Constant Price) |
| *ExpC* | = Export Commodity (Billion Rupiahs, 1995 Constant Price) |
| *Epro* | = Economic process (Billion Rupiahs, 1995 Constant Price) |
| *GDP* | = Gross Dom. Prod. (Billion Rupiahs, 1995 Constant Price) |
| $GDP_T$ | = GDP Total Sectors (Billion Rupiahs, 1995 Constant Price) |
| $sc_{i...n}$ | = Sector Commodity i ... n (Billion Rupiahs, 1995 Constant Price) |

| | |
|---|---|
| $sp_{i..n}$ | = Sector Processes i .. n (No Unit) |
| $t$ | = Time of Study Period (Year) |
| $C_{i...n}$ | = Coal Consumption in Sector i.. n (P-Joule) |
| $TE_{ci..n}$ | = Technical Efficiency of Coal in Sector i .. n (%) |
| $E_{i..n}$ | = Electricity Consumption in Sector i ..n (P-Joule) |
| $TE_{Ei..n}$ | = Technical Efficiency of Electricity in Sector i.. n (%) |
| $H_{i..n}$ | = Hydrocarbon Consumption in Sector i .. n (P-Joule) |
| $TE_{Hp..n}$ | = Technical Eff. of Hydrocarbon in Sector i .. n (%) |
| $P_{Hi..n}$ | = Price of Hydrocarbon in Sector i .. n (US $) |
| $H_{i..n}$ | = Hydrocarbon Consumption in Sector i .. n (P-Joule) |
| $L_{i..n}$ | = LPG Consumption in Sector i .. n (P-Joule) |
| $TE_{Li..n}$ | = Technical Efficiency of LPG in Sector i .. n (%) |
| $pop$ | = Population (Number of People) |
| $G_{i..n}$ | = Natural Gas Consumption in Sector i .. n (P-Joule) |
| $TE_{Gi..n}$ | = Technical Efficiency of Nat-Gas in Sector i .. n (%) |
| $W_{i..n}$ | = Wood-Comb.Renew. Consumption in Sector i.. n (P-Joule) |
| $TE_{Wi..n}$ | = Technical Efficiency of Wood/Comb.Sector i n (%) |
| $TE_{process\ i..n}$ | = Technical Efficiency Process i .. n (%) |
| $TD_{losses}$ | = Electricity Transmission - Distribution Losses (%) |
| $SC$ | = Supply Curve, Electricity Production (Million US $/P-Joule) |
| $DE_{spi....n}$ | = Delivered Energy Sector Process i.. n (P-Joule) |
| $a.......z$ | = Energy Type a.. z (No. Unit) |
| $DL_{a....z}$ | = Distribution Losses Energy Type a .. z (%) |
| $E_{a..z,\ prodplant}$ | = Energy Type a .. z from Energy Prod. Plants (P-Joule) |
| $E_{a..z,\ electricity}$ | = Energy Type a .. z from Electricity Prod. Plants (P-Joule) |
| $E_{a..z,\ heat}$ | = Energy Type a .. z from Heat Fuel Prod. Plants (P-Joule) |
| $E_{a..z,\ transp}$ | = Energy Type a.. z from Transp Fuel Prod. Plants (P-Joule) |
| $Efp_{a..z}$ | = Efficiency Plant Energy Type a.. z (%) |
| $E_{a..z,\ import/export}$ | = Energy Type a .. z Import or Export (P-Joule) |
| $IndiE_{a..z,\ ,prod}$ | = Indigenous Energy Production Type a .. z (P-Joule) |
| $E_{a..z,\ supply}$ | = Energy Supply Type a .. z (P-Joule) |
| $E_{a..z,\ ,supplycost}$ | = Energy Supply Cost for Energy Type a .. z (Million US $) |
| $E_{a..z,.supply}$ | = Energy Supply for Energy Type a .. z (P-Joule) |
| $PC_{a..z}$ | = Production Cost Energy Type a .. z (Million US $) |

#### 8.4.1.1 Economic Module

Economic module consists of an Input-Output economic system, which describes the circular flow between sectors in the economy in which each sector produces and consumes intermediate goods from and within the sector itself. The input and output requirements are given in monetary values and placed in a matrix form to describe sectoral demands from other sectors and sectoral products to other sectors, and so forth. This circular flows within the economic system is described in a simple stocks and flows process, in which the flows to and from certain sector represented by commodity inputs and commodity outputs allowing the calculation of commodity stocks, imports and exports. The assumption of the future growth scalar of each sector in a given time (study period) and the demographic changes (e.g. population) allows the model to forecast the future sectoral Gross Domestic Products, which then can be used to project the future demand of energy of the respected sector in the Energy Demand Module. This economic module is specified in following mathematical equations;

***Mathematical Specification of Economic Module;***

***a. Commodity Stocks***

$$CSt_{sc_{i..n}}(t) = CSt_{sc_{i..n}}(t-dt) + (CIn_{sc_{i..n}} + \mathrm{Im}C_{sc_{i..n}} + COut_{sc_{i..n}} - ExpC_{sc_{i..n}}) * dt \qquad (8.1)$$

*Where:*

*Initial* $CSt_{sc\,i..n} = 0$

**Inflows**

Commodity Inputs

$$CIn_{sc_{i..n}} = \sum_{sp=i}^{sp=n} Epro_{sc_{i..n},sp_{i..n}} \qquad (8.2)$$

Imported_Commodities

$$\mathrm{Im}C_{sc_{i..n}}(t) = CIn_{sc_{i..n}}(t) - COut_{sc_{i..n}}(t) \qquad (8.3)$$

**Outflows**

Commodity_Outputs

$$COut_{sc_{i..n}i}(t) = \sum_{sp=i}^{sp=n} Epro_{sc_{i..n},sp_{i..n}}(t) \qquad (8.4)$$

Exported_Commodities

$$ExpC_{sc_{i..n}}(t) = \lfloor CIn_{sc_{i..n}}(t) - COut_{sc_{i..n}}(t) \rfloor \qquad (8.5)$$

***b. Economic_Processes***

$$Epro_{sc_{i..n},sp_{i..n}}(t) = IntDemCoef_{sc_{i..n},sp_{i..n}}(t) * GrScalar_{sp_{i..n}}(t) \qquad (8.6)$$

*Where:*

*IntDemCoef* = internal demographic coefficient is the coefficient of the respective sector commodity (sc) and sector processes (sp) in the Input-Output Matrix.

*GrScalar* = growth scalar of the respective sector process

***c. Gross Domestic Products***

$$GDP_{sp_{i..n}}(t) = \sum_{sc=i}^{sc=n} Epro_{sp_{i..n}, sc_{i..n}}(t) \tag{8.7}$$

### 8.4.1.2 Energy Demand Module

The Energy Demand Module comprises of the sector final demand for various type of energy. The inputs to this module are the forecasted Gross Domestic Products resulted from the Economic (I-O) Module and the projected technical efficiencies of various end-use energy technologies obtained from the Sub-Module Technical Efficiency Scenarios. The technical efficiencies of final demand sectors are determined separately based on the information obtained from various sources, e.g. an energy conservation company in Indonesia (KONEBA), Ministry of Energy and Mineral Resources, and some references on energy conservation publications. The equations for computing the forecasted final demand for various type of energy and various sectors are determined from the analysis on final energy demand determinants (1970 – 1998) discussed in chapter 5 of this study. The equations explain the correlations between dependent variable (the final energy demand of certain sector) and independent variables such as population, GDP, income per capita and energy prices.

***Mathematical Specification of Energy Demand Module;***

***a. Coal in Manufacturing/Industrial Sector***

$$C_i(t) = 10^{-5.6977+1.7200*\log_{10}(GDP_i(t)/4.9405)} \times (1 - TE_{ci}(t)) \tag{8.8}$$

*The equation (8.8) is derived from equation (5.4) in Chapter 5. The number 4.9405 is a convertion factor for GDP of the Manufacturing/Industrial sector from 1983 to 1995 constant prices.*

***b. Electricity in Manufacturing/Industrial Sector and Household-Commercial Sector***

$$E_i(t) = 10^{-3.7921+1.3047*\log_{10}(GDP_i(t)/4.9405)} \times (1 - TE_{Ei}(t)) \tag{8.9}$$

$$E_h(t) = 10^{-13.6297+2.5153*\log_{10}(Income/Cap/2.2946)} \times (1 - TE_{Eh}(t)) \tag{8.10}$$

*The equations (8.9) and (8.10) are derived from equations (5.1) and (5.6) in Chapter 5. The numbers 4.940 and 2.2946 are convertion factors for GDP of the Manufacturing/Industrial and Household sectors from 1983 to 1995 constant prices.*

*c. Hydrocarbons in Manufacturing/Industrial Sector, Transport-Communication Sectors and Household-Commercial Sectors*

$$H_i(t) = 100.960 + 0.0091 \; * GDPi(t)/4.9405 \times (1 - TE_{Hi}(t)) \tag{8.11}$$

$$H_{Tr}(t) = 10^{-1.8773+1.2836*\log_{10}(GDP_{Tr}(t)/3.6620)-0.3074*\log_{10}(P_{HTr}(t))} \times (1 - TE_{HTr}(t)) \tag{8.12}$$

$$H_h(t) = 10^{-7.8007+0.7806*\log_{10}(Income/Cap(t)/2.2946)-0.3147*\log_{10}(P_{Hh})(t)} \times (1 - TE_{Hh}(t)) \tag{8.13}$$

*The equations (8.11), (8.12) and (8.13) are derived from Chapter 5, equations(5.2), (5.10 ) and (5.7) respectively. The numbers 2.294, 3.6620 and 4.9405 are the convertion factors for GDP of the household, transport and industrial sectors from 1983 to 1995 constant prices.*

*d. LPG in Manufacturing/Industrial Sector and Household-Commercial Sector*

$$L_i(t) = 10^{-6.8069+1.8036*\log_{10}(GDP_i(t)/4.9405)} \times (1 - TE_{Li}(t)) \tag{8.14}$$

$$L_h(t) = 10^{-14.0879+2.9798*\log_{10}(Income/Cap(t)/2.2946)} \times (1 - TE_{Lh}(t)) \tag{8.15}$$

*The equations (8.14) and (8.15) are derived from Chapter 5, equations (5.3) and (5.8). The numbers 4.9405 and 2.2946 are the convertion factors for GDP of the industrial and household sectors from 1983 to 1995 constant prices.*

*e. Natural Gas in Manufacturing/Industrial Sector, Transport-Communication Sector, and Household-Commercial Sector*

$$G_i(t) = 10^{-3.4435+1.3178*\log_{10}(GDP_i(t)/4.9405)} \times (1 - TE_{Gi}(t)) \tag{8.16}$$

$$G_{Tr}(t) = -0.3214 + 0.0001 \times (GDP_{Tr}(t)/3.6620) \times (1 - TE_{GTr}(t)) \tag{8.17}$$

$$G_h(t) = 10^{-7.3727+1.3404*\log_{10}(GDP_T(t)/2.2946)} \times (1 - TE_{Gh}(t)) \tag{8.18}$$

*The equations (8.16), (8.17) and (8.18) are derived from Chapter 5, equations (5.5), (5.12) and (5.9) respectively. Tthe numbers 4.9405, 3.6620 and 2.2946 are the convertion factors for the GDP of industrial, transport and household sectors from 1983 to 1995 constant prices.*

### 8.4.1.3 Electric Power Module

The module calculates the total electricity generated by power plant and the sub-modules (electricity scenario modules) project the future annual power generation by energy type by scenario. The main module sums up the total electricity demand from the final demand sectors and the losses occurred in the transmission-distribution system to determine the total electricity generated by power plants. The sub-modules, which contain all the scenarios defined for the study, produces the forecasted annual power generation supply by energy type. The scenarios, which are presented in the form of supply curve, take into accounts all economic, environmental, efficiency and capacity considerations including the future capacity plans by national electricity companies. The scenarios enable the model to determine the estimated amount of power generated by each type of power plant, which is then converted into the amount of energy use to generate the power in P-Joule per year. The technical efficiency of each type of power plant is taken into account in obtaining the amount of energy use to produce power. The Electricity Generation Module also contains the Electricity Generation Costs sub-module. This sub-module calculates the cost of generating electricity by fuel type (power plant). The cost of producing electricity is obtained from the supply curve, which is given for each scenario. The final products of the main module and sub-modules are total energy generated by power plants, electricity generated by each type of power plant for various scenarios, and the cost of producing the electricity by each type of power plant for various scenario.

**Mathematical Specification of Electric Power Module;**

***a. Mathematical Equations of Total Electricity Generated by Power Plants***

$$TotEG(t) = \sum (EG_{process i \ldots n}(t)) \times (1 + TD_{losses}(t)) \quad (8.22)$$

*Where:*

$TotEG$ = total electricity generated by power plants

$EG_{process\ i \ldots n}$ = electricity generated by power plants

***b. Mathematical Equation for Sub-Module Electricity Generation Scenarios***

$$EEG_{process_{i \ldots n}, scenario}(t) = SC_{scenario} \times f(and, else, if, not, or, then)(t) \times (1/TE_{processi_{i \ldots n}}(t)) \quad (8.23)$$

*Where:*

$EEG_{process\ i..n\ ,\ scenario}$ = energy consumption of process i for electricity generation, for each scenario

*And, else, if, not, or, then* = logical functions of an equation for creating expressions and giving values based upon whether the resulting expressions are true or false. These functions are used for calculating EEG using supply curves (electricity generation cost by fuel type). Supply curves are given for each scenario.

c. ***Mathematical Specification of Sub-Module Electricity Generation Costs***

$$EGC_{process_{i..n},scenario}(t) = SC_{scenario} \times f(and,else,if,not,or,then)(t) \qquad (8.24)$$

$EGC_{process\ i..n\ ,\ scenario}$ = electricity generation cost process i..n, for each scenario

### 8.4.1.4 Heat and Transport Fuel Module

The module determines the total amount of fuel use (non-electricity) in the final demand sectors then separates it into two categories; heat fuel and transport fuel. The total amount of fuel use obtained from the summing up of all final demand consumptions from the final demand sectors (the Energy Demand Module) in accordance to the type of fuel (delivered fuels). The module then computes the total delivered fuels to final demand. The transmission and distribution losses are taken into account in obtaining the total delivered fuels. The projected heat and transport fuels are then determined from the total delivered fuels taking into consideration the scenarios designed for future demand for heat-transport use by fuel type. Historical trends of heat and transport fuel demand were used as reference base (Business as Usual) for developing the other scenarios (economic efficiency, environment, self sufficiency and balancing the trade-off) designed for the model. From this module, the projected amount of energy produced by each type of transformation plant (Refinery, CNG, LPG, coal, wood/biomass) then can be obtained.

***Mathematical Specification of Heat and Transport Fuel Module;***

$$H_{fuel}(t) = \sum_{a}^{z} DE_{sp_{i..n}}(t) \qquad (8.25)$$

*Where:*

$H_{fuel}$ = total heat fuels

$$T_{fuel}(t) = \sum_{a}^{z} DE_{sptransport_{i..n}}(t) \tag{8.26}$$

*Where:*

$T_{fuel}$ = total transport fuels

$$DE_{aK\,n,sp_{i..n}}(t) = E_{aK\,n,sp_{i..n}}(t) \times (1 - DL_{aK\,z})(t) \tag{8.27}$$

### 8.4.1.5 Primary Energy Supply Module

The module contains primary energy supply module and primary energy cost sub-module. The primary energy supply module is used for obtaining the total primary energy supply including import-export and indigenous productions. The primary energy supply by energy type is obtained by using the input data from the Heat-Transport Fuel Module, which is the total amount of energy produced from each plant multiplied by the technical efficiency of the producing plant. The projected indigenous energy productions are produced from the analysis of historical trends of energy productions (crude, coal and natural gas) combined with the result of other similar study by the University of Indonesia. The imports and exports of each energy type (crude, coal and natural gas) are then simply calculated from the total primary energy supply minus indigenous energy production. The primary energy cost sub-module calculates the primary energy supply cost for each type of energy and for the total cost of primary energy supply.

**Mathematical Specification of the Primary Energy Supply Module**

***a. Mathematical Equations of Primary Energy Supply Module;***

$$E_{a..z,prodplant}(t) = (E_{a..z,electricity}(t) + E_{a..z,heat}(t) + E_{a..z,transp}(t)) \times (1/Efp_{a..z}(t)) \tag{8.28}$$

$$E_{a..z,export/import}(t) = IndiE_{a..z,prod}(t) - E_{a..z,prodplant}(t) \tag{8.29}$$

$$IndiE_{a..z,prod} = Graph(time) \tag{8.30}$$

Indigenous energy production type is specified as as a function of time for the study period 1998 to 2020

***b. Mathematical Specification of Sub-Module Primary Energy Costs***

$$E_{a..z,supplycost}(t) = E_{a..z,supply}(t) \times PC_{a..z}(t) \tag{8.31}$$

#### 8.4.1.6 Environment Module

Environment Module is used for calculating the total amount of pollutants emitted by the energy-economic system during the period of the study. The model uses the data of primary energy supply by energy type from the Module of Primary Energy Supply to estimate the amount of pollutants by energy type. The coefficients of emission from each type of fuel are obtained from some literatures and assumed that they can be relevant for the Indonesian case. There are 6 categories of pollutants determined by this environment module, i.e. $CO_2$, CO, $NO_x$, $SO_2$, Particulates, and HC.

**Mathematical Specification of Environment Module;**

$$CO_2(t) = \sum_{a}^{z} CoefCO_2 \ * E_{a..z,\text{supply}}(t) \tag{8.32}$$

*Where:*

$CO_2$ = total carbon dioxide emission

$CoefCO_2$ = coefficient emission $CO_2$

$$CO\ (t) = \sum_{a}^{z} CoefCO \ \times E_{a..z,\text{supply}}(t) \tag{8.33}$$

*Where:*

$CO$ = total carbon monoxide emission

$CoefCO$ = coefficient emission CO

$$HC\ (t) = \sum_{a}^{z} CoefHC \ \times E_{a..z,\text{supply}}(t) \tag{8.34}$$

*Where:*

$HC$ = total hydro carbon emission

$CoefHC$ = coefficient emission hydro carbons

$$NO_x(t) = \sum_{a}^{z} CoefNO_x \ \times E_{a..z,\text{supply}}(t) \tag{8.35}$$

*Where:*

$NO_x$ = total nitrogen oxide emission

$CoefNO_x$ = coefficient emission $NO_x$

$$Pm\ (t) = \sum_{a}^{z} CoefPm \times E_{a..z,\text{supply}}(t) \tag{8.36}$$

*Where:*

$Pm$ = total particulate matter emission

$CoefPm$ = coefficient emission Pm

$$SO_x(t) = \sum_{a}^{z} CoefSO_x \times E_{a..z,\text{supply}}(t) \tag{8.37}$$

*Where:*

$SO_x$ = total sulphur oxides emission

$CoefSO_x$ = coefficient emission $SO_x$

### 8.4.2 Endogenous and Exogenous Variables

The system dynamics model of the Indonesian energy system consists of two variables endogenous and exogenous variables. *The Endogenous variables* of the model are defined as those variables that are part of the system or variables that are directly influenced by or influence the behaviour of the system or sub-system. *The exogenous variables* of the model are characterized by variables unlikely to be affected strongly by the development of the energy-environment system. Followings are the examples of endogenous and exogenous variables of the model.

**Examples of endogenous variables of the model**

*Fuel-type:* is the endogenous variable that is calculated by the model. The input fuel types are further divided into primary energy inputs and consumer energy inputs. Primary energy inputs are crude oils, hydroelectricity, geothermal, coal, natural gas, combust.-wood/biomass and consumer energy inputs are delivered gas, delivered coal, delivered electricity, delivered hydrocarbons, delivered coal, delivered geothermal etc.

*Sector output;* is the endogenous variable that is calculated by the model. The outputs of 19 economic sectors are aggregated into 13 main sectors. This sector output or defined as Gross Domestic Product of the sector drives the sectoral demand for energy. The sectors are agriculture, live-stock and product, forestry, fishery, mining and quarrying, food-beverage-others, petroleum-electricity-gas, construction, trade, restaurant-hotel-commercial, transport-communication, finance-business services, other services.

*Export or import;* is the endogenous variable that is calculated by the model. These are the subtraction of commodity outputs and commodity inputs. The negative result is the indication of imported commodity, while the positive result is the sign of exported commodity. The commodities that are exported or imported are agriculture, live-stock and product, forestry, fishery, mining and quarrying, food-beverage-others, petroleum-electricity-gas, construction, trade, restaurant-hotel-commercial, transport-communication, finance-business services, other services.

**Examples of exogenous variables of the model**

*Energy price*: is the first exogenous variable that is entered into the model. Energy price comprises of primary energy price, consumer energy price and secondary energy costs. The primary energy price includes the price of coal, natural gas, crude oil, wood-biomass, the consumer energy price includes the price of hydrocarbons, electricity, LPG, coal, gas etc, and secondary energy cost covers the production costs of secondary energy like electricity generated from hydro, geothermal, hydrocarbons, natural gas, coal etc.

*Technical efficiency:* is another important exogenous variable that is entered into the model. Technical efficiency is the energy efficiency that can be improved by improvements in equipment or appliances technology in the end-use as well as supply sectors including transmission and distribution sector. The technical efficiency includes the efficiency of household appliances, energy using equipments in industrial sectors, efficiency of vehicles in transport sector, efficiency of various power generating plants, efficiency of energy production plants etc.

### 8.4.3 Time Frame

This research applies the time frame of 22 years covering the period 1998 to 2020, with the base year of 1998 for the study. The selection of this time frame was based on several considerations as follows;

*First,* the selection of 1998 to 2020 term of study is in line with the path of national policy plans, either short-term plan or long-term plan. The Indonesian long-term development plan is developed every 25 years long-term period, which divided into 5 development periods, each of which is 5 years short-term plan. The first 25 years long term national plan was started in 1969/70 and ended in 1995/1996. In this way, the selection of the time-frame which is started from 1998 to 2020 accommodates the national interest on long-term energy-economic and environmental policy planning;

*Second,* the 22 years time frame is just the right or suitable period for the modelling approach which allow exploratory and experimentation of study about a range of possible future, policy implications. This time frame allows or accommodates the need for observing the impact of changes of energy technology, demography, life-styles, investment decision, other policy decision, and draw solutions and policy alternatives to deal with the possible problems.

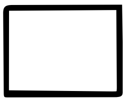
## 8.5 Operationalisation of the Model in STELLA

In building the dynamic energy simulation model for policy analysis, the author used STELLA software. The use of STELLA software was selected for two main reasons; first, STELLA provides a relatively useful method for the array programming especially for the two-dimensional arrays operation required in building the Input-Output Economic Module. Secondly, STELLA also provides more sophisticated graphical presentations and displays which enable the users to quickly do the simulation and see the simulation results in clear images. It provides a more clear and instant pictures of the changes in policy variables during the simulation process. This section discusses four main topics i.e STELLA Nomenclatures, STELLA Diagrams of Each Module, STELLA Inputs, and STELLA Outputs. The purposes of discussing the above topics are; to give basic information about the features of STELLA operation, to show the main structures of the dynamics energy model in STELLA forms and to illustrate some examples of the model' inputs and outputs.

### 8.5.1 Stella Nomenclature

This section briefly describes some of main features and operation of STELLA software; stocks, flows, converter, connecter, graphical input devices (GID), numeric display, sector frame and arrays function as follows;

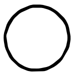
**Stocks**



Stocks are accumulations. They collect whatever flows into and out of them. Stock accumulates its inflows, minus its outflows. Any units, which flow into a stock will lose their individual identity. Stocks mix together all units into an undifferentiated mass as they accumulate.

Flows

Flows fill and drain accumulations. The unfilled arrow-head on the flow pipe indicates the direction of the flow.

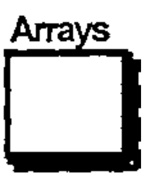


Converter

Converter serves a utilitarian role in the software. It holds values for constants, defines external inputs to the model, calculates algebraic relationships, and serves as the repository for graphical functions. In general, it converts inputs into outputs. Hence, the name "converter"

Connector

Connector, as its name suggests, has the job to connect model elements




Arrays provide a very powerful mechanism for managing the visual complexity associated with respective model structures. In addition, arrays make it possible to easily construct and modify very detailed models.

### 8.5.2 STELLA Diagrams of Each Module

This section presents the diagrams of main modules of the dynamics model of the Indonesian energy systems. The description and explanation of each diagram is discussed in section 8.4.

**Economic Module**

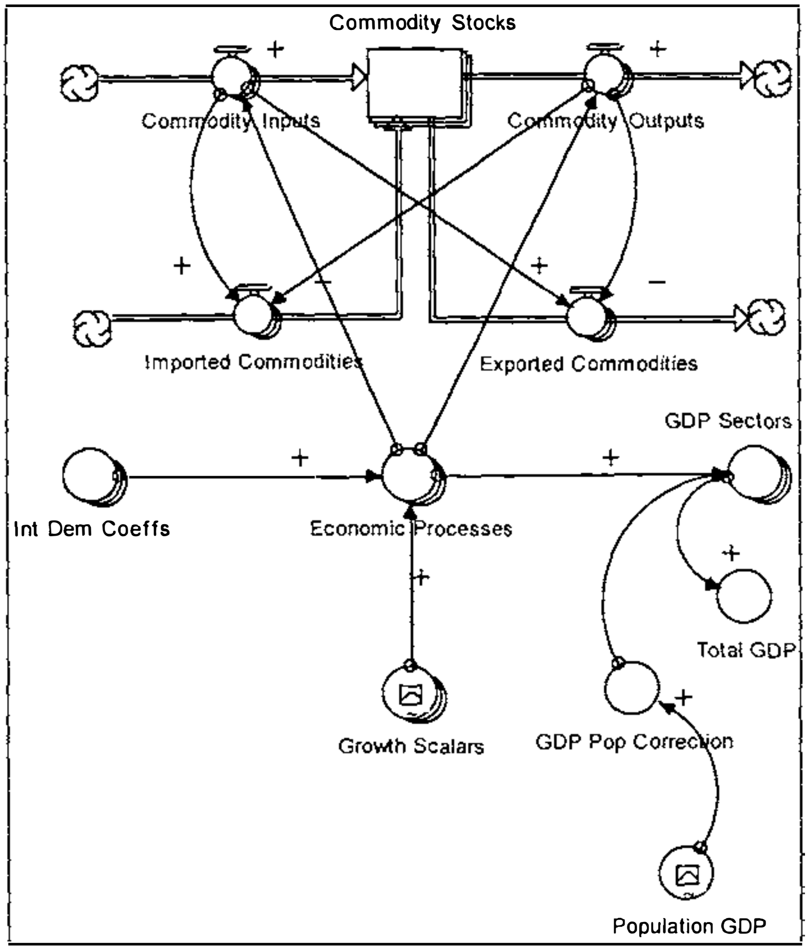



**Figure 8.2 Economic Module of the System Dynamics Model of the Indonesian Energy System**

## Energy Demand Module

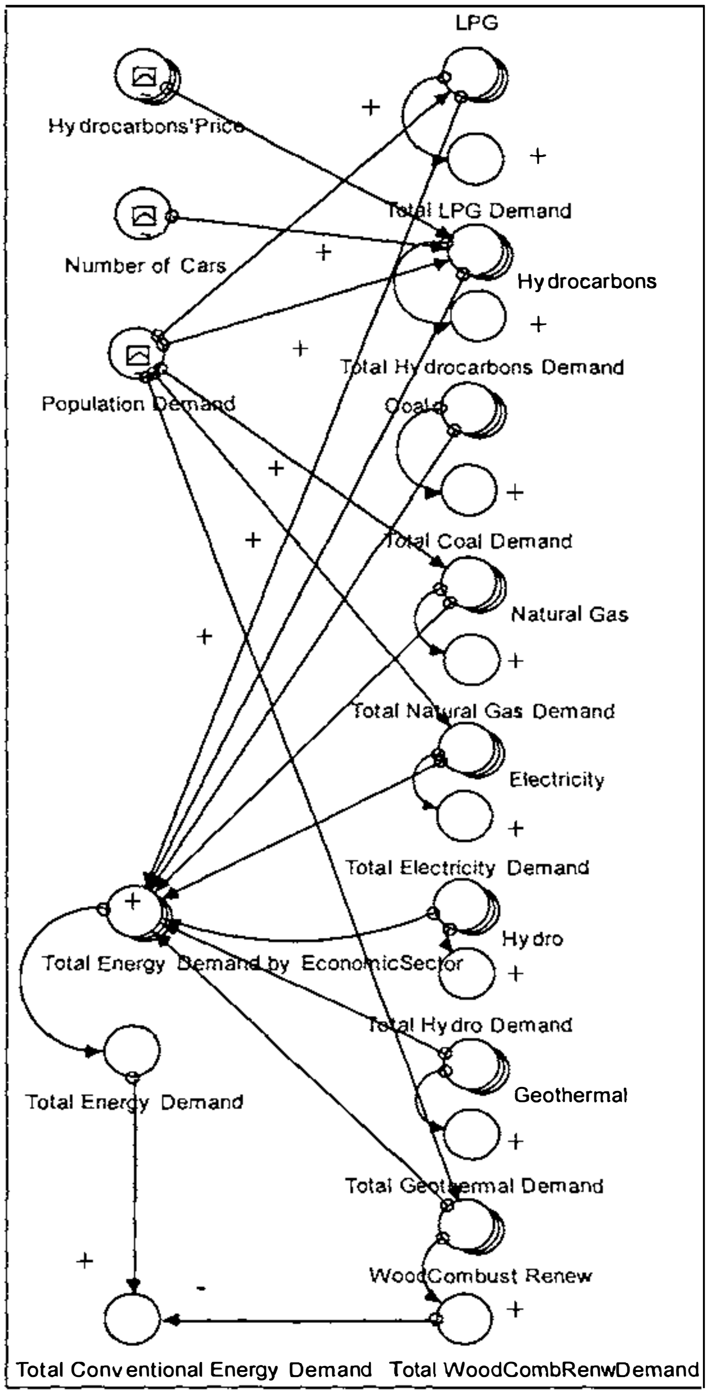



**Figure 8.3 Energy Demand Module of System Dynamics Model of the Indonesian Energy System**

## Electricity Generation Module

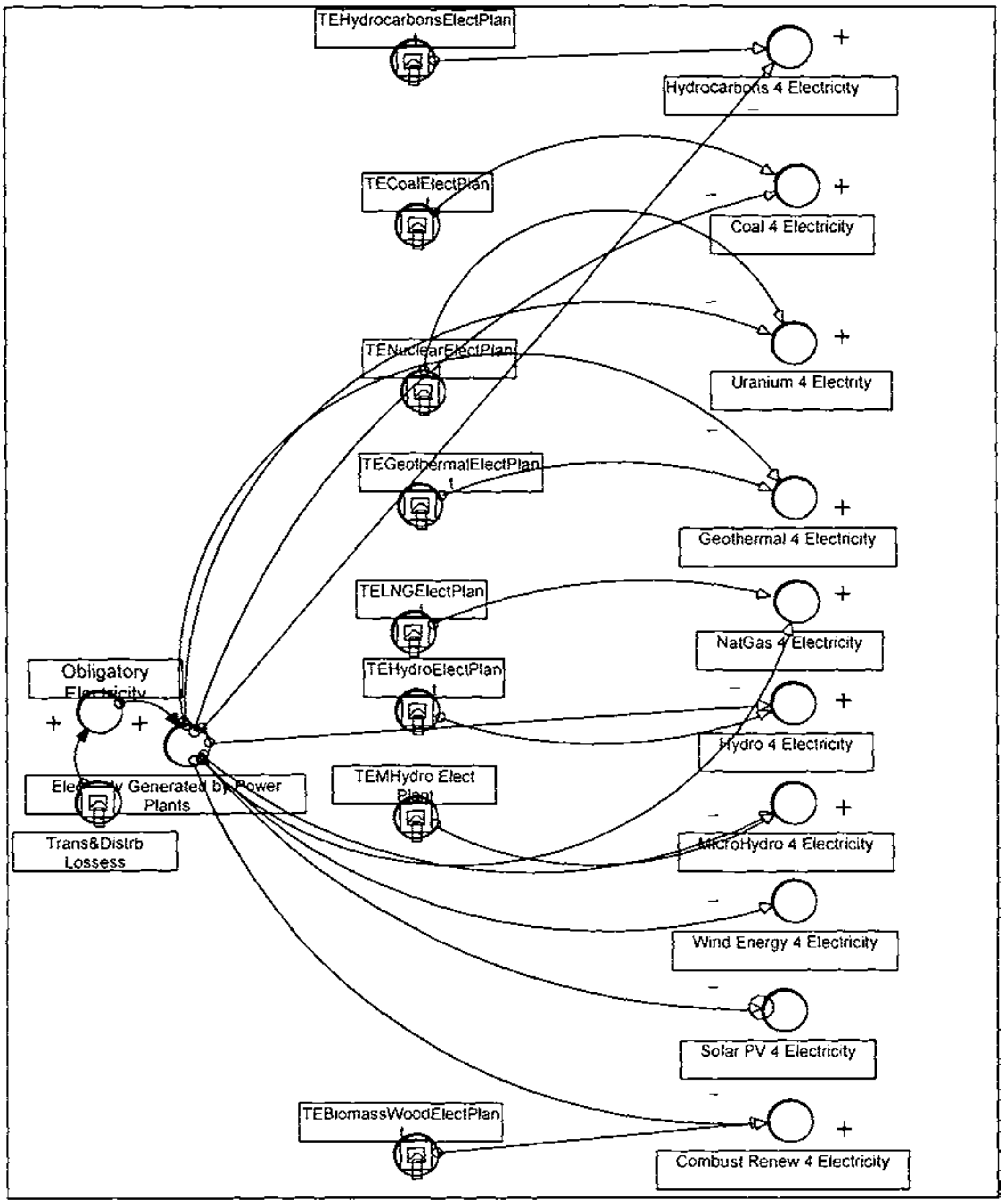



**Figure 8.4 Electricity Generation Module of the System Dynamics Model of the Indonesian Energy System**

## Heat and Transport Fuels Module

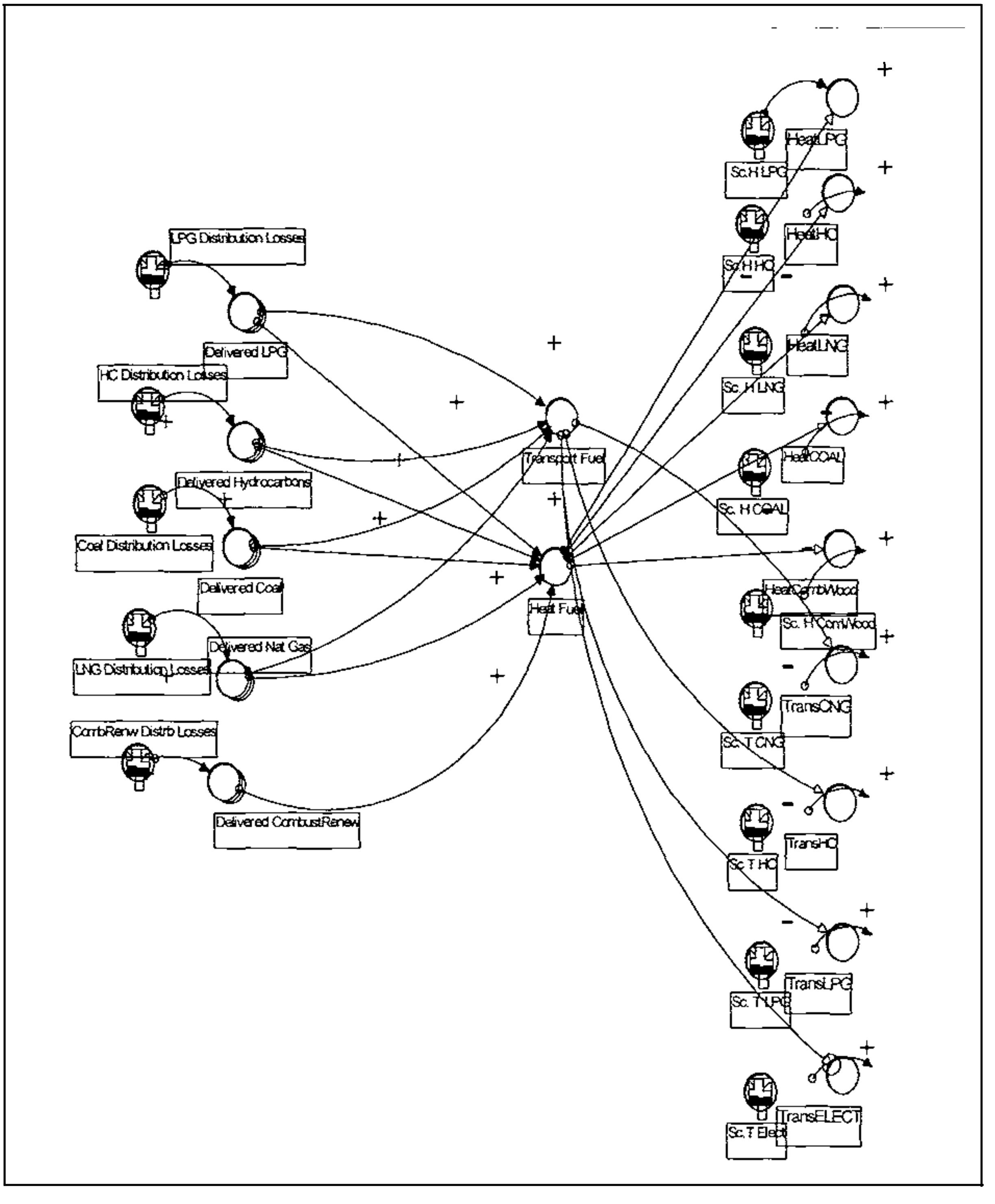



**Figure 8.5 Heat and Transport Fuel Module of the System Dynamics Model of the Indonesian Energy System**

**Primary Energy Supply Module**

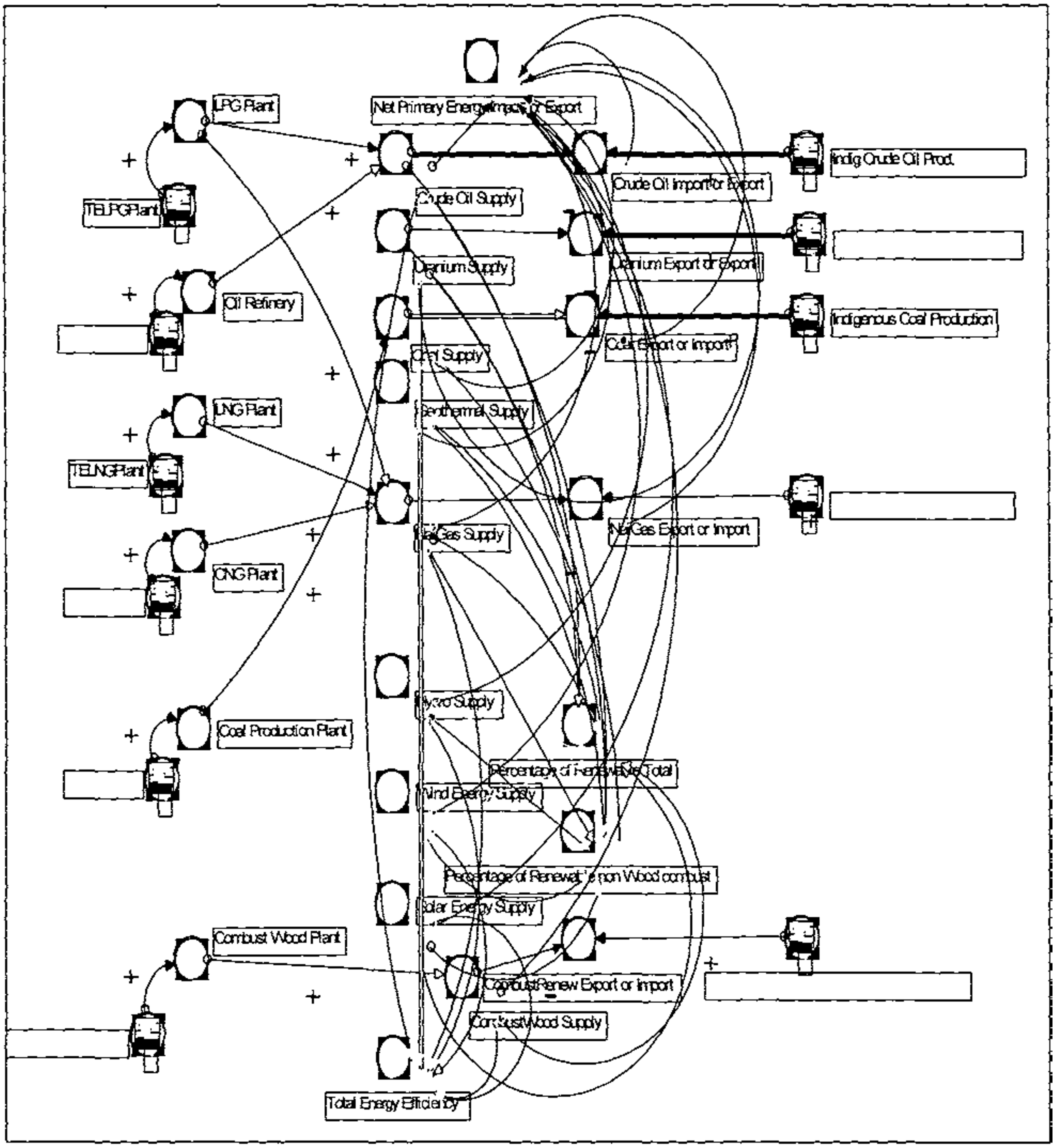



**Figure 8.6 Primary Energy Supply Module of System Dynamics Model of the Indonesian Energy System**

**Environment Module**

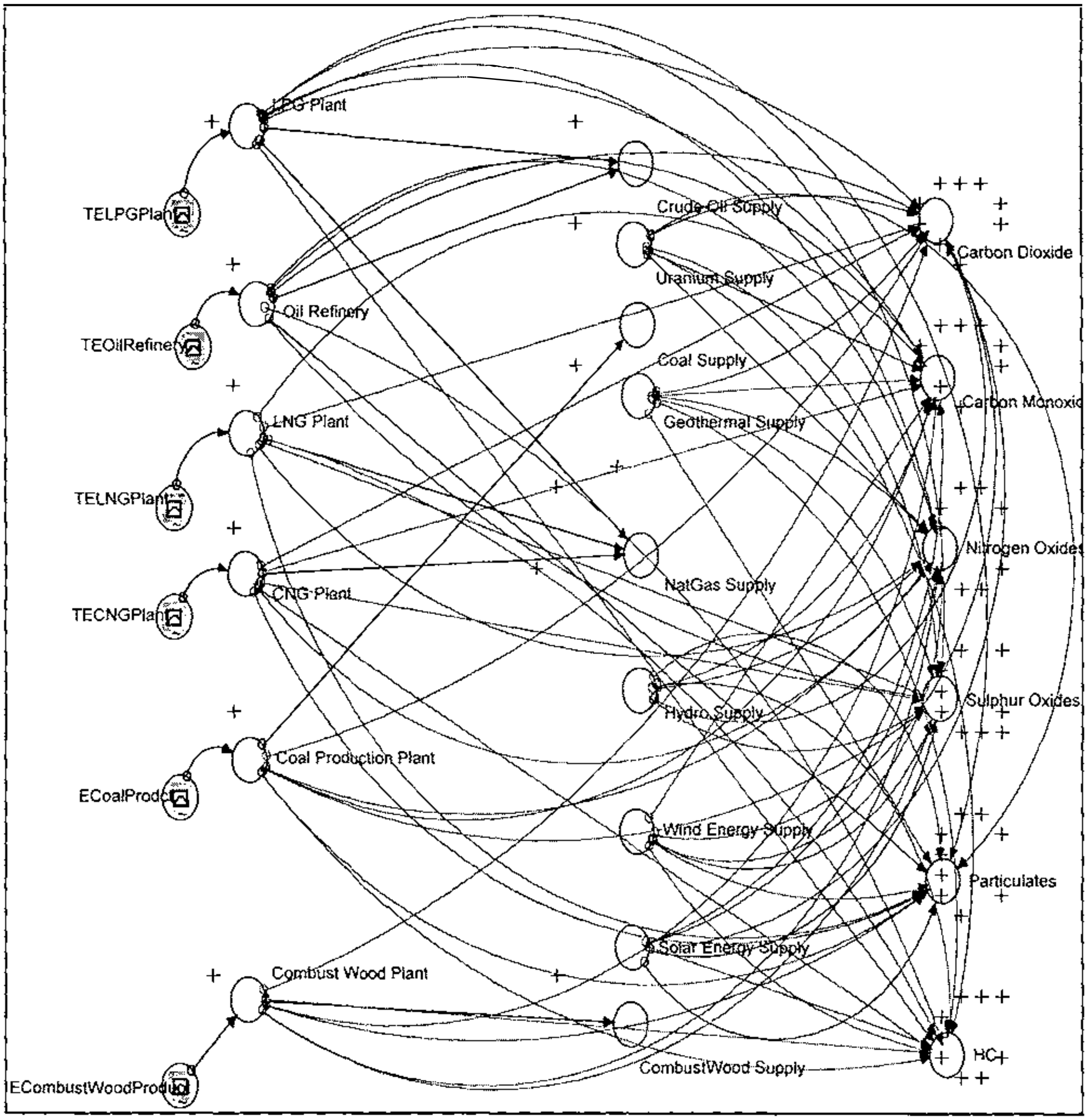



**Figure 8.7 Environment Module of the System Dynamics Model of the Indonesian Energy System**

### 8.5.3 Stella Inputs

The following are the examples of exogenous inputs to the model. The model will pick the input values of each variable in accordance to the requested projected results or indicator variables. All of the inputs to the model can be changed or simulated to assess the effects or sensitivities of variable changes to the model's outputs.

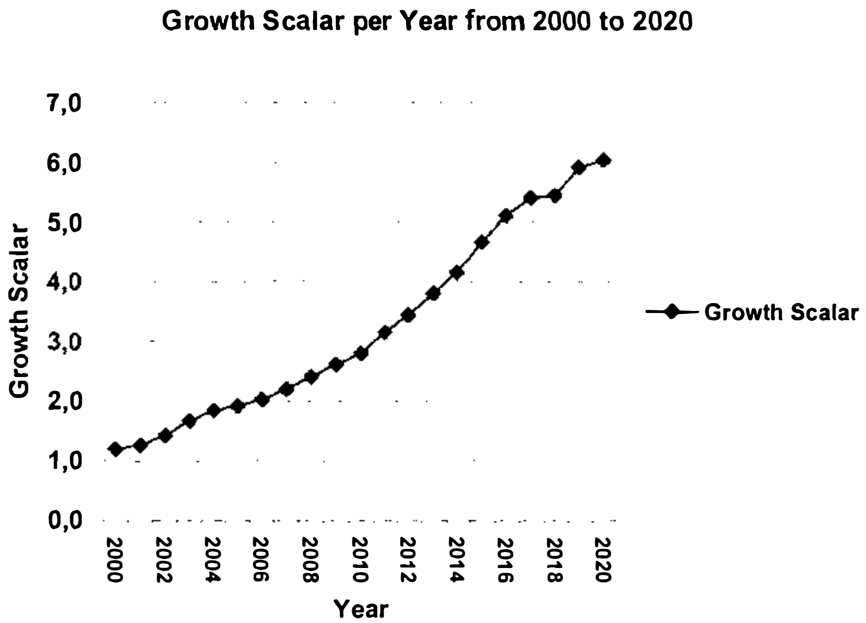



**Figure 8.8 Growth Scalar for the Manufacturing Sector in the Indonesian Energy Model**

The input of the growth scalar, which is the same as the growth of sector activity drives the GDP of the respective sector. The inputs of the growth scalar are given for all sectors that are covered in the model. They are given in time series over the time horizon of the study from 2000 to 2020. The growth scalars for industry/manufacturing sector assumed in the model as given in the above example are ranging from 1.2 to 6.04 taken from 1995's Input-Output table of the Indonesian Central Bureau of Statistic. These future growth scalar inputs are the business as usual scenario derived from the past 20 years of the average GDP trends of 5 countries whose GDPs resemble the current Indonesian GDP. This trend is assumed to be the Indonesian GDP trend for the next 20 years. This input, which is given in the form of graphical input device (GID), enables the user to change the value of Y (growth scalar) and to do the animation for the model simulation at any time of from year 30 (or 2000) to year 50 (2020).

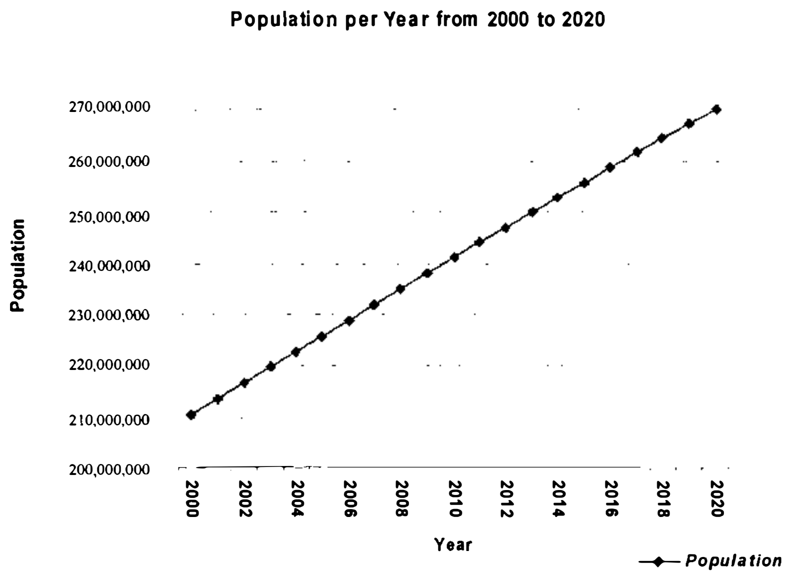



**Figure 8.9 Input of Population Projection into the Indonesian Energy Model**

The input of Indonesian population to the model for the next 20 years (2000 to 2020) is determined from various sources, especially from the CBS (The Indonesian Central Bureau of Statistic) and the assumptions taken from other's energy model (MARKAL) and University of Indonesia (LPEUI, 2003). The trend is assumed to be the continuation of the past trends (1970 to 2000). The population growth of Indonesia is projected to increase by 1.45 % in year 2000 and by 1.09 % in year 2020 which causes the population to increase from 210 Million in 2000 to 270 Million in 2020. The input on population influences the GDP and drives the demand for energy in the demand module.

The input of hydrocarbons prices are given for sectors; industry, transport, and household. The example given below is for transport sector (see Fig. 8.10). The price input for the transport sector is determined or calculated from the combination of various sources and energy studies (IEA, MARKAL, BATAN and UI) and assumed as a 'Business as Usual' price scenario for the next 20 years' period (2000 to 2020).

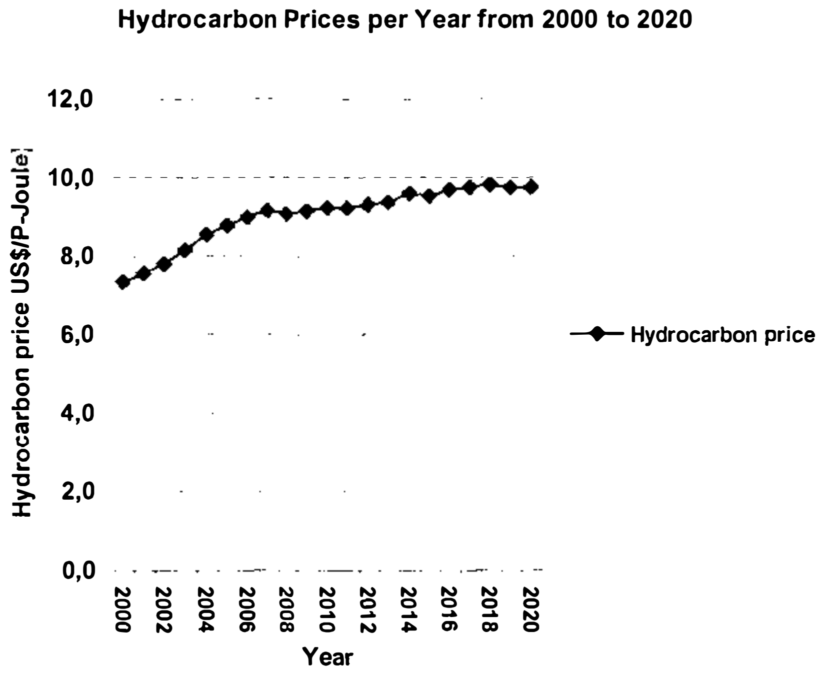



**Figure 8.10 Input of Hydrocarbons' Price into the Indonesian Energy Model**

The future prices of hydrocarbons in transport sector are assumed to increase from 7.35 (2000) to 9.75 Billion Rupiahs/P-Joule (2020). The faster rate of price increases (about 4% per year) are assumed to occur in early years (2000 to 2006) as currently the government is implementing the gradual removal of subsidies for hydrocarbons prices which will take another 3 years (perhaps until 2006).

The number of cars and motorcycles is one of the determinants of energy demand in the transport sector. However, based on the analysis done for the study, the cars' number variable is not a significant one (refer to chapter 5). The input of number of cars and vehicles is given in the model from year 2000 to 2020. The future trends are assumed to be the continuation of the historical data trends taken from the Indonesian Central Bureau of Statistic. The growth of the numbers of vehicles (cars and motorcycles) is assumed to be almost 7 % annually from year 2000 to 2020 (see Fig. 8.11).

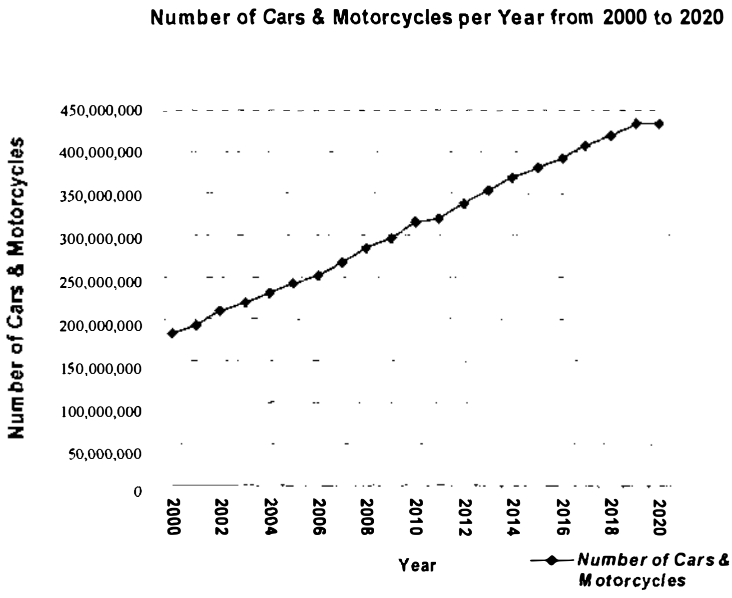



**Figure 8.11 Input of Number of Cars and Motorcycles into the Indonesian Energy Model**

### 8.5.4 Stella Outputs

This section shows several examples of Stella Outputs of the Indonesian Systems Dynamic Model. The following four (4) examples are taken randomly for the purpose of providing an illustration on the type of outputs that STELLA can produce (see Fig. 8.12, 8.13, 8.14 and 8.15). This section does not discuss or explain the model outputs since a more detail explanation on STELLA output is given in Chapter 9 which discusses the model results and analysis. The Stella outputs can be obtained either in the tabular or graphical forms. The following are some examples of the model's outputs given in the graphical forms. The vertical axis (Y) is the value of outputs and the horizontal axis (X) is the study period (from year 2000 to 2020).

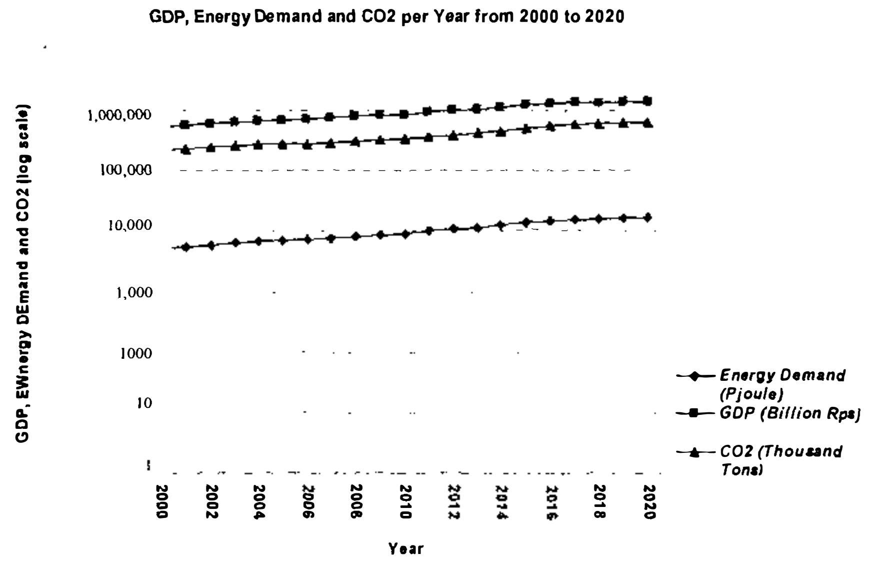



Figure 8.12 Stella outputs of GDP, Energy Demand and Carbon Dioxide ($CO_2$)

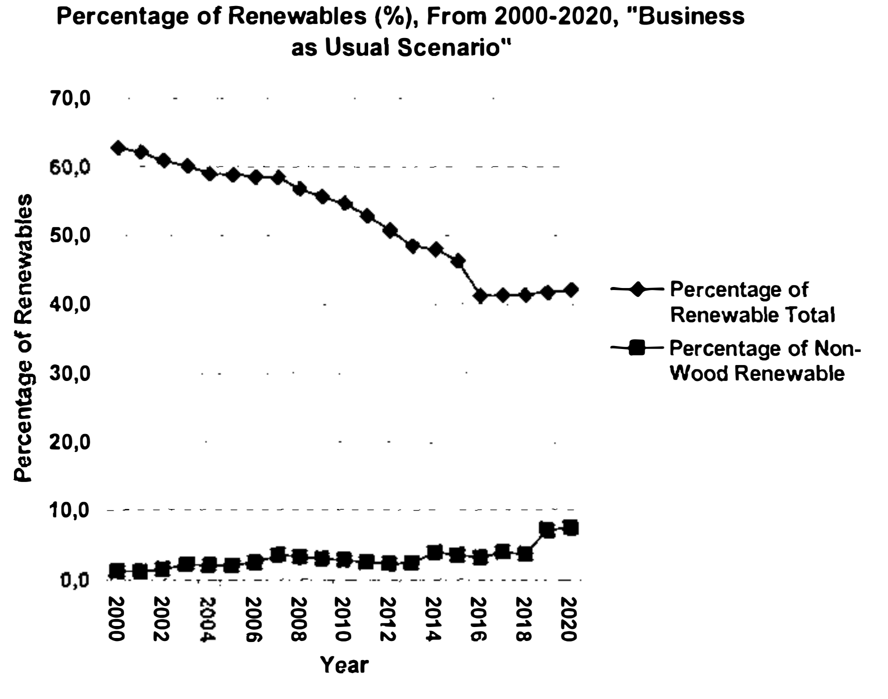



Figure 8.13 Stella Outputs of Percentage of Renewable (Non Wood and Total Renewable)

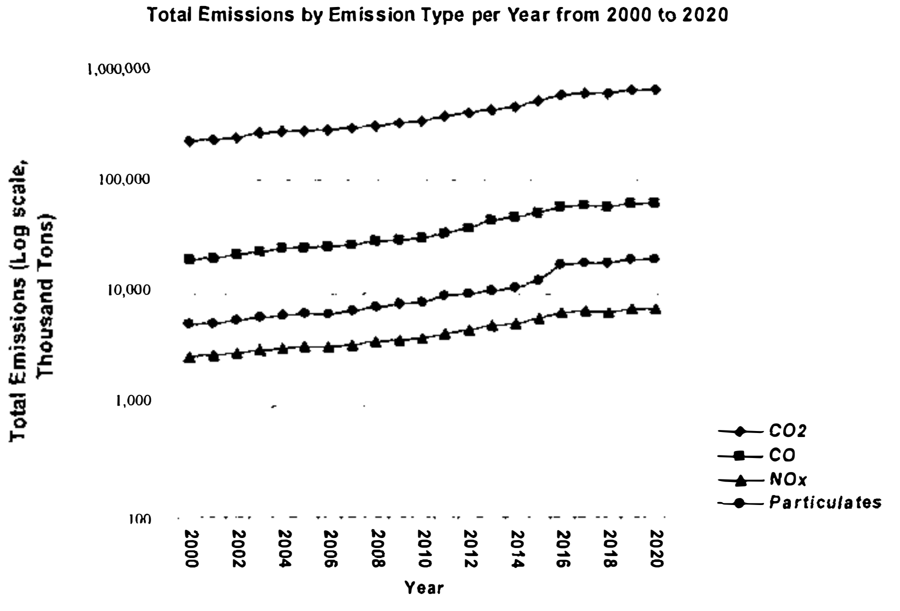



**Figure 8.14 Stella outputs of Total Emissions by Emission Type**

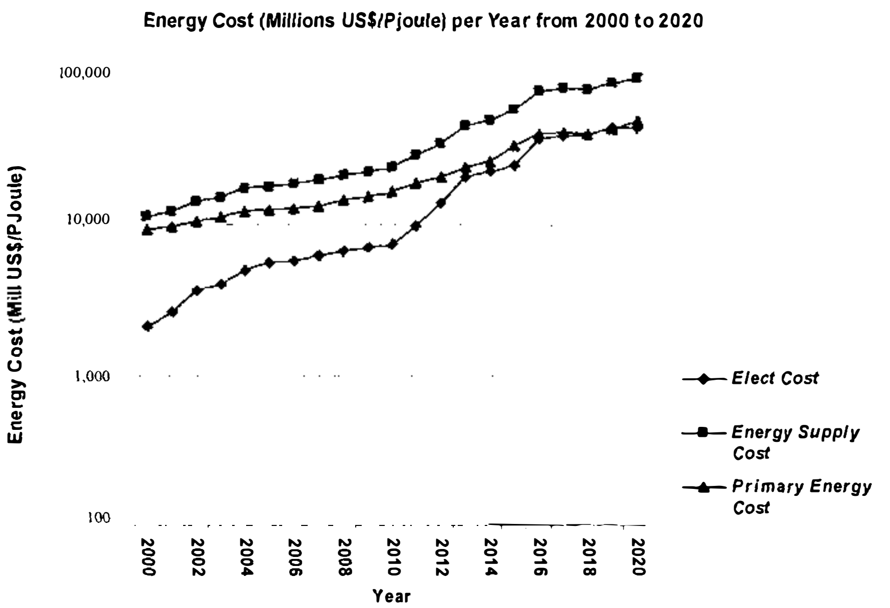



**Figure 8.15 Stella outputs of Energy Costs**

## 8.6 Validation and Testing of the Model

It is important to test and validate models. Model testing and validation discussed in this section is the matching of the model results with the real system. The validation of system dynamic models is

> *"... a consistent, internal logical structure of a model, whilst verification refers to the various ways in which a model's behaviour can be compared with the real word system"* (Mofatt, 1991, pg 30).

Model validation has 2 important aims *First,* providing good statistical information on the certainty, and therefore the accuracy with which decisions based on the model may be made. According to Kelton and Law (1991), if a model is not a "valid" illustration of a system being study, the model results, no matter how impressive they look like, will serve little useful information about the real system. *Second,* the validity of a model needs to be tested for the model suitability for a particular objective. A model can be labelled a robust and defendable model if it achieves what it was prepared for (purpose). If validity serves only as an abstract concept divorced from purpose, it has no useful meaning (Sterman (1984) quoted by Emshoff, J and Sisson R. (1970)).

This section discusses the methods of model testing and validation of system dynamics model. Second, discusses the testing and validation carried out for the system dynamic model of the Indonesian energy system.

### 8.6.1 Methods of Testing and Validating System Dynamics Models

Mofatt (1991) identifies that there are two broad categories of model validation: model structure validation and model behaviour validation.

**Model Structure Validation**

There are three different ways of testing the model structure. First, *structure validation*; a model structure is referred as suitable if it is internally consistent with the assumptions it is based on and when the causal structures contains the keys feedback loops for describing the way in which the model and the real system function. There are two main situations that are required to be satisfied in a good model; the model should be able to describe the behaviour of the system satisfactorily; and the alteration of policy options inserted into the model create the changes in the simulation forecast that closely follows changes in the real world systems. Second, *boundary adequacy*; the model boundary is described as adequate if the model builder is convinced that all key interactions through feedback loops essentially replicate the behaviour of the real world system. Third, *extreme conditions and dimensional consistency;* this test primarily consists of judging the implications of putting imaginary minimum and maximum values of each state variable or combination of state variables which influence a rate equation. If it gives the results that are closely consistent to the real world system then the model can be judged as reliable. In addition, in any model it is essential that the dimensions of the state variables and parameters are correctly specified and consistent. Failure to confirm this basic and important test may cause serious uncertainties in the structure of the model (Mofatt, 1991).

**Model Behaviour Validation**

In testing the model behaviour, there are three categories of methods, i.e. parameter verification and sensitivity, behaviour reproduction and forecasting, and changed behaviour forecasts (Mofatt, 1991). First, *parameter verification and sensitivity*; there are three types of parameters that need to be verified, initial values, other constants and table functions. The initial values should be based upon the most reliable and accurate data available. Similarly, the coefficients, which are assumed to be unchanging during the simulated time period ought to be as accurate as possible. The table-functions, which can be linear or non-linear relationships, are obtained using curve fitting procedures such as linear or non-linear regression. The best-fit curves should be selected for the table functions. *Parameter sensitivity* tests can be described as operating a simulation model by sequentially changing one or more parameters in the model and then contrasting the model output to determine the impacts of the changes. Second, *behaviour reproduction and forecasting*; This is a method that tries to imitate the behaviour of a specific system of interest. This behaviour reproduction is aimed at replicating the magnitude, turning points and interval of the state variables in a system. If the historical path of the state variables is simulated with reasonable level of accuracy then an unconditional forecast may be made. Third, *changed behaviour forecasts;* this method is useful to determine the response of the real system to policy actions. The policy options entered into the model will give rise to the changing behaviour of the systems being studied, this is referred to as changed behaviour forecasts. These new policy options may change the path of the conditional forecasts in different ways. The best of the alternative policy options to influence a desired change can be selected by means of simulating various alternative scenarios (Mofatt, 1991).

In a model used for policy analysis, some model builders argue that the model structure and model behaviour are judged as valid not only in the eyes of the modeller alone, but also in the opinion of the stakeholders and decision makers. That is why it is very important to involve the stakeholders and decision makers who will implement the policy options from the beginning of the model building (Mathias, 2003). However, some may argue that for either the practicality (e.g. time and budget constraints) and the confidentialities of the data or information provided in the model, this may not be an easy task to be implemented.

There are limitations, however on the model testing and validation, which is partly due to the fact that some systems may be rather ill defined and, at the same time, is extremely complex. In addition to that, it is difficult, if not impossible to collect a large amount of data, covering a broad range of details, which are required to accurately validate a complex model. As a result some data are required to be aggregated which may influence the validation results.

### 8.6.2 The Testing and Validation of the System Dynamic Model of the Indonesian Energy System

The validation of model structure and model behaviour carried out for this model involves various parameters and indicator variables in each module, right from economic module through supply module including the parameters in the environment module. Due to the complexity of structure of the energy-economy-environment system being modelled, the validation was carried out step by step basis following the completion of each module. Then the overall structure and behaviour of the model were tested after the whole structures were completed.

Followings are two example of methods of behaviour validation; 1) back casting the model results and compare them with the real or historical patterns and 2) testing the results of future scenarios and compare them with the forecasted results of the other models, in this case the results of MARKAL, and other models developed by other energy related institutions.

Section 8.6.1 provides an example of back casting validation where the model results of hydrocarbon demand in Industrial/Manufacturing sector are compared with historical data. Hydrocarbon demand in the Industrial/Manufacturing sector is chosen as a parameter for testing the validity of the model because the demand for hydrocarbons in this sector has been the highest among all others sectors (transport and household) over the past three decades (1970 to 1998). Section 8.6.2 discusses two examples of testing the results of future scenarios, i.e. GDP (gross domestic product) and total electricity generation. The reason behind the selection of the GDP parameter for future testing is because GDP has been (in the past) and is still the main driver in shaping the future demand for energy in Indonesia.

#### 8.6.2.1 Back Casting

Figure 8.16 below shows the model's result on the back casting of hydrocarbon demand in industrial/manufacturing sector as compared to the real/historical values during the same time horizon. There are two periods of back casting; 1977-1984 and 1993-1997 that do not match the model's results. There are some other factors other than GDP than affected the demand of hydrocarbon in industrial sector during these two periods in the past, perhaps the first and second oil shocks occurred in 1973 and 1986 have caused domestic oil windfalls and acceleration of domestic revenues from oil and gas export, which accelerate economic activity in industrial/manufacturing sector. However, these factors were not significant enough to be taken up by the model. Since the average trend of the model result follows the average trend of the real values and the model correctly specifies the decline in post 1998, it can be concluded that the back casting of model's result matches the normal trend of the real system. In this way, the validation is regarded as fulfilling the expectation for model's accuracy.

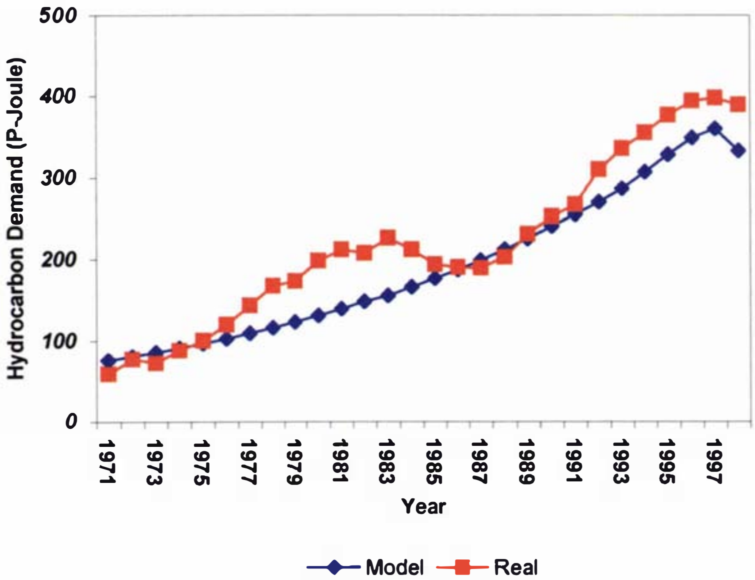



**Figure 8.16 Hydrocarbon demand in Industrial/Manufacturing Sector (Peta-Joule, Back Casting)**

### 8.6.2.2 Testing Future Scenarios

**Testing the future GDPs**

The figure below (fig. 8.17) shows the projected GDPs of the Model as compared to the results of projection of two other studies, MARKAL (BATAN Study Report, 2001) and University of Indonesia (Study Report, 2000) over the same time horizon (2000-2020). The result of a study by MARKAL shows a higher GDP growth than the model's result even though MARKAL assumes annual population growth of only 0.86 percent in average (2000-2025), whereas UI's study shows a slightly lower GDP growth than the model's result and UI applies annual population growth of 1.56 percent per year. However, the results of the three studies do not really show much difference in term of GDP values, which are ranging between 1500000 to 1700000 Billion Rupiahs in 2020. This validation result using the GDP parameter suggests an adequate accuracy of the model.

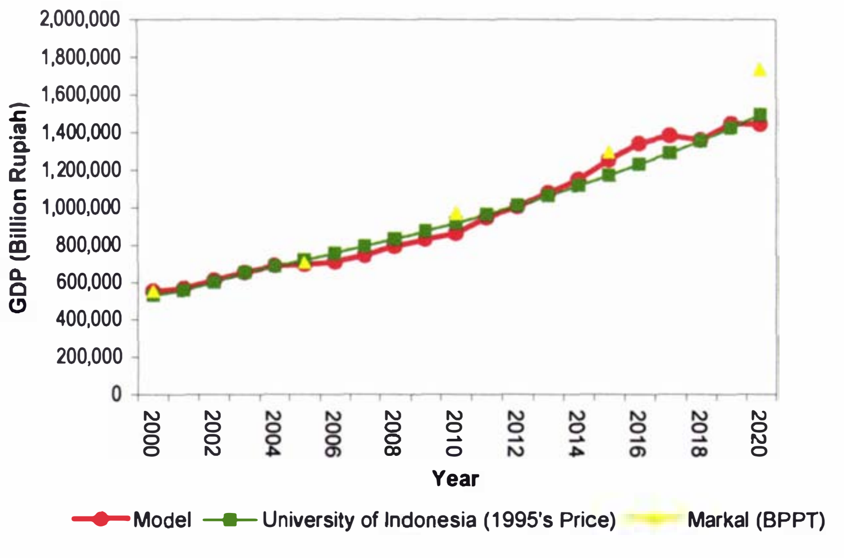



**Figure 8.17 Gross Domestic Product (GDP) in Billion Rupiah, 1995's Price (Forecast)**

**Testing the future Total Generated Electricity**

The figure below (fig. 8.6.2.2.) shows the model result on the projections of electricity generated by power plants during 2000 to 2020. The values of projected electricity by the model closely match the study's result conducted by JICA/PLN (National Electricity Company) and MARKAL especially during early period of study (2000 to 2010). However, during the later years of the study period (2015 to 2020) the projected figures closely match the results of University of Indonesia's study. The differences in future GDP's scenario clearly cause the above differences. The model assumes higher growth of GDP during 2010 to 2016 (7 to 9 percent growth rate) as compared to MARKAL (BATAN)'s study which assumes only about 6 percent GDP growth rate during the same time horizon. From the above figure, it is assumed that the model's future projection has met the reasonable level of accuracy for policy analysis.

In conclusion, the examples given on validity and testing on the model results as discussed above has met the requirements for model suitability for policy analysis. It is advisable, however, for future works, to redo a step by step validation tests (structure and behavioural tests) as more data and information required are available.

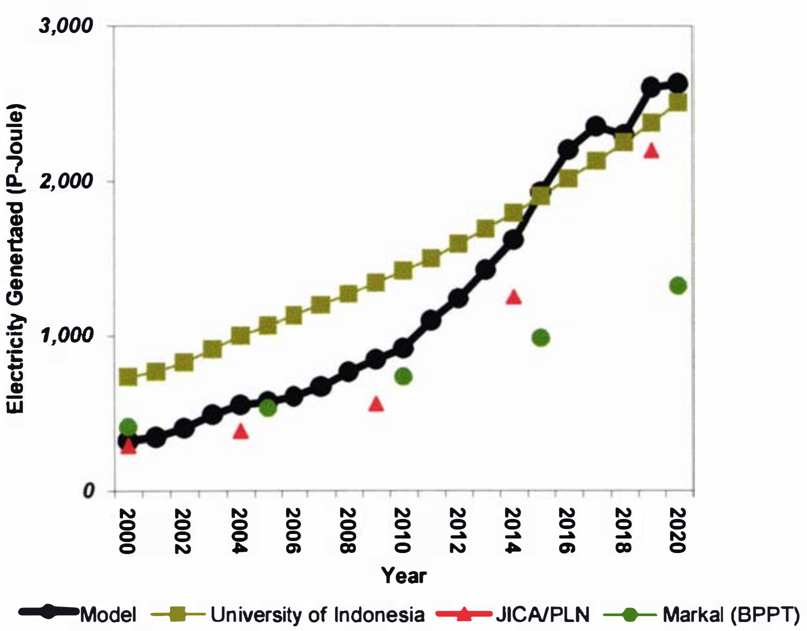



**Figure 8.18 Total Electricity Generated by Power Plants in Indonesia (Forecasted, P-Joule)**

## 8.7 Conclusion

Development of Indonesian energy modelling in the past was very limited and has not accommodated a dynamic approach to policy and environmental changes. In principle, there are three categories of model that have been developed or being developed in Indonesia so far. There are in principle three categories of modelling approaches being developed in the country. *The first category* is a simple regression and forecasting method for developing energy demand and supply analysis; *the second category* is a static and deterministic simulation modelling approach and *the third* category is currently being developed in Indonesia is an optimisation modelling approach. The MARKAL (market allocation) model uses this approach.

It is argued in this thesis that these three categories of modelling approaches that the national institutions are developing are considered as inadequate. This is mainly because of the reason that the country's energy problems are becoming more complex and difficult to manage. The system dynamics modelling approach seems to offer an important answer to the future energy policy formulations and planning problems of Indonesia. The method helps the policy analyst to understand the complexity of dynamic systems and their behavioural patterns, which are changing with passing time and provides a range of possible solutions to deal with the future emerging problems.

A system dynamics simulation modelling approach offers more advantages to Indonesia than other approaches. It allows the users to study and to conduct experiments on the internal interactions of a complex system and or its subsystems. With this dynamic simulation model all the informational, organisational, environmental (policy and regulation) changes can be altered and simulated and the effects of these changes on the model's behaviour can be observed and studied. The system dynamic energy simulation modelling is a valuable and powerful tool for policy analysis not only in the energy sector, but also in the economic and environment sectors because it can accommodate more than one system. Moreover, it is not a black box policy analysis tool. It can accommodate a broad range of supply-and demand technologies and flexible scenario approaches and results analysis.

Despite its various advantages, there are also *some limitations* of this dynamic simulation modelling approach that need to be addressed. The limitations can be categorized into three groups; *theoretical, practical and data limitations.*

*Theoretical limitation*: *First,* this simulation model projects the future based on the coefficients and correlations obtained from historical data (of past trends) GDP, population, prices etc. *Second,* unexpected future changes may not be immediately accommodated in the model leading to inaccuracy of the model's results. *Third,* the level of aggregation may not be suitable to decision maker's need or may not be appropriate for the Indonesian energy system. *Fourth,* there is inadequate information available to guide the preference of time scale/horizon for the study.

*Practical Limitations:* the systems dynamic model utilised in this thesis is based on input-output description of the economy. There are some important analytical limitations which influence the I-O energy model results, 1) the assumption of fixed coefficients of the I-O matrix, 2) the demand orientation of Input-Output model in which the energy supply side is inadequately considered, and 3) Understanding complex systems, and defining their behavioural pattern of interactions and correlations are very difficult tasks. It requires a capable team drawn from many disciplines related to the systems being modelled, and developing countries are generally lacking in this expertises.

*Data limitation;* The problem with data collection in Indonesia includes the lack of sufficient measurement techniques, instruments and resources, which make it difficult to get all the required data. As a consequence, in building the model we sometimes tempted to proceed without satisfactory data or procedures; this may lead to imperfect models.

System Dynamics Model of The Indonesian Energy System discussed in this study is *a simulation model* of the Indonesian energy system that consists of an economic-Input-Output module, an energy demand module, an energy supply module and an environment module

*The overall structure of model*, which consists of main modules and sub-modules, describes physical, technical interactions in the economy–energy-environment sector of which each has its own boundary and as a whole is represented by endogenous and exogenous energy-economic and environment variables. The model provides the physical structure of the whole system (the stock and flow networks of goods, population, energy, money, pollutant, efficiency etc.), including the decision making structure of the various players in the system (the decision flows, impacts and information sources for decisions). In this way, the model will be well suited to examining the quantitative dynamic effects of policy initiatives.

*Testing and validation:* there are two model validation and testing methods carried out for the model. The validation of '*model structure*' and '*model behaviour*' for this model involves various parameters and indicator variables in each module, right from economic module through supply module including the parameters in the environment module.

Because of the complexity of structure of the energy-economy-environment system being modelled, the structure validation was carried out on a step-by-step basis following the completion of each module.

The overall behaviour of the model was tested after the whole structure was completed. For the model behaviour method; there are two methods of testing and validation employed; 1) back casting the model results and comparing them with the real or historical patterns and 2) testing the results of future scenarios and comparing them with the forecasted results of the other models, in this case the results of MARKAL, and other models developed by other energy related institutions.

Both methods described above give satisfactory results as they met the requirements for model suitability.

# CHAPTER NINE

# ANALYSING ENERGY POLICY SCENARIOS FOR INDONESIA

## 9.1 Rationale and Philosophy of the Scenario Approach

Indonesia needs to develop ways of managing risks by looking into the future because in the past it hasn't done this and the costs have been significant. As part of an interconnected world, the risks and failures that Indonesia have experienced are too evident and expensive that the country needs to look into the future and find ways to learn from the failures that sometimes occur and to manage those risks. Here are some examples of inappropriate decisions that could have been avoided if Indonesia had developed a future looking capability.

*First,* the mismanagement of oil and gas resources has led to their early depletion. Indonesia will have to change its status from an oil exporting country into an oil importing country (in 5 or 6 years see section 4.2.1 of chapter 4). The rapid exploration and exploitation of oil and gas resources have caused the R/P (Reserve to Production ratio) of Indonesian Oil decreased from 11 years (1981) to 8 years (1998), while that of gas significantly dropped from 60 years (1980) to only 38 years (1998) (see Section 4.2.1 and 4.2.2 of Chapter 4).

*Second,* the country's electricity crisis that occurs in 1990's was partly caused by unwise decisions on electricity investments and plan. Heavy national debt was mainly caused by bad energy investment policy and mismanagement of subsidies for oil, electricity and gas (Prawira, 1998). Pidd emphasized the need to look into the future by way of forecasting for managing and minimising the risks,

> *"The main argument is that the development and use of rational and logical analysis through forecasting can be a great aid in managing that complexity and in recognising and managing the inevitable risk"* (Pidd M., 1994, pg. 4).

Undoubtedly, by looking into the future by way of forecasting or other approaches, Indonesia will be able to reduce the risk of making inappropriate decisions and more readily respond to the complex dynamic nature of the system.

**Approaches to looking at future**

There are, in principle, two main approaches that can be used for projecting the future outlook of a system: forecasting and scenario approaches (Schnaars, 1987; Wilson, 1978). *The forecasting approach* is defined as a mainly quantitative method that predicts one future and that does not necessarily explore the implications of that future. Forcasting generally assumes that the future will simply follow past trends, or rely only in a single assumption. It is used as a medium term projection tool for looking at the future between 1 to 10 years. Shearer (1994) defines forecasting time horizons as follows: short-term, up to 12 months ahead; medium-term, 1-3 years ahead; long term, over 3 years ahead.

The strengths of the forecasting approach include that because of it is relative simple mathematically, it is generally politically convincing. The forecasting approach can be easily comprehended by policy analysts and decision makers, for it does not require complex mathematical equations and computer programming. The forecasting approach is relatively easy to validate, as it requires only model behaviour validation of the model result and does not need the model structure validation. The results do not require deep and time-consuming analysis and can be easily interpreted by the users. For the same reason (simplicity), data collection and assumptions are usually not a problem for the user of this forecasting approach.

The weakness of this forecasting approach is that it is not good for predicting complex system. Forecasts do not provide means to predict more than one alternative future, which is required for predicting the unknown future. Schnaars (1987) also emphasizes that the result of a forecast model is no more accurate than other approaches. It can deceive its users, because under the disguise of scientific analysis and sophisticated mathematical manipulations of historical data, the method is trying to predict the complexity of a real future. The advantage of scenario approach has become more clear when the uncertainty of the future is high and the historical relationships are changing. He further said that, reviews of past forecasts indicated that most errors were the results of inadequate underlying assumptions in forecasts. In a review of market growth forecasts published in the business press between 1960 and 1979, Schnaars (1994) found many mistakes in the prediction of market growths (e.g. dramatic and continued growth of oil price, fantastic technological growths), which were mainly caused by incomprehensive and incorrect assumptions of the economic conditions.

The Scenario approach is defined as:

> "... *'an exploration of an alternative future' or more precisely, as 'an outline of one conceivable state of affairs, given certain assumptions'*" (SRI/CSSP, 1975, as quoted by Wilson, I.H. 1978, p 225).

Wilson also quoted a more detailed definition by Herman Kahn and Wiener (1978: p. 225.) who defines scenario as, "a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points"

What these definitions show is that scenarios are more about 'exploration' rather than 'predicting' in the case of forecasts. As a result, the scenario approach can investigate several futures. Wilson (1978), moreover, states that scenarios are constructed for many reasons. They may be designed merely to serve the interests of satisfying one's intuitive curiosity about the future, or for more focused roles such as providing frameworks for planning purpose. Scenarios usually take a 'longer term' perspective (up to 100 years) than forecasts and due to their complexity, they require a team-based and an exploratory approach.

Many planners have recognized the importance of the scenario approach, because scenarios avoid the trap of relying on a single forecast that can prove misleading. This view has accelerated the demand for scenario analysis (Schnaars, S.P. 1987). Wilson (1978: p. 6) argued

> *"... however good our futures research may be, we shall never be able to escape from the ultimate dilemma that all of our knowledge is about the past, and all our decisions are about the future' The best that futures research can do is to explore alternative possible futures, and for such an exploration scenarios are admirably suited"* .

However, scenario approaches are relatively expensive, require a huge amount and more detail data, and are politically unconvincing (Patterson, 2000). Moreover, they are difficult to validate. That is, they require model structure and behaviour validity (see section 8.6), which is usually not easy to do especially when there is problem with data availability. Scenarios require both model behaviour and model structure validation. Not only do the results of projections and indicator variables need to be validated, but also that of the whole model's structures.

In addition to that, improper selection of scenario theme is a common problem with the scenario approach. Wilson (1978) states the scenario is only a sketch or an outline. It is a map of the branching points of the future and its causal chains. The selection of the scenario themes is, therefore, will be crucial in scenario approach. Improper selection of scenarios can produce useless results and indicators and therefore useless policy alternatives to deal with the future conditions (Wilson, I.H. 1978). There are also some problems with scenarios because they usually deal with long-term trends. In the long-term range scenarios, the model builder usually assumes that people are caught up in a development process that is fixed over a long-term and cannot be influenced to a great extent. As a result, this approach has little sense for the dynamics or feedbacks of the real world. Boshier et al, (1986) stated that the involvement of people in this approach is disregarded and the approach blindly sticks on to the pre-assumed set of static values. Moreover, she also argued that there might also be misleading results of this approach, when the scenario planners make unreasonable assumptions about the nature and the rate of change of the future.

Finally, the scenario approach is considered as politically risky because it challenges the orthodox views of the future (Patterson, 2000). Many politicians favour a simple method of looking into the future as they can easily see and comprehend the variables and assumption put into the model. One of the weaknesses of the scenarios is that they are not easily understood and trusted by many politicians due to its complexity, either in the model structures, the scenario selection and contents as well as in the variables and data assumptions that are chosen to build the model.

**Approaches Used in This Research and Its Justification**

Despite the limitations of the scenario approach, this research project has adopted 'scenario' approach to investigate the future of the Indonesian energy-economic and environment system, This is because scenarios have several important advantages over the forecasting approach in the Indonesian context.

*First,* scenarios allow more than one forecast (possible alternative predictions) to be investigated. This is very important for Indonesia because the country needs the modelling approach that uses multiple forecasts to deal with the increasingly complex emerging energy issues. In addition to that, the previous approaches to energy modelling in Indonesia that the national institutions developing, were considered as inadequate. Indonesia needs an effective policy planning that employs the scenario approach, which provides a range of alternative solutions to deal with the future changes in behavioural pattern emerges from the policy structure. The use of the approach will help the energy analysts to explore the future performances of each selected scenario. The approach enables the country's energy analysts to see the forthcomings problems in the long-term range of future and provide alternative solutions. In a diverse country like Indonesia, this scenario approach is also very important in building consensus among decision-makers.

*Second,* scenarios have several advantages over forecasting because they are in the form of narrative. Schnaar (1987) stated that scenario analysis is different from forecasting approach in the way that they usually describe how the present will evolve into the future in a more qualitative and contextual way rather than in numerical precision. In the case of Indonesia, this qualitatively judgemental approach is best able to anticipate those 'history-less' events that characterised the complex and dynamic domestic energy issues facing the country, for example, the issue of self-sufficiency which is very much influenced by the level of exploitation of domestic scarce resources. Scenarios will help the Indonesian planners to outline the environment and reorganize priorities and options. The narrative style, especially if it is not too quantitative, is also a better way of communicating to the public, decision makers and stakeholders. Many decision makers in the country find it difficult to comprehend complex mathematical correlations between variables. The narrative form will help overcome this problem because it is usually characterized by a holistic, clear and interactive approach. Boshier et. al. (1986, page 19) pointed out the advantages of the scenario approach,

> *"... 1) the scenario explores the limits of understanding and challenges a narrow view of the future by considering change across a broad front, 2) the scenario traces how people might act in the face of perturbations and surprises, 3) the scenario provides a common ground for communication between groups of different interests and backgrounds and offer a coherent framework on which they can base a meaningful debate, 4) the scenario promotes convergence among managers and researchers about management strategies, including investment priorities".*

*Finally,* scenarios can help the planners to enhance the ability of an organization to see the future as a totality, rather than piecemeal (SRI/CSSP, 1975). This advantage is very important in the case of the energy policy formulation and analysis in Indonesia. The energy policy formulation and analysis is the responsibility of the BAKOREN (The National Energy Coordinating Board). The Board includes, amongst others, Ministers of energy related departments, Heads of energy related State Owned Companies, the Chairman of the National Development Planning Board (BAPPENAS) and representatives of Universities/Academies and NGOs. The BAKOREN has the responsibility to pull together the potentially conflicting activities of the Energy Ministry and other ministries and bodies with an involvement in managing energy resources. The scenario approach is crucial in the way that it can assist the BAKOREN in the formulation of energy policy analysis, which integrates and coordinates all energy related activities as a whole not as a piecemeal. In this way, the initiatives can be optimised and risks of potentially contradictory activities can be anticipated and minimized. Wilson (1975, p. 2) pointed out that the scenario approach is useful in the way that "in order to maximize the initiatives it chooses to take, and minimize the reactions it is forced to take".

## 9.2 Methodology

### 9.2.1 Methodological Issues in the Scenario Approach

This section outlines the important methodological issues confronted when working with the scenarios. In addition to this, in each discussion, the approach taken to resolving this issue in this project is also discussed. The methodological issues addressed are as follows; a) number of scenarios, b) time horizon, c) methods of constructing and writing scenarios.

**Number of Scenarios**

There is no agreement on the number of scenarios that should be selected. However, there seems to be a consensus in the literature that three scenarios are most appropriate in a scenario analysis (Schnaars, 1987). Linneman and Klein (1979) revealed that that more companies in the US adopted three scenarios than any number. Wilson (1978) said that two scenarios are likely to be categorized as 'good-and-bad', and more than three become uncontrollable in the hands of users, resulting in their attending to only a subset anyway. He, however, cautions that the use of three scenarios often cause planners to focus mostly on the scenario that seems representing the 'middle position' as the safest bet. This is especially true when the future direction of a quantifiable trend is under observation. He prescribes that in such cases the scenarios should be distinctly 'themed' to make them appear equally likely. Heijden (1996) adopted more than three scenarios (four scenarios) for the reason that they can better reflect the future uncertainties and in conformity with the issues of concern to the client. More than three scenarios are good as long as they are best selected and in the interests of the model builder for better reflection of the future plans, strategies and direction (Heijden, 1996).

For this research study, the number of scenarios selected is five scenarios (including the business as usual scenario). The reasons behind this selection is; *first,* for exploratory work to enable the author to experience running different kind of important variables and to see broad variation of results and indicators and to compare between one result or indicator to another. *Secondly,* the five scenarios are considered as better in accommodating the issues that Indonesia may be facing in the next 20 years, as there are about eight policy issues (eight policy objectives) that are currently emerging in the Indonesian energy-economic-environment system (see section 3.5).

**Time Horizon**

Most analysts agree that scenario analysis is primarily for long term forecasting (Wilson, 1978; Schnaars, 1987; Armstrong, 1978; Linneman and Klein, 1979; and Heijden, 1996). They argue because the characteristics of scenario approach is to offer more than one forecast, each in the form of a deliberately unclear narrative, that is why they are best suited for more long term and less certain forecasting purpose. However, they also acknowledged that there is no empirical evidence that scenarios are inappropriate over shorter time horizons. Zentner (1982), (as quoted by Schnaars (1987)) noted that the substance of the scenario becomes gradually unclear as the time horizon extends. Armstrong as quoted by Schnaars defines the time range of forecast as *'the length of time over which large changes in the environment can be expected to occur*" (Schnaars, 1987. p. 108). In the case of Indonesia, the author selected 22 years (from 1998 to 2020) as the time horizon for the study. The selection is based on the consideration as discussed in section 8.4.3 of chapter 8.

**Methods of constructing and writing scenarios**

Wilson (1978) outlines 5 elements that needs to be covered in constructing and writing scenarios; 1) a framework for combining different alternative of environmental developments, 2) the likely discontinuities and possibilities which will be used as early warning systems, 3) a framework for translating various environmental developments into economic terms and alternating economic forecasts, 4) evaluating the range of possible outcomes resulting from the interaction between alternate environments and variable industry/market growth, 5) an examination of the results of a range of competitor strategies in various environments.

**Scenarios Writing**

Herman Kahn who credits himself with inventing the term 'scenario', is considered the first scenario planner. He wrote scenario analysis in the form of stylised narrative or referred as 'scenario writing'. Schnaars (1987) said that although scenario writing may include the results of quantitative models, it tends to be a highly qualitative procedure and based on the theory that the future is not simply some mathematical behaviour of the past. Rather it is the combination of some forces, past, present and future that can best be comprehended by simply thinking about the problem. As narratives, scenarios can either be longitudinal or cross-sectional as defined by Kahn and Weiner (1967), "a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points". (as quoted by Schnaars, 1987, p 106).

The story line needs to be detailed, plausible, conceivable and coherent. Many industries, products and markets are primarily affected by only a handful of factors, that are fairly easy to identify, but notoriously difficult to predict. Scenario analysis should perform well in such instances. According to Heijden (1996), the story needs to be *'provocative, memorable, eliciting a rich imagery'*. The scenario writer should make the most appealing and informative stories. A story should have a beginning, a middle, and an end. Each scenario must reveal a 'gestalt', an integrated story that must be interpreted as a whole rather than as a piecemeal. Moreover, it must be logical, transparent and can be expressed in a simple flow diagram. A scenario must be internally consistent based on its original structural (mostly qualitative) model. Agreed predetermined factors need to be reflected in all scenarios, and main variables should be quantified to product a list of indicators (Heijden, 1996).

### 9.2.2 Methodological Processes

There are 8 main steps in the scenario process which are important in obtaining a consistent and comprehensive picture of the modelling results and analysis. These main steps are shown in the diagram below (Fig. 9.1). A more detail discussion of the diagram is given for first, the ideal process and second, the scenario process used in this research study.

**Ideal Process**

An 'ideal process' which embodies the principles drawn from the scenario literature could involve the following steps (refer to Figure 9.1).

1) Selection of the scenario themes. In selecting the scenario themes for examples: 'environmental concern", 'economic expansion', 'energy efficient economy', a large number of potential future outcomes are studied and then a few plausible scenario themes are chosen. The plausible scenario themes are decided based on the following considerations: *first*, the scenario themes must develop in a cause and effect way from the past and the present. *Second*, the scenario themes must be internally coherent or events within a scenario must be linked through cause and effect lines of argument, which cannot be contradictory.

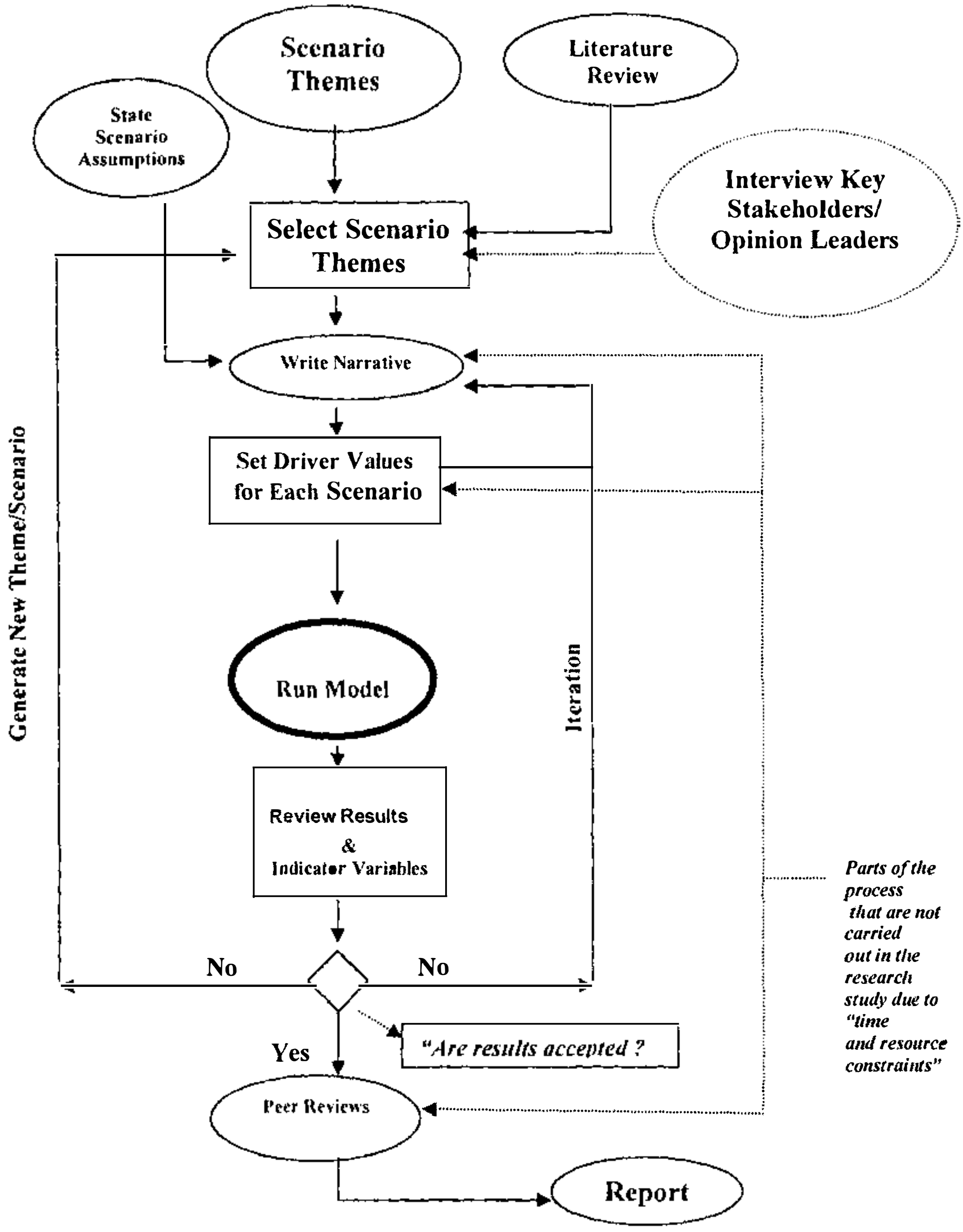



**Fig. 9.1 Methodological Process for Generating and Analysing Scenarios**

*Third,* the scenario themes must be applicable to the issues of concern to the client. They must offer useful, comprehensive and challenging idea generators and test conditions, against which the client can consider future business plans, strategies, and direction. *Fourth,* the scenario themes must produce a new and original perspective on the client's issues (Van der Heyden, 1996). These scenario themes can also be selected based on literature review, opinion of stakeholders and prominent government figures. Literature review is conducted to determine plausible scenarios that have a careful consideration of future possibilities and carefully select appropriate key variables for designing each scenario approach. In addition to that, some opinion of key stakeholders, all diverse groups and leaders regarding what would likely be the future of energy picture, dominant themes of the future that will affect the economy are also taken into consideration. This is done through interviews, group discussion, meetings or seminars. A common view, common language, a common way of understanding of the possible or probable occurrence of future environment are generated from the discussion for the purpose of selecting the scenario theme. The interview with prominent government figures in energy-economic sectors will also serve the need to identify the favourable scenario theme in the eyes of the government (favourable to sponsor). Ideally, the story line including its detailed assumption of variables in each scenario should be developed by the scenario team (all of the above diverse groups) to ensure diversity in thinking that is important in generating plausible and rich scenarios. In selecting the scenarios, the segments of the total environment that critically affect national energy-economic sector (the dominant forces operating in those segments) are taken into consideration.

2) The writing of a narrative for each scenario describing in detailed, plausible, informative and coherent story lines (Van der Heijden, 1996). The scenarios need to describe background, quantified variables, indicators, assumptions, and considerations that are used to design the scenario. As much as possible, the scenario should be written in a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points (Wilson, 1978). The story line should consist of a beginning, a middle, and an end. A long-term time horizon is applied to each of the scenarios. For the purpose of communication, the story line can be supported with a simple flow diagram of energy scenario analysis to help describe its logical and transparent consistency (Van der Heijden, 1996).

3) The setting of initial driver values or base case for each scenario. In energy modelling, the drivers that need to be specified include: economic (e.g. GDP, income per capita), energy prices, and demographic indicators. Correct specification of the driver values is very important consideration as the driver values are the main determinants of each scenario. Wrong setting of the driver values could mislead the results causing inappropriate scenario analysis.

4) Run the model and generate the results for indicator-variables for each scenario. The indicators will cover variables that can be used to evaluate the modelling results and the validation of modelling structures and behaviours.

5) Reviewing the model results and indicator variables for the selected scenario. If the results show 'reasonable' values (i.e. they meet expectations), then generate the next theme/scenario by repeating steps 1 to 5. If the results are not 'reasonable' then this indicates improper specification of the driver values. The response to this is to readjust the data in step 2 and 3 until results conform to expectations. In reviewing the model results and indicator-variables, stakeholders and interest groups should ideally be involved. Their opinion, views and valuable inputs are needed for the judgement of model results or for comparing of the model's results with other models' outputs for the purpose of model and scenario refinements. The refinements may include narrative rewriting, driver values' resetting, indicator variable redefinition, and the model structure improvement. In this way, a more accurate model structure and reasonable results can be expected.

6) Finally, reporting the results of the model and presenting the analysis and possible policy implications for each scenario. Comparison of the results between scenarios is very important for providing the 'insight' on the advantages and weaknesses of each scenario approach. This will enable the decision makers to select the best or combination of some scenario approach to obtain the optimal/best national energy policy option.

**Actual Process Used in This Research**

The approach used in this research does not completely follow 'the ideal process' described above. Some steps are not carried out due to resource and time constraints. The omitted steps are the involvement of stakeholders and leaders in i.e.: the selection of scenario themes, scenario writing, the driver values' setting and in the model results' reviews (see the dot lines indicated in figure 9.1. above). The steps used in this research are described as follows:

1) The selection of scenario themes. In selecting the scenario themes for this research, a large number of potential future outcomes were studied and a few plausible scenario themes were selected based on the considerations outlined above. Literature review has been conducted to determine plausible scenarios that hold a careful consideration of future possibilities. The scenario themes chosen are:

- Business as usual
- Environmentally beneficial
- Economic efficiency
- Self-sufficiency
- Balancing the trade offs.

2) Some important key variables were chosen for designing each scenario approach, for examples GDP, population, energy prices, number of motor-vehicles etc.. However, due to the time and resources constraints, opinion from key stakeholders, all diverse groups and leaders regarding what would likely be the future of energy picture have not been taken in designing the scenarios. However, the literature review and the author experience in working with the energy policy institution for more than 15 years sufficiently serve the need to identify the favourable scenario theme in the eyes of the government. The story line including its detailed assumption of variables in each scenario was developed by the author and not by scenario team as ideally required. In selecting the scenarios, the segments of the total environment that critically affect national energy-economic sector were also taken into consideration.

3) The writing of narrative for the scenario describing each scenario in detailed, plausible, informative and coherent story lines. The scenarios describe the background, quantified variables, indicators, assumptions, and considerations that are used to design the scenario. As much as possible, the scenario was written in a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points. A 22 years time horizon was applied to each of the scenarios.

4) The setting up of driver values for each of the scenario. In the energy modelling used in this research, the drivers include: sector GDP, technical efficiency, fuel mix (for electricity generation and primary energy mix for heat and transport fuels), export/import of energy, energy price, income per capita, import/export of other commodities etc. These settings need to be reviewed and readjusted in accordance to the model results to assure the best model results based on the selected scenario.

5) Run the model and generate the results for indicator-variables for each scenario. The indicators-variables cover i.e. the cost of energy supply, level of $CO_2$ emissions, energy self-sufficiency (reduction of imported energy or more used of indigenous energy sources), energy efficiency (reduced demand and supply of energy), the resilience of energy system (more use of renewable, or more diversified energy sources).

6) Reviewing the model results and indicator variables for the selected scenario. If the results (indicator-variables and other results) show logical values in accordance to what was expected by the scenario, then go to the first step again to generate new theme/scenario and then follow similar process up to step 5, otherwise (if the results show illogical values) readjust step 2 and 3 to get the best results. In reviewing the model results and indicator-variables, I only involved my peers (other energy modellers in Indonesia), the stake-holders and interest groups were not involved in deriving their opinion, views and valuable inputs. However, the comparison of my model's results with other models' outputs has been done to enable me to make the refinement of my scenarios, driver values, to do narrative resetting and policy indicator variable redefinition, as well as the model structure improvement.

7) Finally, reporting the results of the model and presenting the analysis and possible policy implications for each scenario. Comparison on the results between scenarios has been carried out to show the advantages and weaknesses of each scenario approach. This will enable the decision makers to select the best or combination of some scenario approach to obtain the optimal/best national energy policy option.

## 9.3 Outlines of the Scenario Generated in This Research

This section presents scenario outlines or scenario description for each scenario developed for the future outlook of the Indonesian energy system. The results of 'the model run' (section 9.3) and thereby the 'policy implications' (section 9.4) will be very much influenced by the story and assumptions made in the scenarios. There are five scenarios applied in this research study, i.e. Business as Usual, Environmentally Beneficial, Economic Efficiency, Self Sufficiency and Balancing Trade-Offs.

### 9.3.1 Business as Usual Scenario

The "Business as usual" scenario follows historical socio- economic and energy trends. It assumes no surprising socio-economic and demographic changes. It is the continuation of the past trends.

In developing the "Business as Usual" scenario, most official data for historical trends were gathered from energy related institutions, namely the National Electricity Company (PLN), National Energy Atomic Agency and Ministry of Energy and Natural Resources and IEA. The historical trends of consumption, energy demand and supply determinants (including efficiency figures) described in chapter 4, 6 and 7 are applied for this scenario. The data about existing and future electric generation costs, generation capacity including future committed electric power projects as well as the existing Joint Operation Contract (JOC) from year 2001 to the year 2010 and their operating years obtained fro PLN and other power utility companies. In this BAU scenario, a possible extension of the existing power plants to the maximum capacity of production, is also assumed as it has already been planned by the utility companies and government. Utility Company's scenarios for future energy supply mix for electric power generation as well as the average generation costs for all operating power plants in Indonesia from year 2001 to 2006 were taken into account.

Economic development does not undergo any major breakthrough, it is assumed to grow at 5 percent per annum following the average past trends of 5 selected developing countries that have similar level of GDP per capita in the past 20 years as Indonesia. Income per capita is projected to increase in proportion with the growth of GDP. The primary energy mix (oil, gas, LPG, coal, wood/combustible waste, CNG) is assumed to follow past trends as specified in chapter 4, section 4.3, whereas the power generating mix is assumed to follow the utility companies' plan (based on the existing and committed electricity projects). Wood-combustible waste or biomass supplies about 64 percent of total energy mix in 2000 but decreases to 40 percent of total energy in 2020 due to the shift of fuel use from biomass to LPG and kerosene for cooking purpose in the household-commercial sector. The use of hydrocarbons is also assumed to decline from 27 percent to 20 percent during the same period, mainly caused by the shift of fuel use in Industrial sectors. However, the role of hydrocarbons in the transport sector is still high throughout the study period. The proportion of hydrocarbons to total transport fuel remains approximately 99 percent, as the introduction of transport fuel alternatives like CNG and LPG are still facing investment and infrastructure problems in Indonesia.

The "Business as Usual" scenario assumes that there is no major energy conservation effort and no significant change of awareness toward energy efficiency in the demand sector. The efficiency of energy industry (power generation plant, refinery-gas-coal plants, transformation-distribution losses, etc.) is assumed to follow the description in Chapter 7. Today's increasing global environmental concern about the impact of $CO_2$ emission from fossil fuel utilisation doesn't force national efforts to abate the emission of $CO_2$. It is assumed that there will be more imports of oil and gas as the existing reserve will not be sufficient to support increasing domestic energy need. The export/import of other commodities follows the 'business as usual' trends. Energy price, especially for primary energy production (crude oil, gas and coal) is assumed to follow official data obtained from IEA, which basically grows at a flat rate (see section 7.4 of chapter 7).

In this scenario generation fuel mix, the role of coal and hydrocarbons are still significant though decreasing in an absolute terms, being replaced by nuclear after 2015. For this scenario, a supply curve (generation capacity versus generation costs) for various energy sources for electric power plants was also developed based on data and information gathered from the above institutions and from several studies conducted by the National Electricity Company (PLN), National Nuclear Energy Agency, Ministry of Energy and Natural Resources (BATAN) and the Agency of Assessment and Application of Technology (BPPT). Data and information on the future government plans for GO-Nuclear Program were also taken into consideration in developing the supply curve for nuclear power generation. Official data and information about investment costs of the existing and future power plants and assumed inflation rate of 10 to 7 percent per annum during the study period, as assumed by the energy institutions were also included in the building of supply curve of various power generating plants. The flow diagram describing 'the business as usual scenario' outlines is given in the appendix D (Figure D1).

### 9.3.2 Environmentally Beneficial Scenario

This scenario is developed in response to the increasing global concerns about the environment impacts of the fossil fuel burnings. In this "Environmental Beneficial Future" scenario, several combined socio-economic and technological changes will be employed. Indonesia, with its rapid escalating growth of energy demand approaching 9 percent per year in the past 30 years, is forced to bend to the global environment demand to commit on $CO_2$ emission reduction starting from year 2005. As a result, the country's economy (as reflected by GDP) will suffer de-accelerated growth about 10 percent during from year 2000 to the end of the study period (2020). Energy intensities in the demand as well as supply sector is assumed to be lower than in the business as usual scenario (between 5 to 20% over the period) emphasizing greater efficiency and more efficient energy alternatives and technologies.

The price of hydrocarbons, particularly in the transport sector is assumed to increase by 10 percent each year from 'Business as Usual' price starting from year 2000 to stimulate energy conservation efforts. National targets and sector potential of savings based on the government surveys as well as based on the available energy efficient technology is also assumed to be fully implemented in the demand sector. The policy on less carbon fuel mix in the electricity generation sector is assumed to take place. Electricity generation from fossil fuels mainly coal and hydrocarbons is assumed to be lower than those projected in the BAU scenario and the use of renewable such as hydro and geothermal and nuclear will be greater to replace coal and hydrocarbons after the year 2005. In this way the model assumed that the shift would occur from carbon intensive to less carbon intensive or carbon free energy sources.

Changes in fuel mix of the demand sector, in this approach are assumed. A range of possible fuel mix changes are determined for energy use for heating and transport purposes. Fuel supply considerations (cost and availability) were taken into account before changes are made to fuel mix assumptions. The use of hydrocarbons and coal for heating purposes are decreasing replaced by natural gas and LPG. Moreover, the scenario assumes that the trend of wood/biomass energy use follows 'Business as Usual' scenario. The use of hydrocarbons in transport sector is gradually and slowly declining replaced by CNG, LPG and Electricity. Less exports and import fossil fuels' policy will be assumed and indigenous renewable energy production (geothermal and hydro) is encouraged. As also with fossil fuels, the export and import of other commodities will also be assumed to decrease in this "Environmentally Beneficial Future" scenario.

### 9.3.3 Economic Efficiency Scenario

Economic Efficiency Scenario, developed for maximising the sectoral economic growth (GDP) and enhancement of primary energy supply to satisfy the demand for energy to support the economic growth. Acceleration of sector's activity is assumed to increase GDP by 15 percent from 'Business as Usual' level. As a result, energy demand will escalate and major environment problems, especially CO2 emissions will increase. The national CO2 abatement program is assumed to not exist. Rapid industrialisation will characterised this scenario.

Energy efficiency programs in the demand sectors will also be given more attention to enforce implementation. Energy conservation promotional program such as labelling, campaign, and training programs for all sectors will be conducted, and this effort is expected to encourage "without investment" or "housekeeping" efficiency programs. Whereas technical efficiency in the energy industry (electricity generation sector) and energy supply sectors will be assumed to follow the past trends business as usual scenario. Both the cost of energy supply for electricity generation and the cost of fuel mixing for transport and heating process are assumed minimized to achieve economic efficiency. The utilisation of cheaper energy sources for electricity generation like coal, hydropower and geothermal, for it justifies the economic consideration, will also be assumed to increase in this scenario started from year 2005. But the utilisation of hydrocarbons in the power generation sector will be the last option as it is the most expensive form of energy in the sector. In the primary supply mix, the use of hydrocarbons for heating purpose will be reduce gradually replaced by coal which is cheaper and abundantly available in the country.

The use of hydrocarbons in transport sector, which is currently still more than 90 percent of the total and relatively the cheapest fuel among other fuels, will be kept growing at the BAU scenario's trend. Energy price will be assumed at "business as usual" level to stimulate sectoral economic growths. As the economy needs to be brought toward a more global economy, import and export of good and industrial products will increase. The indigenous production of fossil fuels such as coal, natural gas and crude oil will be increased each by 50% of 'Business as Usual' level to ensure adequate supply of energy to support the economic growth. The enhancement of oil recovery, exploration and development activities will be pursued. The use of expensive renewable sources of energy e.g. photovoltaic as well as wind energy for power generation will be avoided to minimise the supply cost.

### 9.3.4 Self Sufficiency Scenario

The likely changing status of Indonesia, from an energy exporting country to an energy importing country in the not too distant future, created the need to have the Energy Self Sufficiency Scenario. In this scenario, less dependency on hydrocarbons either as fuel resources for power generation or for transport and industrial use are assumed. Increased use of alternatives fuel (LPG and CNG) to replace hydrocarbons for transport and more use of coal (abundant resources), hydropower, micro-hydro, geothermal and uranium in the power sector were also assumed. Population growth is assumed to decrease by 5 percent annually from 'Business as Usual' growth level affecting the sectoral growth of GDP, thus causes energy demand to decline.

In this scenario, the improvement of technical efficiency of energy use in all consuming sectors is assumed to be much higher than business as usual scenario. 'A low or no cost' energy conservation implementation in all sectors is assumed to increase as the Government allocate budget for promotional energy conservation programs such as energy efficiency campaigns, labelling and training programs every year starting from year 2000. More use of natural gas (LPG) in household sector for cooking purpose is also considered. The price of energy will be assumed to increase to stimulate energy efficiency effort. Economic growth is expected to grow steadily as the BAU scenario. Primary energy supply mix and power generation mix are also assumed to use more renewable energy and use more abundant fuel (coal) and to reduce the use of hydrocarbon and natural gas to sustain 'self sufficiency' purpose. Energy price for oil (scarce resources) in the transport sector will increase by 10 percent to encourage the shift to other alternative fuels such LPG and CNG. Import of energy will be assumed to be nil as the policy of "self sustained energy' is being enforced. Production of fossil fuels crude oil, coal and gas to be increased subsequently by 50 percent, 75 percent and 50 percent from 2005 to 2015, and 75 percent, 100 percent and 75 percent from 2015 to 2020 by way of intensification and exploration. Export and import of other commodities are assumed to continue the past trends.

### 9.3.5 Balancing the Trade-Offs Scenario

Balancing the Trade-offs is an ideal or an optimal scenario, which optimise the combination of the four future goals of economic efficiency, self-sufficient energy supply and environmental impact. It is the combination of most realistic variables in each of the four scenarios. The scenario is expected to give Indonesia 'the most liked' scenario which balance between increasing the country's economic growth, encouraging more use of the countries indigenous renewable thus lowering CO2 emission and lowering the supply cost of energy by moderating demand growth. In the scenario, the economic growth is assumed to grow moderately by 10 percent above 'Business as Usual' level.

Hydrocarbons' price will be increased 20 percent above Business as Usual' level to moderate energy demand, especially in transport sector, which is influenced by hydrocarbons' price's increase though not significantly. National energy conservation effort are assumed to be implemented quite successfully with more vigorous energy campaign and training programs stimulating "no cost" energy conservation implementation like housekeeping and attitude awareness. Technical efficiency in the supply sectors is improving (efficiencies are increasing between 5 to 25 percent) through the period of the study so that the demand for energy will be kept lower than business as usual. This will lead to a more moderate growth of CO2 emission.

The fuel mix in the power generation sector will as much as possible use a bigger percentage of fuels with moderate fuel price but quite abundantly available in the country, such as hydro, geothermal and coal. In this scenario the 'economic efficiency' scenario for power generation sector will be used. Whereas the primary energy supply mix (heating and transport fuel mix) will follow 'Business as Usual' scenario. The use of hydrocarbons in the transport sector will be assumed to follow 'Business as Usual' trend as the substitution of hydrocarbons to LPG and CNG will be uneconomical and costly. Domestic energy demand will be as much as possible be fulfilled from domestic/indigenous energy sources and the past policy of using 'hydrocarbons and natural gas' for foreign exchange purpose will need to be avoided. Import fossil fuel energy (coal, crude oil and natural gas) assumes to be prolonged by increasing indigenous production of coal (50 percent), natural gas (25 percent) and crude oil (25 percent) from 'Business as Usual' level. Export and import of other commodities will follow the past/historical trends depending on the global market trends.

## 9.4 Results and Indicator Variables

### 9.4.1 Model Results

As a result of the application of the five scenarios outlined in the previous section (section 9.2), the model produces various results and indicator variables. They are ranging from energy demand and supply projections by energy type as well as by consuming sectors, to economic and environment indicator variables. Here are some interesting results that can be derived from the model and their analysis.

#### 9.4.1.1 Gross Domestic Product Across the Scenarios

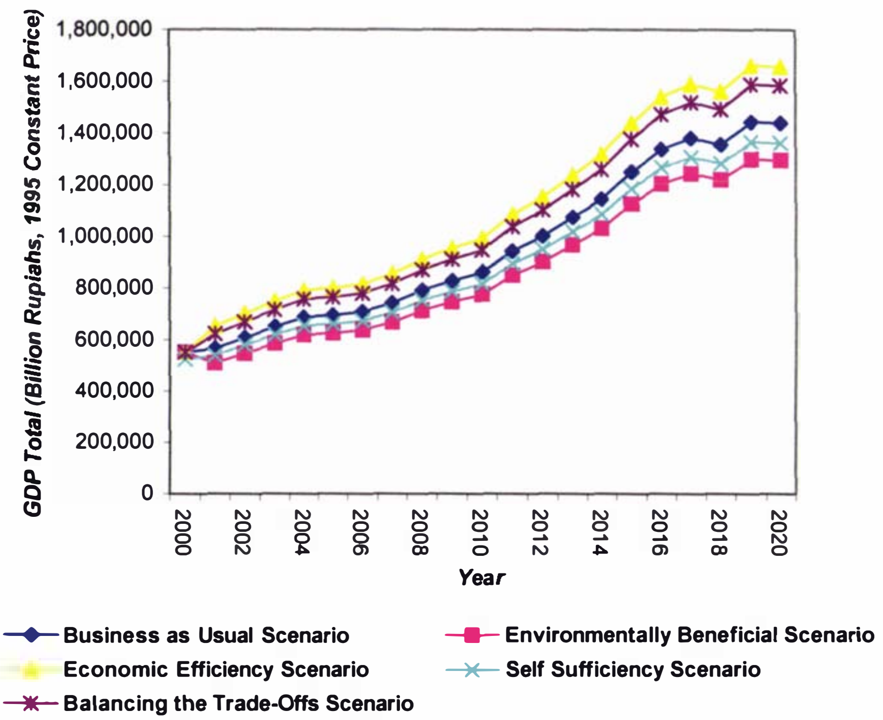



**Figure 9.2 Projected GDP of Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

Based on the assumptions which is referred as *'Business as Usual'*, for which the annual population is assumed to increase at the rate of 1.3 percent, the model gives the following results. Over the period of the study (2000-2020), Indonesian GDP increases from only 553164 to 1441485 Billion Rupiahs (1995 Constant Price), or almost 3 times the 2000's level, or increasing at the rate of about 4.9 percent annually (see Figure 9.2). As a result of the implementation of an *'environmentally beneficial'* energy-economic policy, Indonesia is assumed to suffer lower GDP growth about 10 percent from the 'Business as Usual' scenario. Based on this scenario, the model estimates a GDP growth rate of 4.4 percent annually, compared to 4.95 percent of GDP growth in the 'Business as Usual' Scenario. The country's GDP increases from 553164 (2000) to 1297337 Billion Rupiahs (2020) as shown in Figure 9.2, or the GDP increases to less than 2.5 times in 20 years, which is lower than the increase of about three times in 'Business as Usual' Scenario. Significant drop occurs in 2001 of about –7 percent from the previous year as the impact of the economic crises in 1997/98 are still significantly influencing the economy.

The scenario *'Economic Efficiency'* which assumes higher economic growth in the economy or 15 percent increase from the 'Business as Usual' level of annual GDP growth, produces Gross Domestic Product growing at 5.7 percent annually from 2000 to 2020. GDP increases from 553164 (in 2000) to 1657708 Billion Rupiahs in 2020, which is a substantial increase from the 'Business as Usual' figure of 1441485 Billion Rupiahs (1995 Constant Price) (see Figure 9.2). This high GDP growth will significantly escalate the demand for energy to support the growth of the economy as a result of 'Economic Efficiency' policy.

The *'Self Sufficiency'* Scenario assumes that population growth decreases by 5 percent from the 'Business as Usual' level or growing at the rate of 1.2 percent (the 'Business as Usual' scenario assumes that the population grows at the rate of 1.3 percent). This will have an impact on the economic activity of all sectors and will cause the GDP to decrease from 'Business as Usual' level. The Gross Domestic Product of this "Self Sufficiency' Scenario grows at the rate of 4.9 percent over the study period (2000-2020), only slightly lower when compared to 'Business as Usual' GDP growth which is about 4.9 percent. The annual GDP at the beginning of the study period (2000) is 525607 Billion Rupiahs and reaches 1364260 Billion Rupiahs by 2020, an increase of approximately 2.5 times (see Figure 9.2).

The *'Balancing Trade-Off'* scenario, which assumes higher GDP growth (+10%) than the 'Business as Usual' level, but a little slower (-5 percent) than the 'Economic Efficiency' scenario has resulted in higher GDP growth than that of the 'Business as Usual' level over the study period, as shown in Figure 9.2. Annual GDP grows from 553164 Billion Rupiahs in 2000 to 1585633 Billion Rupiahs in 2020, or increases by less than three times over 20 year period. Most of the increase has been attributed by the GDP increase in the Industry/manufacturing sector. However, when compared to the 'Economic Efficiency' scenario, the increase in the total GDP is still lower (in the 'Economic Efficiency' scenario, GDP increases more than 3 times in 20 years period reaching the GDP figure of about 1657708 Billion Rupiahs in 2020).

#### 9.4.1.2 Energy and Electricity Demand Profile Across the Scenarios

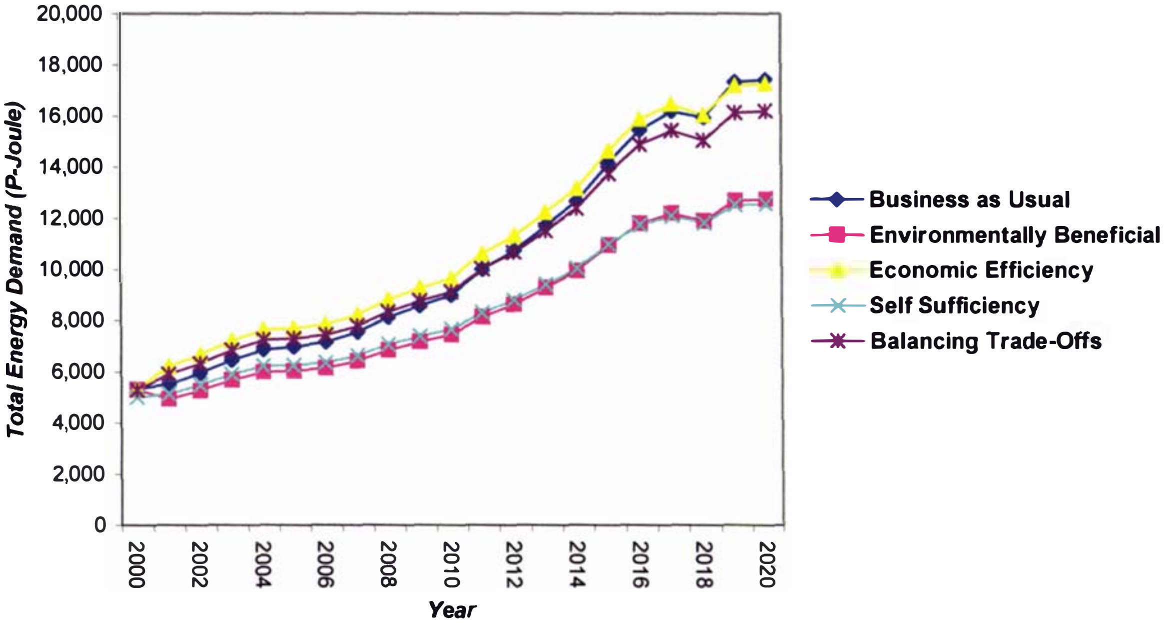



**Figure 9.3 Total Energy Demand for Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

**Energy Demand**

In the 'Business as Usual' scenario, total energy demand grows at the rate of 5.7 percent annually starting at 5269 P-Joule in 2000 and reaches 15827 P-Joule in 2020. The share of electricity, hydrocarbons, and natural gas are as follows; electricity increases from 4.9 to 13.4 percent, hydrocarbons decrease from 39.1 to 32.6 percent, natural gas increases from 4.6 to 12.9 percent, whereas wood/biomass decreases from 49.8 to 32.5 percent over the period of the study (2000-2020). At the beginning of the study period (2000), the household sector is the biggest consumer with a share of 66.3 percent, followed by the transport sector 17.9 percent, manufacturing/industry 14.3 percent, and the energy sector 1.5 percent. At the end of the study's period, the share decreases to 54.7 percent for the household sector, 14.9 percent for transport, and 0.3 percent for the energy industry, but increases to 30 percent for the manufacturing/industrial sector. The declining share of the household sector has been attributed to the declining use of biomass/wood as fuel for cooking being replaced by kerosene, LPG and electricity (as income per capita increases), which possess a higher energy quality.

According to the *'Environmentally Beneficial'* scenario, energy demand is expected to grow slower affected by lower growth of GDP and also the policy to increase the price of hydrocarbons of about 10 percent from 'business as usual' level starting from year 2000. The demand will further decline as energy conservation program is also assumed to take place, though only for 'housekeeping' or 'no-cost' energy conservation implementation in all economic sectors. Total energy demand grows at the rate of 4.19 percent annually started at 5241 P-Joule in 2000 and reaches only 11745 P-Joule in 2020, which is much lower compared to 15827 P-Joule in 'Business as Usual' Scenario (see Figure 9.3). Over the period (2000-2020), the share of electricity increases from 4.9 percent to 11.2 percent, hydrocarbons decrease from 38.8 to 32.3 percent and natural gas increases from 4.6 to 10.6 percent, whereas biomass/wood decreases from 50 percent to 38.9 percent. The combined energy demand drivers, that is, lower GDP growth, energy conservation, and increased price of hydrocarbons in the transport sector, seem to affect more on the electricity and natural gas demand rather than wood/biomass and hydrocarbons demand. The household sector is the largest energy-consuming sector with a 66.6 percent share, but this decreases to 59.2 percent at the end of the study period. The second largest consumer is the transport sector with 17.4 percent of share in 2000, but the share decreases to 14.8 percent in 2020. Unlike the transport and household sectors, manufacturing/industry's share increases from only 14.4 to 25.7 percent over the period (2000-2020).

The application of *'Economic Efficiency'* scenario produces different results. The scenario assumes higher economic growth (15 percent higher) than 'Business as Usual'. In addition, the scenario also assumes that 'energy conservation' implementation takes place over the period (2000-2020), and this could bring about a lower energy demand growth than that of the 'Business as Usual'. According to this scenario, energy demand grows at 5.6 percent annually (as compared to 5.7 percent of 'Business as Usual' scenario) over the study period (2000-2020). The demand starts at 5269 P-Joule (2000) and escalates to 15315 (2020). The highest demand growth is recorded in 2015, which reaches 9.7 percent annually (see Figure 9.3). As also the case with the other scenarios, the household sector consumes the biggest portion of energy, 66.3% (2000), however, this figure declines to 58.1 percent in 2020. The second largest consumer is manufacturing sector with 14.3 percent (2000) increasing to 26.2 percent (2020). The transport sector, 17.9 percent in 2000, decreases to 15.3 percent in 2020. For comparison, in the 'Environmentally Beneficial' Scenario, the second largest consumer is the transport sector. The conclusion is that the assumed economic growth stimulates an increase of energy demand growth more in industry/manufacturing sector rather than in transport sector. Wood/Biomass still constitutes the largest source of energy demand even at the end of the study period (2020) comprising of almost 35 percent of the total energy demand, follows by hydrocarbons (32.4 percent), electricity (13.3 percent), natural gas (11.2 percent) and coal (8.1 percent).

The *'Self Sufficiency'* scenario assumes population grows 5% lower than 'Business as Usual'. The scenario also assumes that the economy carries out an energy conservation 'housekeeping' effort and applies higher hydrocarbon prices (10 percent increase from the 'Business as Usual' price) in transport sector. This scenario produces a relatively lower energy demand than the 'Business as Usual' one. Total energy demand grows at the rate of 4.7 percent annually over the study period (2000-2020) a much lower than the 'Business as Usual' growth which is about 5.7 percent over the same period. The total energy demand starts at 5010 P-Joule (2000) and increases to 12378 P-Joule in 2020, an increase of less than 2.5 times, whereas in the 'Business as Usual' scenario the increase is about 3 times over the same period. The largest source of energy is wood/biomass with 50.6 percent (2000) decreasing to 38.2 percent (2020), followed by hydrocarbons with 38.6 percent (2000) decreasing to 32.3 percent (2020). The shares of three other energy sources show an increase pattern over the same period, i.e. natural gas share increases from 4.5 percent to 10.8 percent, coal from 1.5 percent to 7.2 percent, and electricity from 4.7 to 11.6 percent, see figure 9.6.2.2 below. The demand for electricity is 237 P-Joule (2000) escalating to 1442 P-Joule (2020), which is more than a 6 times increases. In term of sectoral demand, household sector is still the largest consumer of energy with 66.7 percent (2000) of share though its share is decreasing to 55.8 percent in 2020. At the beginning of the period (2000), the second largest consumer is the transport sector with 17.3 percent, but in 2005 its role is replaced by industry/manufacturing sector with 17.5 percent, and at the end of the period, the share of transport sector is only 16 percent whereas the industry/manufacturing sector' share increases to 27.8 percent or almost double of the 2000's share of about 14.5 percent.

The *'Balancing Trade off'* scenario applies a combined policy of energy conservation and higher price increase (by 20%) on transport fuel. As a result, the total demand of energy grows 5.3 percent annually over the study period which is lower than the demand growths of the 'Economic Efficiency' and the 'Business as Usual' scenarios, which are 5.6 and 5.7 percent respectively. This lower demand growth can still be further lowered if the population growth is also reduced, which is not the case in this "Balancing Trade-off" scenario. The household sector is still the major energy consumer with 67 percent (2000) decreasing to 58.7 percent in 2020. The second largest consumer is the transport sector with 17.1 percent in the early years of study period, but this soon replaced by industry/manufacturing sector in 2004 with 17.7 percent of share which further decreases its share to 26.4 percent in 2020. The share of demand in transport sector declines quite significantly over the study period and reaches 14.6 percent in 2020. In terms of fuel type use, wood/biomass is the dominant fuel with its share decreases from 50.3 percent to 36 percent (2020), followed by hydrocarbons with 38 percent share (2000) decreases to 31.8 percent (2020). The shares of other fuels i.e. coal, electricity and natural gas, on the other hand, are increasing. Coal share increases from 1.6 percent (2000) to 7.9 percent (2020), electricity share also increases significantly from 5 percent to 13 percent, and natural gas from 4.6 percent to 11.2 percent over the same study period.

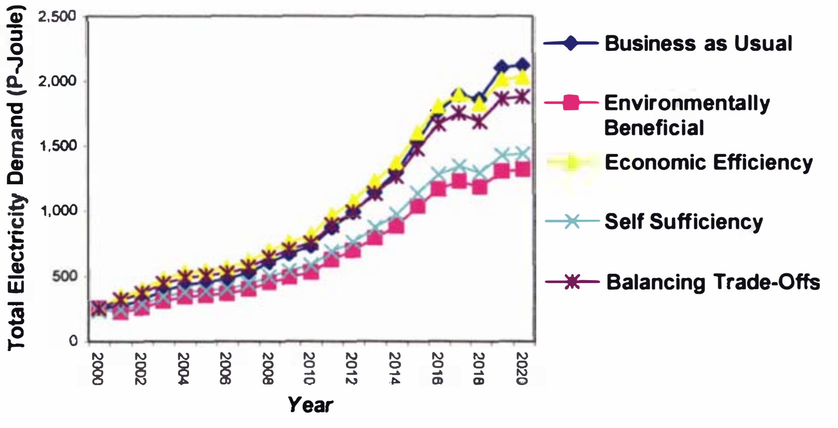



**Figure 9.4 Total Electricity Demand for Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

### Electricity Demand

According to the *'Business as Usual'* scenario, total electricity demand grows annually at the rate of 11.3 percent over 20 years period of the study. The household sector remains the biggest consumer of electricity (63.4 percent) with an annual consumption of 164 P-Joule (in 2000) increasing to 1376 P-Joule (in 2020), follows by manufacturing/industry (34.8 percent) with annual consumption of 90 (in 2000) increases to 746 P-Joule (in 2020), whereas electricity consumption in the energy industry constitutes only 2 percent (in 2000) and declines to only 0.2 percent in 2020.

Total electricity demand grows more slowly in the *'Environmentally Beneficial'* scenario, at only 8.8 percent annually over the period of the study as compared with the 'Business as Usual' Scenario, which grows at the rate of 11.3 percent. The slower growth of electricity demand is more the result of lower economic growth rather than 'housekeeping' energy conservation effort. Total electricity demand is 259 P-Joule (2000), and increases to 1320 P-Joule in 2020. Electricity is mostly used in the household sector with over 60 percent share, and the second largest consumer of electricity is industry/manufacturing sector with almost 40 percent in 2020, whereas, the energy sector (refinery, gas plant etc.) uses less then 0.2 percent of the total electricity demand.

The application of the *'Economic Efficiency'* Scenario causes the total electricity demand grows at an average of 11.1 percent annually, slightly lower than the 'Business as Usual' growth of 11.3 percent over the same study period. The household sector in this scenario, is still the largest electricity consumer with 63.4 percent (in 2000) increasing to 64.8 percent (in 2020), followed by the industry/manufacturing sector, 34.8 percent (in 2000) increasing slightly to 35.1 percent (in 2020), see figure 9.5.2.2.

The *'Balancing the Trade off'* scenario produces an electricity demand which grows at 10.6 percent on average over the study period, which is lower than the 'Business as Usual' and 'Economic Efficiency' figures, (11.3 and 11.1 percent) over the same study period. This lower figure is mainly the cause of lower GDP growth combined with energy conservation in the demand sector. Total electricity demand grows from 259 P-Joule to 1880 P-Joule in 20 years period, which much lower then 2035 P-Joule in 2020, for the Economic Efficiency Scenario and 2126 P-Joule in 2020, for the Business as Usual Scenario).

#### 9.4.1.3 Primary Energy Supply Profile Across the Scenarios

The five scenarios produce interesting profiles of the country's primary energy supply. The total primary energy supply is presented below (Figure 9.5). For the purpose of a more thorough analysis, the total primary energy supply is further broken down into three most important types of primary energy supply, that is, crude oil supply (Figure 9.6), natural gas supply (figure 9.7) and coal supply (figure 9.8)

Total energy supply according the *'Business of Usual'* scenario is 8523 P-Joule (2000) increasing more than 3 fold to 26980 P-Joule by 2020 (see Figure 9.5). Wood/biomass energy remains the main energy supply for meeting domestic energy need, with a share of 62.3 percent (or 5311 P-Joule) in 2000. However, the share decreases to only 37.4 percent (or 10094 P-Joule) in 2020. Whereas, the shares of crude oil, natural gas, coal, hydro and geothermal are 28.5, 5.2, 3.6, 0.3 and 0.2 percent respectively in 2000. At the end of the study period (2020), the share of coal increases to 17.1 percent, natural gas 15.5 percent, hydro 1.3 percent, geothermal 0.6 percent, but crude oil's share decreases to 25.3 percent. With this 'Business as Usual' scenario, nuclear energy starts at 2016 with the share of 0.04 and increases to 2.8 percent in 2020 (or 767 P-Joule).

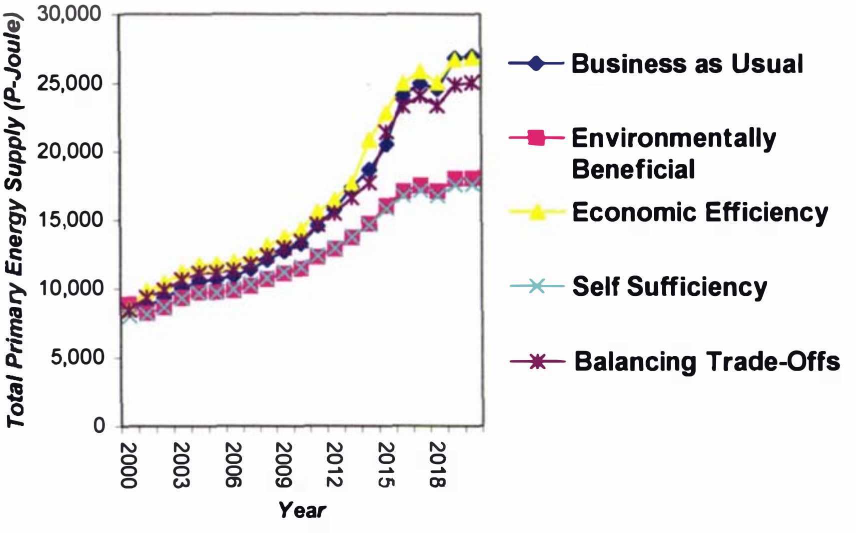



**Figure 9.5 Total Primary Energy Supply for Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

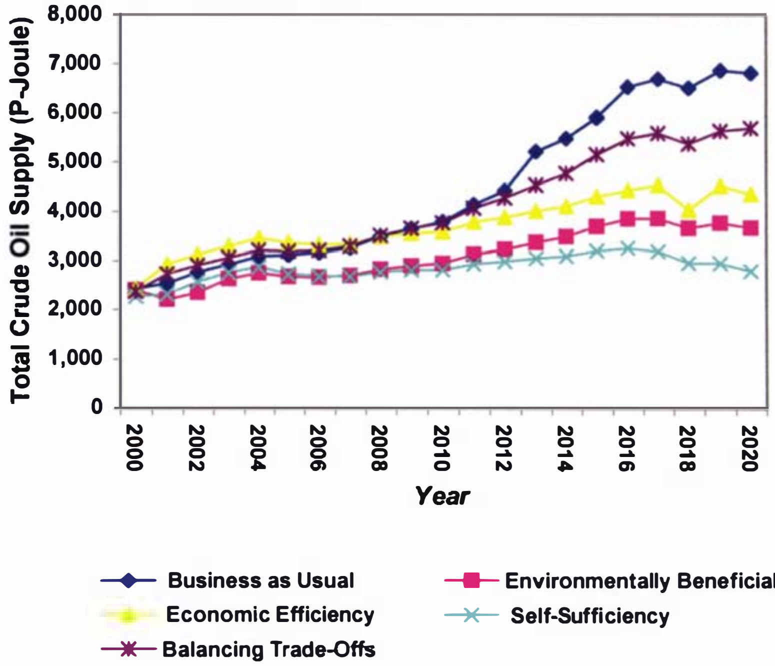



**Figure 9.6 Total Crude Oil Supply for Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

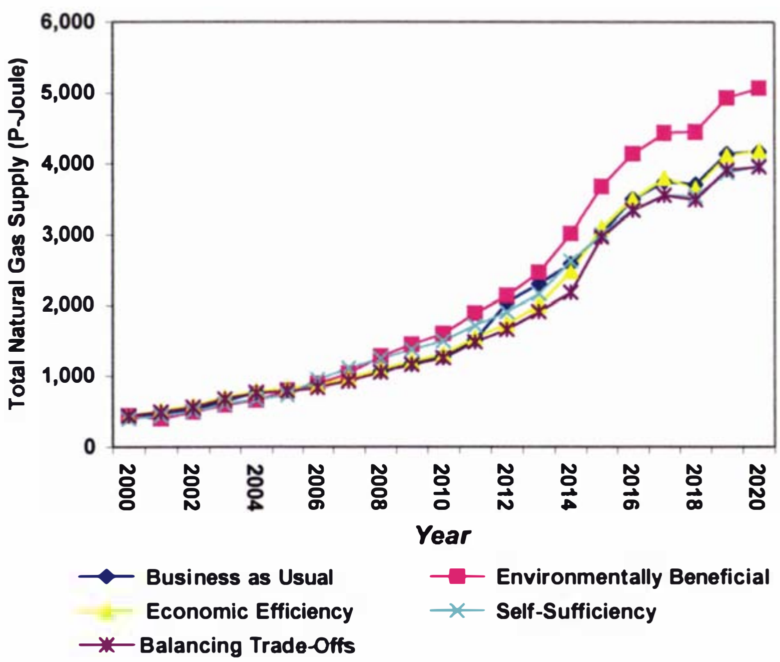



**Figure 9.7 Total Natural Gas Supply for Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

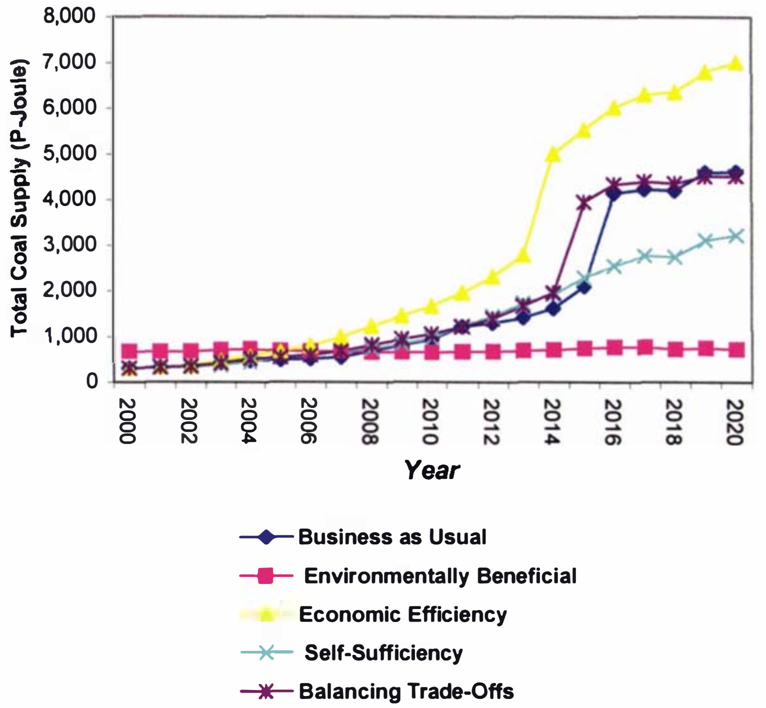



**Figure 9.8 Total Coal Supply for Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

Total energy supply based on the *'Environmentally Beneficial'* scenario is 8858 P-Joule (2000) increasing to 18015 P-Joule (2020), which is substantially lower than the figure in "Business as Usual' scenario which is about 26980 P-Joule (2020). At the end of the study period, wood/biomass remains the main energy supply to meet domestic energy need though its share is decreasing. Wood/biomass share is still high or about 41.8 percent in 2020 followed by natural gas 28.1 percent, crude oil 20.4 percent, coal 4 percent, uranium 3.6 percent and then hydro 1.7 percent. The share of coal decreases from 7.6 percent (in 2000) to 4 percent (2020), mainly as a result of 'Environmentally Beneficial' policy to shift away from coal to less carbon content fuels i.e. nuclear, geothermal and hydro in the power generation sector.

Total primary energy supply in the *'Economic Efficiency'* scenario increases from 8523 PJ in 2000 to 26853 PJ in 2020 or more than three fold over the 20 years period, slightly lower than in the 'Business as usual' scenario which is about 26980 P-Joule (2020). At the end of the study period (2020), wood/biomass remains the largest contributor of energy supply with a 37 percent share or about 9923 P-Joule, followed by coal with 26.1 percent or 7014 P-Joule, crude oil with 16.2 percent or 4363 P-Joule, natural gas 15.6 percent or 4181 P-Joule, and nuclear 3.3 percent or 883 P-Joule. Other sources of fuel, like geothermal and hydro are 0.5 and 1.3 percent respectively.

In the *'Self Sufficiency'* scenario, the total energy supply is 8037 P-Joule in 2000 which increases to 17578 P-Joule by the end of the period (2020) or more than double in 20 years, with wood/biomass as the major contributor (62.8 percent), followed by crude oil (28 percent), natural gas (5 percent), and coal (3.7 percent). However, by the end of the period (2020), the share of coal and natural gas to total energy supply increases to 18.3 percent, natural gas 22.6 percent, whereas wood/biomass' share decreases to 41 percent and crude oil share decreases to 15.9 percent. The declining share of wood/biomass supply is the result of fuel shifting from wood/biomass to kerosene and LPG for cooking purpose in the household sector as the income per capita improving over the period.

Total energy supply of the *'Balancing Trade-Off'* scenario is 8462 P-Joule in 2000 increases to 25047 P-Joule in 2020 or increases more than 3 folds in 20 years period which is still lower than the 'Business as Usual' and the 'Economic Efficiency' scenario, which are 26980 P-Joule (2020) and 26853 P-Joule (2020) respectively. As also the case with other scenarios, wood/biomass unavoidably is still the major supplier with 62.8 percent or 5311 P-Joule (2000) with decreasing share to only 37.9 percent in 2020. The second largest supplier is crude oil with 28 percent or 2367 P-Joule (2000) decreasing to 22.8 percent (2020). The third is natural gas with 5.2 percent (2000) increasing to 15.8 percent at the end of the study period. The coal share increases from 3.6 percent in 2000 escalating to 18.1 percent in 2020. Nuclear energy supply (uranium) starts in 2015 with 0.2 percent (49 P-Joule) share and increases to 3.5 percent (or 883 P-Joule) in 2020. The role of other forms of energy, such as geothermal and hydro, does not show significant changes over the study period.

### 9.4.2 Indicator Variables

There are five important indicator variables selected from the results of the 'model run' for the five scenarios for the purpose of cross analysis. that is, 1) Percentage of renewables (%), total and non-wood renewables, 2) Total energy supply costs (Million US $), 3) Total energy efficiency (T-Joule/Billion Rupiahs), 4) Net primary energy import or export (P-Joule), and 5) Carbon dioxide emissions (Kilotons). Following are the discussions on the five indicator variables.

#### 9.4.2.1 Percentage of Renewables (Total and Non-Wood Renewables) Across the Scenarios

Based on the *'Business of Usual'* scenario, the share of renewable (if wood is included) decreases from 62.8 to 42.2 percent over the period of the study (2000-2020, see Fig. 9.9). However, if wood/biomass is unaccounted, the share increases from 1.2 to 7.6 percent (see Figure 9.10). The declining share of renewables (if wood is included) is caused by the declining share of wood/biomass in household sector (as also discussed above) due to the shift of wood/biomass use to kerosene and LPG for cooking purposes. The increasing share of renewables (see Figure 9.10; wood excluded) has been attributed by the increasing use of renewables, mainly geothermal, hydro and nuclear (starts in 2016) in the power generating sector.

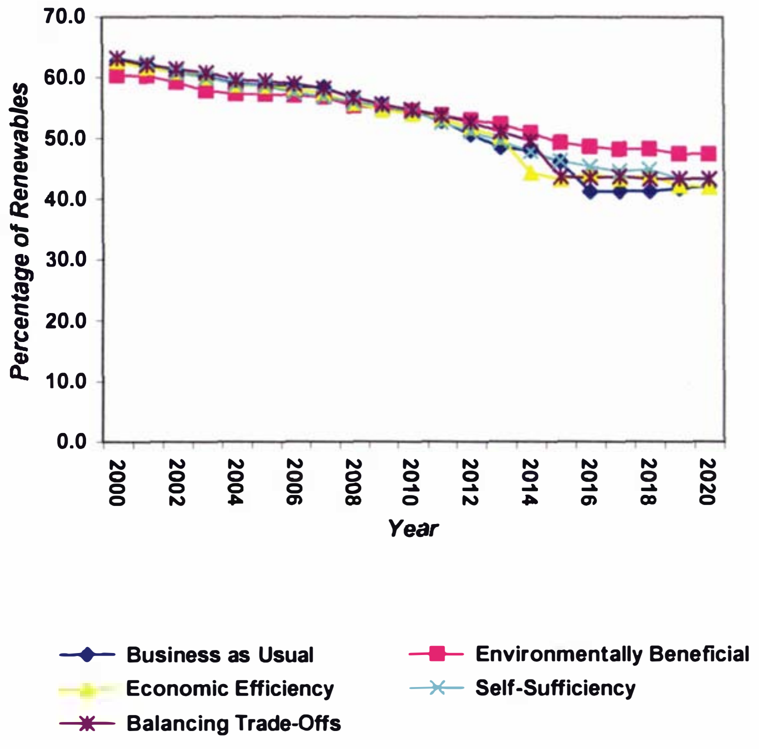



**Figure 9.9 Renewable Energy Used by Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

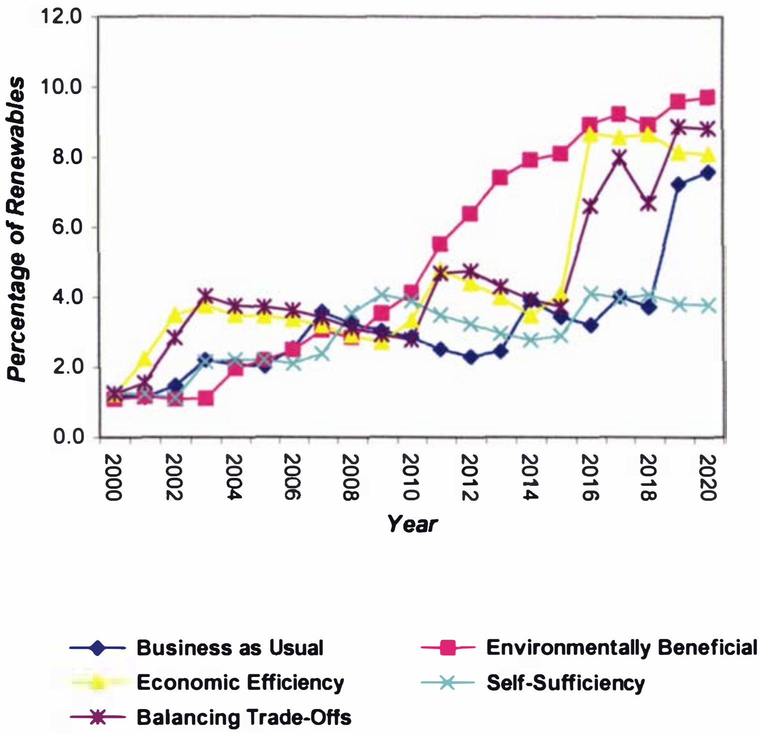



**Figure 9.10 Non-Wood Renewable Energy Used by Indonesia (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

According to the *"Environmentally Beneficial'* scenario, the share of non-wood renewables increases substantially from 1.1 percent (2000) to 9.7 percent (2020), which is much higher than the 'Business as Usual' scenario which is only about 7.6 percent (2020). If wood/biomass is accounted, the share of renewables declines from 60.4 percent (2000) to 47.5 percent (2020). The increasing trend of non-wood renewables in this scenario is mainly the result of the policy of 'less carbon' fuel mix in the electricity generation sector and the policy to replace hydrocarbons use in the transport sector with CNG, LPG and Electricity, though in a very insignificant role (1-3 percent) due to the difficulty of the nature of diversification in the transport sector (high investment costs, infrastructure and institutional problems).

As in other scenarios, the percentage of renewable energy use in the *'Economic Efficiency'* scenario is categorized into two; 1) non-wood renewables and 2) wood-included renewables. If wood is included, the share of renewable in the country's energy mix is 62.8 percent (2000), which decreases to 42.1 percent (in 2020). However, if wood/biomass is excluded, the renewable energy share increases from 1.2 percent (2000) to 8.1 percent (2020), see Figure

9.10. above. The decreasing percentage of wood-renewables' is attributed to the shift of use from wood/biomass into other form of energy i.e. LGP and kerosene for cooking purposes, as the economy grows, the wood/biomass share declines. Whereas, the increasing non-wood renewable share is a result of a'fuel mix' program in electricity generation sector which assumes a more intensive use of cheaper renewables such as hydro, geothermal and nuclear to replace hydrocarbons, which is very expensive in term of generating cost.

According to the *'Self Sufficiency'* scenario, the percentage of renewables (if wood/biomass is included) decreases from 63.2 percent (2000) to 43 percent (2020). However, if wood/biomass is excluded, the share increases from only 1.3 percent to 3.8 percent (2020). The increase of non-wood-renewable share is much lower than the 'Business as Usual' scenario, which is about 7.6 percent (2020). This indicates that 'Self Sufficiency' scenario put more roles on coal to replace hydrocarbons rather than on other indigenous renewables, such as hydro and geothermal, especially in the power generation sector and heating fuel (for industry). The scenario assumes that there is not so much diversification effort done for transport fuels, which will still be heavily rely on hydrocarbons fuel.

The *'Balancing Trade-Off'* scenario produces a higher share of non-wood renewable at the end of the study period, increasing from 1.2 percent (2000) to 8.83 percent in 2020, compared to the 'Business as Usual' renewable share at 7.6 percent (2020) and the 'Economic Efficiency' renewable share which is about 8.1 percent (2020) (see Figure 9.10.). The total renewable share (if wood is included) drops from 63.2 percent (2000) to 43.4 (2020). This significant drop is caused by the shift of wood/biomass fuel use to kerosene and LPG in the household sector. The increase of non-wood renewable energy has mainly been the result of 'fuel mix' policy in the power generation sector, which encourages more use of hydro, nuclear and geothermal to replace hydrocarbons.

#### 9.4.2.2 Total Cost of Energy Supply Across the Scenarios

Over the study period with the *'Business as Usual'* scenario, cost of energy supply per annum shows an increasing trend from 11456 Million US$ (2000) to 93893 Million US$ (2020), or more than 8 fold (see Figure 9.11). This escalating supply cost has been attributed to an increasing electricity generation supply cost rather than by the primary energy supply costs (heat and transport fuel costs). The 'scenario run' shows an increasing electricity supply cost from only 2130 Million US$ (2000) to 44621 Million US$ (2020) or almost 20 times in 20 years, whereas for primary energy the increase is relatively slower with 9325.7 Million US$ (2000) to 49271 Million US$ (2020). The share of electricity supply cost which is less than 20 percent in 2000 increases to more than 50 percent in 2020. This relatively high increase of supply cost for electricity generation has been caused mainly by the cost of hydrocarbons fuel generation power plant which is assumed still being intensively operated in this 'Business as Usual' scenario.

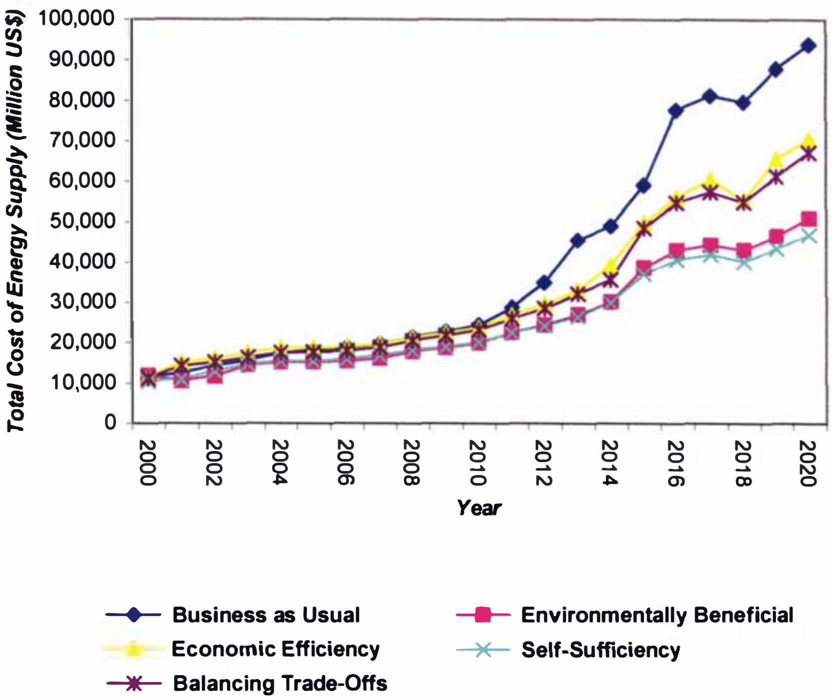



**Figure 9.11 Total Cost of Energy Supply for Indonesian (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

The *'Environmentally Beneficial'* scenario results in a less expensive total energy costs than the 'Business as Usual' one. The total cost of energy supply increases relatively slowly from 11761 (2000) to 51059 Million US$ (2020), compared to 93893 Million US$ (2020) of the 'Business as Usual' scenario. The reduction of cost is mainly the result of combination of policies of 'lower GDP growth', pricing policy for hydrocarbons in transport sector and the 'fuel mix' policy in the generation sector to replace coal with nuclear, geothermal and hydro which are relatively cheaper than coal. The cost of electricity supply constitutes one third of the total supply cost.

As the consequence of the *'Economic Efficiency'* scenario, the total cost of energy supply increases from 25867 Million US$ in 2000 to 97368 Million US$ in 2020, which is higher than the result given by 'Business as Usual' scenario. This is the result of higher GDP growth assumed in this scenario (15 percent higher). Although this 'Economic Efficiency' scenario considers the implementation of energy conservation efforts and 'fuel mix' policy to shift to more cheaper fuels, the cost of energy supply is still high compared to the 'Business as Usual' scenario. The use of cheaper fuels such as coal, hydro and geothermal to replace hydrocarbons has helped reduce the cost of electricity supply from 44621 Million US$ (in the Business As Usual scenario) to almost half or 29051 Million US$ (2020). The success of reducing electricity supply cost doesn't help reduce the total supply cost of energy however, because a large percentage of expensive hydrocarbons is still used especially in transport sector as the shifting to non-hydrocarbons (CNG or LPG) in this sector is still facing infrastructure and financial problem, and only less than 2 percent of hydrocarbons in the sector can be replaced by CNG or LPG.

The *'Self Sufficiency'* scenario results in a much lower cost of energy supply compared with the 'Business as Usual' one. The total cost of supply at the end of the period (2020) can be reduced from 93893 Million US$ to only 46813 Million US$, which is more than half of 'Business as Usual' cost of supply. The cost reduction is attributed more by the reduction of electricity supply cost (as a result of the policy of more use of coal) rather than by the primary energy supply cost, though both contribute quite significantly to the total cost reduction. At the end of the period (2020), electricity cost is 17780 Million US$ and primary energy cost is 29030 Million US$, compared to the 'Business as Usual' figures, which is 44622 Million US$ for electricity and 49271 Million US$ for primary energy.

The total cost of energy supply is significantly lower than that of 'Business as Usual' and 'Economic Efficiency' scenarios as in the balancing trade off scenarios, (see Figures 9.11 above). Total energy cost can be reduced to only 67207 Million US$ (2020), compared to 93893 Million US$ (Business as Usual in 2020), and to 97368 Million US$ (Economic Efficiency in 2020). The supply cost of electricity contributes more on the reduction of total cost rather than the cost of primary energy supply. The cost of electricity supply can be reduced from 44621 Million US$ (Business as Usual, 2020) to 23724 Million US$ in 2020. The use of cheaper fuel like coal plays dominant role in reducing the electricity supply cost.

#### 9.4.2.3 Total Energy Efficiency Across the Scenarios

Total Energy efficiency of the *'Business as Usual'* scenario (Fig. 9.12) shows an increasing trend, which indicates inefficiency of the total energy system. This indicator is measured in term of total energy supply (T-Joule) divided by GDP produced by the economy (Billion Rupiahs). Total energy efficiency increases from 15 T-Joule/Billion Rupiahs (2000) to 19 T-Joule/Billion Rupiahs (in 2020). There is a notable increase in 2016, which coincides with the introduction of nuclear power plant, in which the power generation cost increases by about 50% from the previous year's (2015), see Figure 9.12 below.

Unlike the 'Business as Usual', the '*Environmentally Beneficial*' scenario shows an improving 'energy efficiency of the economy' indicated by the declining trend of total energy efficiency or lower energy supply per gross domestic product (GDP). Total energy efficiency significantly decreases from 16 at the beginning of the period (2000) to 14 T-Joule/Billion Rupiahs (2020) showing a more 'energy efficient' system. This is mostly the result of deaccelerated economic growth and energy conservation implementation in the demand sector.

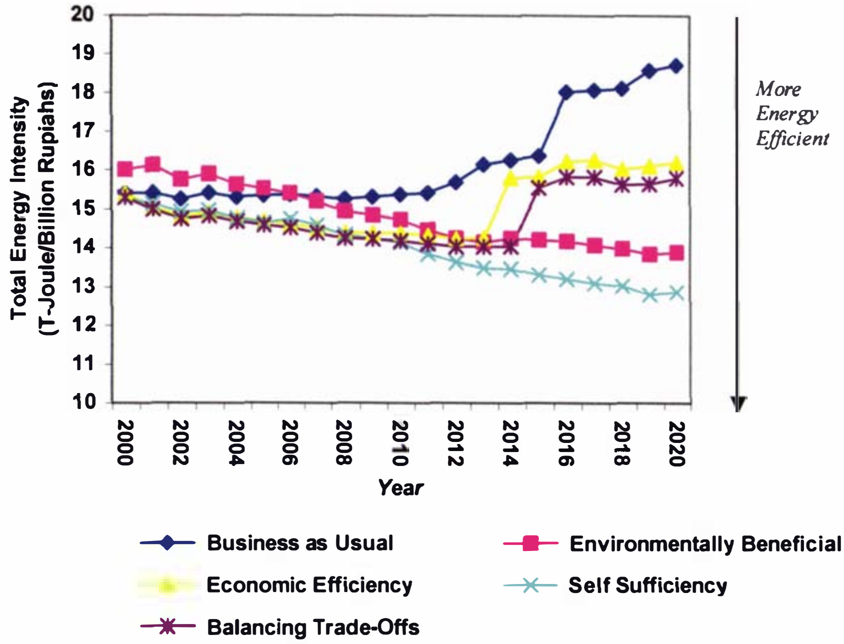



**Figure 9.12 Total Energy Intensity for Indonesian (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

For the '*Economic Efficiency*' scenario, figure 9.3.2.3 shows that energy efficiency in this scenario indicates an improving trend during the beginning of the period to 2013 from 15 to 14 T-Joule/Billion Rupiahs, but becoming less efficient after 2014 and increasing to more than 16 T-Joule/Billion Rupiahs. This in-efficiency has been caused by the use of more nuclear and natural gas and relatively less use of hydro (which is cheaper) due to availability and capacity considerations, as the capacity development of hydro and geothermal power plants is more restricted and constrained by locally available resources.

On the other hand, the total energy efficiency of the '*Self Sufficiency*' scenario shows an improving pattern throughout the study period (2000-2020). At the beginning of the Study period (2000), the total energy efficiency, which is about 15.3 T-Joule/Billion Rupiahs decreases to 12.9 T-Joule/Billion Rupiahs. Lower population growth combined with energy conservation, fuel mix, and price increases of hydrocarbons for the transport sector have brought about positive impact on the total energy efficiency of the economy.

Total energy efficiency of the *'Balancing the Trade off'* scenario also shows significant improvement over the 'Business as Usual' and 'Economic Efficiency' although not as low as the 'Environment Beneficial' and 'Self Sufficiency' scenarios, see Figure 9.12. Total energy efficiency tends to decrease during the period 2000-2014, from 15 to 14 T-Joule/Billion Rupiahs, but increases during 2015 to 2020, from 14 to 16 T-Joule/Billion Rupiahs. The increase in the total efficiency is attributed to the increase use of nuclear energy, which is relatively more expensive than hydro and geothermal (which have a capacity constraint in the period).

#### 9.4.2.4 Net Primary Energy Import and Export Across the Scenarios

Based on the *'Business as Usual'* scenario, the country's net export of energy is approximately 37 P-Joule (in 2000) as shown in Figure 9.13. Assuming that crude oil and natural gas production are declining and only coal production is increasing (data on fossil fuel production provided by the University of Indonesia Study (LPEUI, 2003) with the 'Business as Usual' Scenario, Indonesia will have to change its status from a 'net exporting country' to 'a net importing country' in 2010, with a total net of energy import 3 P-Joule.

The total energy import gradually increases to 37 P-Joule in 2020. With further efforts on intensification of exploration and exploitation, especially increasing new findings of oil and gas well in Eastern parts of Indonesian, increasing oil and gas recoveries and coal, gas and crude oil production, the status might be prolonged which will be discussed in "Self Sufficiency" scenario.

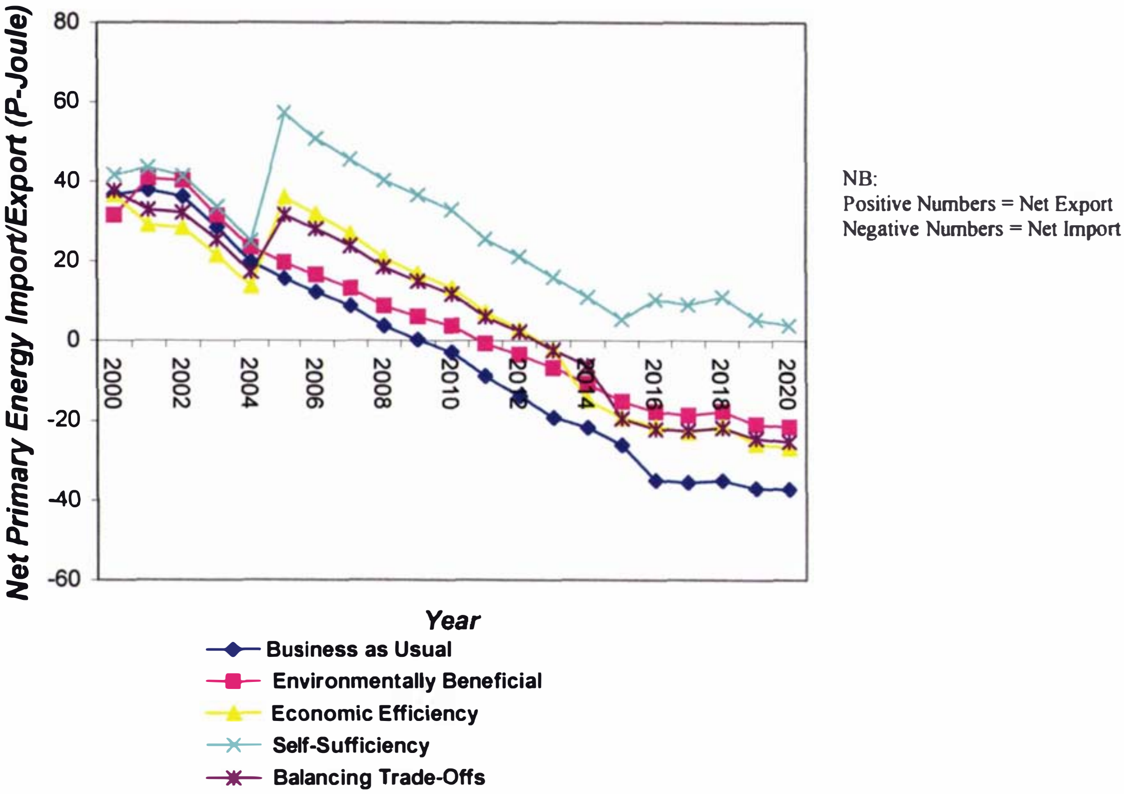



**Figure 9.13 Total Net Primary Energy Import or Export for Indonesian (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

According to the *'Environmentally Beneficial'* scenario, which assumes no additional production of fossil fuel (follows the past trend), Indonesia becomes a net importer of energy in 2011 as shown in Figure 9.13 above. In this year, the country starts to import energy (0.81 P-joule) and increases to 21.6 P-joule in the end of the study period (2020). As described in the scenario description above, the scenario assumes that the production of coal, natural gas and crude oil follows the same trend as 'Business as Usual' scenario. However, with this scenario, Indonesia can prolong its status to be 'a net energy importer' by 1 (one) year from the 'Business as Usual' scenario.

In the *'Economic Efficiency'* scenario, Indonesia is projected to be a net energy importer in 2013 or 3 years later than in the 'Business as Usual' scenario (which starts in 2010). 15 percent higher economic growth than 'Business as Usual', combined with enhancement of indigenous domestic production has slowed the change of the country's status from an energy exporting country toward an energy importing country in (2013). By the end of the study period, Indonesia will have to import 2.19 P-Joule of energy to fulfil the domestic energy need, see Figure 9.13. Only with a more vigorous effort of intensification and exploration of oil and gas fields, especially in eastern part of Indonesia can this changing of status be further prolonged.

As a result of the policy to increase all fossil fuel production (coal, natural gas and crude oil), explained in the *'Self Sufficiency'* scenario, the country can meet its domestic energy need, and even at the end of the study period (2020), Indonesia still hold its status as 'a net oil exporting' country and can still export 4 P-Joule of energy, see Figure 9.13. By comparison, in the 'Business as Usual' scenario, Indonesia will have to start to import energy in 2010 and moreover, at the end of the study period (2020) its total import of energy reaches 37 P-Joule.

As the *'Balancing Trade-off'* scenario assumes increased production of fossil fuel, coal by 50%, natural gas by 25% and crude oil by 25%, Indonesia's status as a 'net oil importer' (which is supposed to be in 2010 according to the 'Business as usual' or in 2008 according to the 'Economic Efficiency' scenario), can be further prolonged to 2013, or 3 and 5 years longer than the two previous scenarios. According to this scenario, Indonesia starts to import energy in 2013 amounting to 2.39 P-Joule, and by the end of the study period the total import of energy will be 25.25 P-Joule.

#### 9.4.2.5 Carbon Dioxide Emissions Across the Scenarios

The application of the five scenarios outlined in the previous section produces the following results of $CO_2$ emission. Total $CO_2$ emission of energy system of the economy, according to *'Business as Usual'* Scenario, shows a rapid increasing trend. Carbon dioxide emissions increase to almost 3 times the 2000's level, from only 228 Million Tons (2000) to 639 Million Tons (2020). By comparison, another similar study e.g. by University of Indonesia (Study Report, 2000), projected a level of $CO_2$ emission of more than double that of this scenario. According to the study, $CO_2$ emissions increase from 487 Million Tons (2000) to approximately 1506 Million Tons (2020).

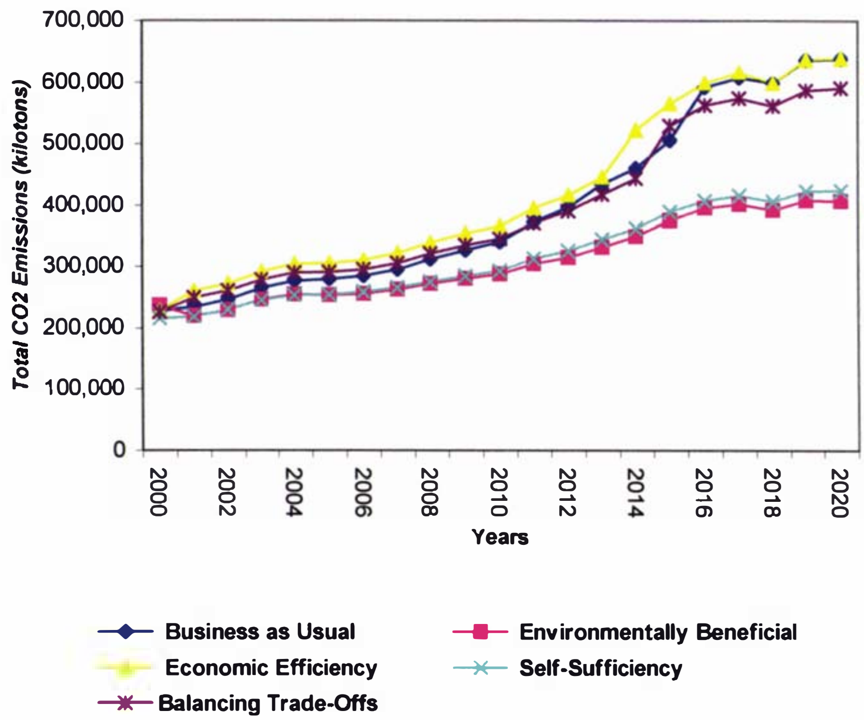



**Figure 9.14 Total Carbon Dioxide Emission for Indonesian (2000-2020) Generated by the System Dynamics Model, for Five Scenarios**

With the *'Environmentally Beneficial Future'* scenario, total carbon dioxide ($CO_2$) emissions can be significantly reduced, - more 30 percent lower than the 'Business as Usual' scenario. At the end of the study period (2020), the total amount of $CO_2$ is only 408 Million Tons, which is much lower than the 639 Million Tons of the 'Business of Usual' scenario in 2020. The significant reduction of in $CO_2$ emissions is the result of ' lower GDP growth', pricing policy, energy conservation and 'fuel mix' in electricity generation and primary energy as explained the scenario description section above.

The 15 percent higher economic growth designed for the *'Economic Efficiency'* scenario escalates CO2 emission from 228 Million Tons (2000) to 640 Million Tons, surprisingly only a slightly higher than the 'Business as Usual' scenario (which is about 639 Million Tons). Energy conservation has helped to maintain the $CO_2$ emission's level similar to 'Business as Usual' level. Compared to 'Environmentally Beneficial' scenario which creates only 407 Million Tons of $CO_2$, the $CO_2$ emission level of this scenario is much higher though. Therefore, it can still be further reduced by a combination of efforts e.g. slightly lowering economic growth and higher price of hydrocarbons in the transport sector to curtail demand.

The amount of total carbon dioxide ($CO_2$) emission produced from the *'Self Sufficiency'* scenario, is much lower than in the 'Business as Usual' level. In 2000, $CO_2$ emission is 215 Million Tons and increases to 423 Million Tons in 2020 or double the 2000's emission level, a much lower level when compared to the 'Business as Usual' scenario, which is about 228 Million Tons in 2000 and increases to 639 Million Tons or almost 3 times the 2000's emission level. The lower growth of population scenario, combined with energy conservation and the policy to shift away from hydrocarbons to coal, hydro and geothermal has brought about reduced $CO_2$ emission by approximately 200 Million Tons in 2020 alone.

The assumptions given in the *'Balancing Trade-Off'* scenario, increases the total $CO_2$ emission about 2.5 times in 20 years (2000-2020). Carbon dioxide emission is 226.4 Million Tons (2000) increases to 590 Million Tons (2020). The figure, however, is lower than that of 'Business as Usual' and 'Economic Efficiency', which is about 639 Million Tons (2020) and 640 Million Tons (2020).

## 9.5 Policy Implications

The analysis of the policy implications for each scenario described below is developed from the results and the indicator variables obtained from the dynamics simulation model for the Indonesian energy system. The future policies and measures that need to be undertaken as a consequence of the application of these five scenarios are discussed as follow:

### 9.5.1 Policy Implications for Business as Usual Scenario

The *'Business as Usual'* scenario assumes that there is no major new energy and economy related policies be undertaken. As a result, the economic activities and GDP will continue to follow the past trend (in this case assumed to follow the average 20 years trend of 5 selected countries with similar GDPs as Indonesian current GDP US$ 800, as already discussed above). Population growth will be let to follow the past trend and no new policy to influence population of the country.

There is no new pricing policy and fossil fuel remains the cheapest form of fuel and adequately available to drive the economy. However, the past and current government plan to gradually increase the price of hydrocarbons and electricity will still be assumed to take place. No major changes on energy conservation policy or programs though this doesn't mean that there is no energy conservation policy implemented. The past policy, such as INPRES 9/1982 (Presidential Instruction no. 9/1982), the requirement for government/non government building/institutions to report on energy conservation effort is still being enforced. And other regulations/policies that require state own energy companies to report and implement energy conservation activities will still have to be undertaken.

In the power generation sector, the fuel mix policy will be based on the current government and utility companies' plan or policy. The government plan to build some new committed projects (coal, natural gas, hydro, biomass and geothermal power plants) all over Indonesian region will continue in accordance to the plan and time schedule (until 2010). As for nuclear power, the government (Nuclear Energy Atomic Agency) plan to start nuclear power program in 2016, in which some studies , regulations and preparations are now being carried out, is assumed to go on in accordance to the schedule.

For the primary energy supply, the scenario also assumes that there is no major policy changes be undertaken to influence the demand pattern for heating fuel as well as transport fuel purposes. The past trend of hydrocarbon consumption in transport sector will be assumed to continue, the government policy on hydrocarbons price will not significantly influence the current and future demand pattern which still be dominated (99%) by hydrocarbons fuel. The current policy on CNG and LPG will still continue without giving significant changes to the future trend.

The scenario assumes that there is no new government effort in the enhancement of fossil fuels' production. The current and the likely future productions of coal, natural gas and crude oil is assumed to follow the official projection figures (Study Report, 2000), which is increasing for coal, but declining for both oil and natural gas, due to the depleting reserves (see the production figure 9.3.2.8 above). The R&D efforts and activities will take place according to the government plan without bringing significant changes or breakthrough on the current level of productions. New government policies on oil and gas investment (privatisation of oil and gas companies, which opens more opportunity to foreign investors) are assumed did not take place due to legal and public acceptance constraints.

### 9.5.2 Policy Implications for Environmentally Beneficial Scenario

For the *'Environmentally Beneficial'* Scenario, the government will need to enforce the policy on energy conservation standards to encourage energy users especially manufacturing/industry and household sector to implement energy conservation programs. Labelling and building codes will be promoted to increase efficiency of energy use. In the past there has been some initiatives to begin the labelling effort and this needs to be realised to speed up the implementation of energy efficiency program. Training and campaign program combined with 'free preliminary energy auditing' to identify energy saving potential in the manufacturing and commercial sectors need to be intensified. Government surveys that have been conducted in the past showed quite significant potential of savings in some energy using sectors, e.g. in transport sector 25 percent potential of saving, industry/manufacturing 15-30 percent and household/commercial sector 10-30 percent. Some of this saving can be realised through 'no cost' and 'low cost' energy saving implementation. Gradually, the government should apply mandatory energy audit for industry and commercial sectors to realize this potential of savings. The government will need to introduce a mandatory regulation that will require industries and commercial buildings to have an energy audit as part of its feasibility study.

In the transport sector, the government could implement progressive taxes for car/automobiles, carbon taxes and incentives for using less carbon fuel e.g. CNG (compress natural gas) or LPG (liquid petroleum gas). Government shall increase the price of hydrocarbon fuel by at least 10 percent to encourage the use of alternative fuels in this sector.

In the power generating sector, the utilisation of less carbon fuel should be encouraged through giving renewable investment tax credits, low-cost loans for electricity generation and biomass fuels production. To discourage investment on new coal and hydrocarbons plants, the government needs to accelerate capital depreciation for existing coal and hydrocarbons power plants. The government can also issue bans on new coal-fired and hydrocarbons power generating plants. The Government needs to issue policy for the integration of the renewable energy technologies into the existing power grids. In the short term, the integration needs to apply for geothermal power sources. In the long term, similar plans shall apply to biomass, solar and wind power.

To meet the growing need for demand of electricity, the government needs to start nuclear power plant in 2010 at the latest to replace coal-fired and hydrocarbons power plants. Campaign program and public education to increase public acceptance on nuclear power will need to be started now. BATAN' study recommended that nuclear power plant can be started in 2016, but an earlier installation is possible with a more strict environment standards can be enforced now. According to the study by Energy Atomic Agency of Indonesia (BATAN), *"the more the environmental standards are tightened and enforced the more and the earlier nuclear becomes part of the optimum generation mix"* (Study Report, 2001)

Energy conservation effort in the power generating and energy industry sector needs to be intensified. The issuance of Presidential Decree no. 43/1992 requiring the energy industries to report activities in energy conservation effort need to be re-enforced to enhance energy saving program in this sector. Free preliminary energy auditing shall be provided by the government to the energy industry to encourage implementation of energy saving in this industry. Co-generation system will have to be promoted and for this, some incentive mechanisms will need to be designed.

Government also need to speed up and enhance R&D programs on clean energy technology, fluidised bed and IGCC technology. R&D on nuclear program for nuclear reactor design as well as on waste disposal technologies will also need to speed up in line with the effort to embark on this nuclear power program. R&D on other renewables that are potentially available in rural and remote areas, such as biomass, wind, solar PV and biomass energy will need to be intensified. Government shall disseminate research results and provide training program on renewable to rural people.

Cooperation with other APEC members through energy working group activities on the implementation of the 14 binding policies needs to be intensified to increase energy conservation and energy diversification to ensure the implementation of more environmentally benign energy utilisation in the country. Government needs to enhance or encourage the use of renewable through formulating a favourable regulatory treatment for renewable energy use such as credits, loans and incentives (financial and non-financial) for renewable energy use especially wind, photovoltaic and biomass energy for remote areas.

### 9.5.3 Policy Implications for Economic Efficiency Scenario

This *'Economic Efficiency'* scenario put higher emphasis on economic growth rather than other matters. Important factors to economic growth are law, political and economic stabilities. These factors will ensure the growing of economic activities especially for important sectors like manufacturing/industries and commercial sectors that provide high contribution to the nation Gross Domestic Product. All of these crucial factors will need to be guaranteed by the government to create conducive environment for economic growth. Indonesia has learned 'hard lesson' from economic crises, which created economic turbulence for almost 4 years since 1997. Policies on attracting foreign direct or indirect investments and loans (private capital inflows) to sustain economic recovery and to increase the country's economic growth will need to be undertaken. Liberalisation of the economy, trade regime, reducing protection, privatisation, and other reform measures on taxes, reducing tariff and trade barriers, lessening restrictions on exports and imports will be very important to ensure economic efficiency. The government plans on privatisation to enhance the efficiency of state-owned enterprises will also need to be undertaken. Moreover, careful monetary policy that allows inflation and interest rates to decline and rupiah to strengthen can help improve the 'economic efficiency'.

As the economy grows, the energy demand will escalate in almost all economic sectors, which then triggered the need to supply more energy to meet the growing demand. The energy policy for this 'Economic Efficiency' scenario will therefore, be focused on expanding energy supply rather than reducing demand in order to support the economic growth. The need to increase production of indigenous fossil fuels will require the country to determine new oil and gas reserve findings or to enhance oil and gas recoveries. R and D on oil and gas technology for more efficient recovery, exploration and exploitation technologies will need to receive greater attention. New regulation on oil and gas (Oil and Gas Law no. 22/2002) that has recently been issued and agreed by the Indonesian Parliament will help open the opportunity for production increases of coal, natural gas and crude oil, as foreign investors are more welcome to participate in the oil and gas business.

Equally important is that the scenario requires a plentiful supply of relatively cheap fossil energy during the period, but still does not cause major environmental problems and doesn't induce controls on energy demand. The price of energy will need not be increased to boost the economic activity and industrial development.

The government should not issue new policies on environment that will hamper the productivity of manufacturing and commercial sectors, such as policy on $CO_2$, $SO_2$ and $NO_x$ emissions controls.

The energy demand required to support this 'economic efficiency' scenario shall not also be curtailed by the government policy on energy conservation. However, for the purpose of moderating the rapid escalation of energy demand leading to the efficiency of the economy as a whole, the government still needs to encourage public adoption of energy conservation and efficiency through well-research public campaign. Public campaign is very important in ingraining behavioural change. Public campaign and providing information and training on housekeeping or no cost or low cost energy saving programs need to be given to energy users. Training for industries and other energy intensive users is also needed to provided them with technical skills to implement energy saving. The government also needs to formulate energy labelling and standardization scheme for appliances entering the market, so that customer will be able to choose the most energy saving products while at the same time providing incentives for appliance manufacturers who have developed the energy efficient appliances. R and D to enhance efficiency or to improve combustion for improving generation efficiency or emission control for coal burning will still need to be undertaken.

### 9.5.4 Policy Implications for Self Sufficiency Scenario

Unlike the 'Economic Efficiency' scenario, the focus on the *"Self Sufficiency'* scenario, is more on reducing or making 'more efficient' the demand for energy so as not to require the country to rely on other countries to supply its domestic energy requirement.

Self-dependency on supplying its domestic energy demand will require the policy to control the demand to ensure adequate supply of energy. Pricing and energy conservation policies combined with the environment policy will consequently need to be carried out to encourage or promote more wise and rational use of energy, especially fossil fuel energy i.e. hydrocarbons and natural gas. Whereas, promotion on the use of abundantly available energy resources, such as coal and renewables such as hydropower, geothermal, mini-hydro and biomass, will be encouraged.

Population remains an important factor to 'Self Sufficiency' objective. Family planning program will need to be vigorously implemented to deaccelerate population growth. Providing incentives to 'small families' (less than 2 children) or diss-incentives to 'big families (more than 2 children) will help curtain the growth of population. Training and public campaign are also useful to reduce the population growth.

Increased energy prices for 'scarce resources' such as hydrocarbons and natural gas to discourage the consumers, whereas giving more subsidies to coal users, as coal reserves are abundantly available in the country. The government needs to allow the users realize the true cost of energy by adjusting administered prices of hydrocarbons and natural gas and aiming at gradually removing the subsidies to both natural gas and hydrocarbons.

Energy conservation policy will be needed to encourage the use of more efficient appliances through; providing incentives for investment in energy efficient products or introducing a scheme that will assist companies investing in energy efficient appliances and technologies in the form of tax incentives and soft loans, and public information and assistance package to help companies gradually through the bureaucracy. Public campaigns that increase public awareness toward the importance of energy conservation need to be more vigorously carried out. Moreover, energy labelling and standardisation will be important to help energy users to choose the most energy efficient appliances or products.

The government needs to promote the use of renewable energy through providing incentives for imports and use of renewable energy technologies. The government will also need to construct pertinent regulations that can induce imports, use and technology transfer of renewable energy technologies through i.e. tariff reduction, tax breaks, proper land regulation, and other incentives.

Increased indigenous energy production both for renewable and non-renewable sources of energy. For non-renewables, government needs to increase domestic production of coal, crude oil and natural gas by carrying out enhanced of recoveries program, intensifying exploration and exploitation activities. Whereas, for renewable energy, the government needs to encourage and increase private sector involvement in producing power, with priority on renewable energy sources. Small-scale producers need to be encouraged to participate in providing power based on renewable energy sources (geothermal, mini-hydro, biomass or wind energy) through the existing scheme (PSKSK or Small Scale Private Power Generator and Cooperatives).

Reduce fossil fuel export and to give priority to meeting domestic demand for energy. The past policy of the government was to enhance oil export for increasing foreign exchange for funding the economic development. In this 'Self Sufficiency' scenario, the government needs to discontinue this 'foreign exchange' oriented policy and use indigenous fossil fuel products for meeting domestic energy demand. Oil, natural gas and coal's exports will need to be stopped.

Government needs to introduce and promote the use of CNG and LPG in transport sector to gradually replace the use of hydrocarbons (which is still more than 98%) in this sector. More LPG and CNG stations need to be built in Java and Sumatra in the short term and other islands in the long term. Financial incentives and subsidies' scheme also need to be developed for promoting these fuels.

National capability in science and technology needs to be enhanced through R&D as well as through education and training. R&D for improving technology in determining new oil and gas reserves needs to be carried out. The country needs to conduct research activities on finding new areas and potential reserves of renewables, i.e. geothermal, hydro, wind energy. Encourage R&D of local renewable energy technologies. Research may include efforts to map renewable energy resources and implement pilot projects of renewable energy power sources. Develop science and technology for enhanced oil recoveries, improved exploration and drilling techniques. R and D on improving coal combustion efficiency and reduce its environment impacts will also useful as the 'Self Sufficiency' scenario also emphasizes on the use of coal to replace hydrocarbons.

### 9.5.5 Policy Implications for Balancing The Trade-Offs Scenario

The *'Balancing Trade Off'* scenario adopts moderate economic growth (15 percent) from 'Business as Usual' level, or 5 percent lower than 'Economic Efficiency' scenario, which will still allow a moderate and stable energy demand growth, ensure adequate supply of energy and maintain a reasonable level of CO2 emission. This scenario also expects little disruption on the supply by as much as possible prolonging the 'net importing' status of the country.

In order to achieve a sustain moderate economic growth, as also the case with 'Economic Efficiency' scenario, the government needs to create a conducive environment for economic growth by ensuring political and economic stabilities. The economy will need to retain its market and trade oriented character over the period. The economy should remain to adopt private-market oriented, more open to foreign capital to ensure stable economic growth. A steadily increasing private sector role in the economy should be guaranteed. Enhancement of the efficiency of state-owned companies will have to be encouraged and pursued to help avoid economic inefficiency.

The 'Balancing Trade-Off' scenario also requires that the government to continue the policy of maintain the population growth by less than 1.2 percent by continuing to carry out the past policies on family planning program. This will include providing incentives for 'small family' and regular training programs.

As a result of this 'moderate' economic growth as well as controlled population growth, the demand of energy will escalate higher than 'Business as Usual' level but significantly lower than 'Economic Efficiency' scenario. The demand can still be moderately curtailed by energy conservation and efficiency efforts. Incentives and tax exemption programs for energy conservation efforts can be provided to enhance energy conservation implementation. Energy conservation that requires no cost or low investment will need to be promoted. Free preliminary energy auditing, voluntary energy labelling, building codes and energy efficiency standards can be provided to ensure the intensive implementation of energy conservation program. Other low cost programs, such as public campaign and trainings will help create 'efficient' energy using behaviour and reduce energy demand growth without curtailing economic growth. Pricing policy in transport sector (for hydrocarbons) will also help moderate the demand for energy in the sector that is still heavily dependent on hydrocarbons.

Due to a moderate growth of energy demand in this 'Balancing Trade-Off' scenario, the environmental degradation caused by energy utilisation can be reduced. Therefore, with a less strict environmental standard or regulation, the level of environmental pollutions, particularly $CO_2$ emission can be controlled at a lower level than 'Business as Usual' and 'Economic Efficiency' scenario. In the power generating sector, the government will encourage the use of cheap fuels (like coal) but encouraging R&D on developing efficient combustion technology, so as not to emit much $CO_2$ emission. The government will also need to encourage using cheaper but more abundant domestically available renewable resources such as hydro and geothermal which are free carbon content fuels.

In the case of energy supply, a moderate growth of energy demand combined with the policy of energy conservation and environment, will also positively support the goal of adequately supplying the country's domestic energy need. However, in this 'Balancing Trade-Off' scenario, the enhancement of indigenous productions of fossil fuels such as coal, natural gas and crude oil will be pursued. The enhancement of indigenous oil, coal, and natural gas production will be pursued through energy exploration activities carried out through continuing surveys and exploration activities for energy with the aim of increasing indigenous reserves, in particular coal, oil and natural gas. The search for energy will be focused in areas that have not been surveyed (Eastern parts of Indonesia), while those areas with some indications will need efforts to upgrade their reserve status to more certainty. Enhanced oil and natural gas recovery programs will also need to be carried out to increase production efficiency.

# CHAPTER TEN

# CONCLUSIONS

Frequently the analysis of national energy scenarios and forecasts is carried out in the absence of a good knowledge of the broader economic, social, technological, political and historical influences at play. This often results in the development of mathematical models that are of limited practical use, as they project future policy scenarios that do not consider the broader drivers of change and policy influences. The aim of this thesis was therefore to develop a tool for simulating future energy scenarios for Indonesia, which takes into account these broader factors in a more integrated fashion.

## 10.1 Research Findings and Contributions to Knowledge

### 10.1.1 Contextual Analysis

*An important contribution of this thesis was to provide an integrative analaysis of the broader economic, social, technological, political and historical influences on energy policy devlopments in Indonesia.* This analysis (Chapters 2 to 7) was not only valauable in its own right, but importantly it was subsequently used for the model and scenario development (in Chapters 8 and 9) - refer to Fig 8.1. The main findings of Chapters 2 to 7 are summarised below.

The history from the colonial to the post-independence eras discussed in *Chapter 2* shows that the political and economic objectives of successive governments has had a significant influence on the energy policy of Indonesia. In particular, there are two important influences that can be argued to have significant impacts on the energy policy.

Firstly, the excessive exploitative approach inherited from the colonial era has continued up to the present policy approach and brought about rapid depletion of natural resources and caused environmental problems. The colonial era was characterised by the excessive exploitation of mineral resources for the benefit of the colonial governments disregarding the environmental impacts and the sustainability of future energy supply, especially oil and gas.

Secondly, during the Sukarno and Soeharto eras, it also became evident that there was heavy reliance on one revenue stream for the government which was imprudent. Specifically, when a government places heavy reliance on mineral resource export earnings to finance economic development, it can eventually lead to economic difficulties. The heavy reliance on oil and gas revenues and imprudent government spending of oil and gas windfalls have caused severe economic problems like inflation and devaluation. Future policy should consider lowering dependence on oil and gas to generate export earnings and utilise them more for meeting domestic energy needs especially when Indonesia is faced with the possible change of status to a net energy importing country.

*Chapter 3* argued that energy policy making in Indonesia is characterised by many challenges for integrated policy development. Particular problem areas include: the inadequacy of analysis and information, lack of stakeholder involvement in the decision-making process and finally the lack of policy implementation. Some specific recommendations are made to overcome these problems.

In this chapter, future and emerging energy policy objectives are also discussed in the context of the Indonesian institutional and political frameworks. Economic and environmental considerations have increased in importance in Indonesia and are now major inputs into decision-making in the energy sector. There is an emerging interest amongst stakeholders that energy efficiency, economic growth and protection of the environment be included in the objectives of the national energy policy. These important policy objectives are further broken down into some elements - i.e.: energy security, economic efficiency, energy efficiency, $CO_2$ reduction, energy self-sufficiency, more renewable energy, foreign exchange earnings and robustness. These objectives need to be considered carefully in the policy analysis to make sure that robust and optimal policy options are recommended. These policy objectives are represented and accommodated in the five scenarios built for the energy systems dynamic simulation model outline in Chapter 9.

*Chapter 4* discusses the historical trends of the country's energy demand and supply in the 18 years from 1980 to 1998. The patterns of consumption growth, possible causes of the escalating increase and the implications if the growth continues are discussed in the chapter. In addition to that, Chapter 4 provides a discussion on the potential of indigenous energy resources in the country. This is required to evaluate future energy policy options for supplying domestic use. Over the 18 years (1980-1998), delivered energy demand grew at the rate of 4 percent per annum. However, if biomass is excluded from the consumption pattern, the growth was 9.2 percent per annum and reached 12.5 percent per annum in the last decade. This is very high compared to the world growth in delivered energy demand, which was around 2 to 3 percent during the same period. It is also relatively high compared to other

ASEAN countries such as Malaysia (9.1 percent), the Philippines (3.1 percent) and Thailand (9.9 percent) per annum growth during the last two decades. This high growth of delivered energy demand can be attributed to the fast growth of industrialisation, increased incomes and the rapid increase in energy demand by the transport sector.

Electricity demand grew at the rate of 10.9 percent, almost 4 times the world's electricity growth rate, of about 2.8 percent per annum during the same period. Hydrocarbons grew at the rate of 6.6 percent, meanwhile coal and LPG grew very rapidly at the rate of 10.5 and 13.1 percent respectively during the same period. The rapid growth of LPG is attributed primarily to the use of LPG to replace kerosene and combustible renewables in the residential sector and small-scale industries.

*Chapter 5* utilized the data from Chapter 4, to quantitatively determine the main economic and social influences (GDP growth, prices, lifestyle factors, income and so forth) on energy demand. This is undertaken by regression analysis, using several functional forms (linear, log-linear) as well as autoregressive methods to take account of time lags. The analysis, which covered the time period 1971-1998, derived a series of regression equations with high levels of explanation (of shifts in energy demand) across the four main sectors in the Indonesian economy.

This study concluded that GDP as well as household income had a significant influence on the demand for energy in the country and that, as a consequence, as GDP and income rise through time, they are likely to exert more than a proportional influence on energy consumption in the country. The effect of fuel price rises, on the other hand, did not exert a significant influence on the demand for energy in the country. From the analysis conducted in this study no clear conclusion can be drawn on the 'price effects', especially when it is referenced to electricity, coal and natural gas. The effect of a fuel price rise, however, was significant only when the fuel had reached a saturation level in certain sectors, for example, hydrocarbons in the transport and the residential sector. In the long run, however, beside fuel price changes, other factors – like lifestyles, and other changes of a social and political nature – may play a more important part. The country must start to consider the effects of the social and political environment on its energy demand trends and policy analysis in the near future. The limitation of data availability as well as data accuracy were the main problems in determining the influence of the changes these social and political factors bring to the demand for energy in the country.

The regression analysis presented in Chapter 5, represents the most comprehensive thus far undertaken for the Indonesian energy sector – previously studies have typically only considered one explanatory variable (eg. GDP), covered only a few economic sectors, and have not covered a time series spanning as long as 27 years.

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*Chapter 6* analysed the technological determinants of energy demand - in particular, improvements in the technical efficiency of energy using devices. The divisia decomposition method was used to isolate technical efficiency improvements for structural shifts in the economy, by analysing Energy:GDP time series data. Over the entire Indonesian economy, technical change (improvement in technical efficiency) was found to give a greater contribution to energy efficiency improvements than structural changes. Structural changes especially in the residential sector contribute negatively to the Energy:GDP ratio of the country. The industrial and transport sectors, made a small positive contribution, offsetting the negative effect of residential structural change.

Further analysis of technical change, revealed that technical change in the residential sector seems to play an important role in the improvement of energy efficiency compared to the other sectors (transport and industry). More efficient electrical appliances have contributed significantly to efficiency improvement in the residential sector. In addition transport equipment used by industry has moderately, contributed to improvements in technical efficiency in the industrial sector. In the transportation sector, no technical efficiency improvements were observed. The increasing number of new imported cars and vehicles, during the period, did not bring a positive impact to efficiency improvements in the transport sector.

The divisia decomposition analysis presented in Chapter 6, represents the first attempt at such an analysis in Indonesia. It provides a sophisticated quantitative explanation for the 37 percent decrease in Indonesian Energy:GDP ratio over the 1971-1998 period – most of this decline in the Energy:GDP ratio is explained by technical improvements (40 percent) rather than structural shifts (20 percent ) in the economy.

Chapter 6 also provides a brief analysis of the current and future energy end-use technologies in Indonesia, as well as quantifying the potential energy savings from using improved technology and management practices.

*Chapter 7* reviews the main determinants of energy supply in Indonesia over the last 3 decades:

1. *Government Policy.* Various governments in Indonesia have had a major impact on the nature and patterns of energy supply in Indonesia, either through policy interventions or government investments in energy projects. Chapter 7 questions the quality of government interventions and cites a number of examples of ineffective policy interventions that have not had desirable outcomes.

2. *Technology.* This chapter argues that the current status of energy supply technologies (international and domestic) will not significantly influence energy supply technologies in the short term. Only over 20-30 time horizons are shifts in technology likely to have a significant impact, but even then these could be different from those expected.

3. *Economics.* This chapter argues that the economics of primary energy supply (natural gas, oil and coal) in the future will not greatly influence the future patterns of the energy supply mix. Moreover, the electricity supply pattern will not be affected to a great extent by the costs of electricity supply. The reasons for this are electricity demand in the household sector in the next 10 to 20 years will not reach saturation level and the electrification ratio is currently low, as many remote areas in the country do not have access to electricity. The section also concludes that Indonesia's energy supply mix will not, even in the long term, undergo a dramatic shift from conventional primary energy supply to more environmentally benign energy supply sources by utilising more environmentally benign New and Renewable Sources of Energy (NRSE) technology. This is mainly due to barriers associated with NRSE technology costs and NRSE market penetration.

### 10.1.2 Model Development and Scenario Analysis

*Arguably, the main achievement and contribution to knowledge of this thesis has been the development of an operational system dynamics model of the Indonesian energy system.* This is an important development because: (1) it is the first such model to be developed for Indonesia, building on the existing modelling efforts that have been restricted to regression-based forecasting and optimisation modelling; (2) in this thesis, the model is used to generate new knowledge about future energy scenarios for Indonesia (refer to pages 295-301 for a summary of these scenario results).

**Strengths and Weaknesses of the System Dynamics Model**

*Integrative Approach.* The first advantage that the systems dynamics model has over the previous models (regression, optimisation) of the Indonesian energy systems, is that it is 'integrative' in the sense that it connects a wide range of information on the economy–energy-environment system interlinkages. That is, almost all of the pressing energy policy issues in Indonesia, have not previously been addressed using a reliable integrated energy policy model that clearly explains the impacts of various policies on economic factors (such as prices), technologies, environment, lifestyle, GDP, population and so forth. As a result, many energy problems have not been sufficiently or appropriately addressed and have even caused unintended economic and social consequences. Issues associated with the increasing population, economic growth and rapid technological change in almost all sectors, makes the challenges of the energy problems more complex and provides the impetus for a better modelling approach that can integrate these changes and provide alternative policy solutions.

Neither the MARKAL (optimisation) approach or the regression-based models, previously used in Indonesia, provide a detailed picture of economic transactions, as does the input-output economic module in the Indonesian energy model presented in this thesis. Nor do these previous approaches contain information about the expected consequences of energy sector activities on the environment, as does the model presented in this thesis by way of the "Environment Module".

*Dynamic Approach.* The second advantage of the model developed in this thesis is that it introduces a dynamic simulation approach to energy sector modelling in Indonesia. The regression based 'forecasting' approach, projects future levels of energy demand based on analysing past trends. The MARKAL optimisation approach is limited as a truly dynamic model for a number of reasons:

1. It assumes optimising behaviour, which often does not occur in the real world due to political, institutional, stochastic factors amongst other considerations.

2. It does not include dynamic feedbacks.

3. Many of the non-linearities that exist in the real world are not captured by the MARKAL approach.

The regression based 'forecasting' approach also does not take account of dynamic changes and feedbacks. It assumes past structural relationships will persist into the future.

There are however a number of *limitations* to the system dynamics model of the Indonesian energy system that was developed in this thesis:

1. This simulation model projects the future based on the coefficients and correlations that are often obtained from historical data (of past trends) GDP, population, prices etc. These data were imported as exogenous data into the model – the future development of the model should attempt to a greater degree to endogenise into the model the "dynamics of these variables", rather than rely on data that has been exogenously determined often in a quite deterministic fashion.

2. Unexpected future changes may not be able to be accommodated into the model leading to inaccuracy in the model's results. Political events and instabilities can and have, had a profound impact on the Indonesian energy system and such events cannot be taken account of by the system dynamics simulation model. Nevertheless the model is capable of simulating 'unexpected future changes', by using the scenario approach.

3. The level of aggregation may not be suitable to decision-maker's need or may not be appropriate for the Indonesian energy system. For example, the MARKAL model contains more structural data on energy supply options and in this way it may be more suited to meeting the needs of some decision-makers.

4. The system dynamics model utilised in this thesis is based on an input-output description of the economy. In particular, stemming from this, there are some important analytical limitations which influence the energy model results: (a) the assumption of fixed coefficients in the input-output matrix, (b) the demand orientation of the Input-Output model which means that the energy supply side is inadequately considered

5. Understanding complex systems, and defining their behavioural pattem of interactions and correlations are very difficult tasks. It requires a capable team drawn from many disciplines related to the systems being modelled. Such skills are often lacking in a developing country such as Indonesia.

6. There are significant data limitations to the development of this model, given the lack of sufficient measurement techniques, instruments and financial resources. For example, there is only limited data on the end-use of energy, which curtails the use of the model for exploring detailed end-use and conservation options.

**Scenarios Formulation and Modelling Results**

The system dynamics model was used to develop five scenarios, over the 1998-2020 period, for the future development of Indonesia's energy system. These scenarios reflected five themes Business-as-Usual, Environmentally Beneficial, Economic Efficiency, Self-Sufficiency and Balancing Trade-Offs.

***Business-as-Usual Scenario:*** The economic activities and GDP are assumed to continue to follow past trends. There is no new pricing policies introduced and fossil fuels remain the cheapest form of fuel and are adequately available to drive the economy. However, past and current governments plan to gradually increase the price of hydrocarbons and electricity is still assumed to take place. No major changes in the current energy conservation policy or programs are included. The government plan to build some new committed projects (coal, natural gas, hydro, biomass and geothermal power plants) all over the Indonesian region will continue in accordance to the plan and time schedule (until 2010). As for nuclear power, the government (Nuclear Energy Atomic Agency) plan to start a nuclear power program in 2016, for which some studies, regulations and preparations are now being carried out, is assumed to go on in accordance to the schedule. There is no new government effort for the enhancement of fossil fuel production. Research and Development efforts and activities will take place according to the government plan without significant changes or breakthroughs affecting the current level of production. New government policies on oil and gas investment (such as privatisation of oil and gas companies, which opens more opportunity to foreign investors) are assumed not to take place due to legal and public acceptance constraints.

The Business-As-Usual Scenario exhibits the third highest level of economic growth (175 percent increase) of all five scenarios over the 1998-2020 period. Energy Demand growth is the highest of all of the scenarios due to "the continuation of past trend population growth and no energy conservation effort" assumptions, at an increase of 249.8 percent over the period. Related to this increase in demand is a large increase in $CO_2$ emissions (189 percent), and a steep increase in the estimated cost of energy supply from $US million 761 to $US million 10,003 (761 percent). The reason for this rapid increase in energy supply cost is the high energy supply costs to meet rapid increasing primary energy demand.

At the end of the scenario period, the Business-As-Usual scenario, although producing a mid range performance in economic growth (3$^{rd}$ out of 5 scenarios), it performs poorly across all of the other performance objectives, having the highest rate of growth of energy demand, next to lowest percentage of renewables, next to highest cost of total energy supply and next to highest level of $CO_2$ emission. In terms of 'net energy export/import' performance, this scenario also produces the worst outlook compared to other scenarios which all maintain

Indonesia's energy exporting status for longer. Under this 'Business-As-Usual' scenario, Indonesia's status as a net energy exporting country is maintained only until 2010 when it imports 3 PJ. This contrasts for example with the 'Economic Efficiency' scenario, which maintains Indonesia's status as an energy exporting country until in 2013 when it imports 2.19 PJ of energy

***Environmentally Beneficial Scenario:*** The government will need to enforce policies that encourage society to use energy more efficiently and wisely, to achieve a more environmentally benign energy utilisation. Measures, like energy conservation standards labelling, energy auditing, low cost or no cost energy savings, and building codes will be promoted to increase efficiency of energy use. Training and campaign programs combined with 'free preliminary energy auditing' in energy using sectors needs to be intensified. In the transport sector, the government could implement progressive taxes for cars, carbon taxes and incentives for using less carbon fuel e.g. CNG (compress natural gas) or LPG (liquid petroleum gas). The Government under this scenario will increase the price of hydrocarbon fuel by at least 10 percent to encourage the use of alternative fuels in this sector. The Government also needs to pursue policies to encourage the substitution of carbon intensive fuels used in existing power plants and to promote the integration of renewable energy technologies into the existing power grids. In the short term, the integration needs to apply for geothermal power sources. To meet the growing need for demand of electricity, the government needs to start nuclear power plant construction in 2010 at the latest to replace coal-fired and hydrocarbon power plants. Although the BATAN study recommended that nuclear power plant can be started in 2016, an earlier installation is possible if stricter environment standards are enforced. Government also needs to speed up and enhance research and development programs on clean energy technology, fluidised bed and IGCC technology. Research and development on the programme for nuclear reactor design, as well as on waste disposal technologies will also need to be speeded up.

The modelling results show that the 'Environmentally Beneficial' scenario, had the lowest level of economic growth of all the scenarios – as it grew by only 147 percent over the 1998-2020 scenario period. As to be expected, this scenario does however perform well against other policy performance criteria that reflect environmental and resource conservation concerns. For example, it has the lowest levels of $CO_2$ emissions increasing by 85 percent, which is less than half the rate of increase of the 'Business-as-Usual' and 'Economic Efficiency' scenarios. Energy Demand (92 percent increase) also increases the least of all of the scenarios due to less growth in the economy, as well as efficiency improvements. The energy intensity in fact decreases by 2.25% under this scenario, indicating an increase in energy efficiency over the scenario period.

At the end of the scenario period, the 'Environmentally Beneficial' Scenario performs best of all the scenarios against the energy use (demand), use of renewables and $CO_2$ emissions criteria. It performs second best of the five scenarios against the energy efficiency (intensity), total cost of energy supply and cost of electricity supply criteria. The modelling results suggest that this is the expense of having the slowest rate of increase in economic growth of all the scenarios, certainly at a rate lower than that recorded in the Indonesian economy over the last few decades.

***Economic Efficiency Scenario:*** This 'Economic Efficiency' scenario put higher emphasis on economic growth rather than other matters. Factors important to economic growth are the regulatory and legal environment, as well as political and economic stability. These factors will ensure the growth of economic activity especially for the important sectors like the manufacturing industries and commercial sectors that provide a large contribution to the nation's Gross Domestic Product. Policies to attract foreign direct or indirect investments and loans (private capital inflows) to sustain economic recovery and to increase the country's economic growth will need to be undertaken. Liberalisation of the economy, reducing industry protection, privatisation, tax reform, reducing tariffs and trade barriers, as well as lessening restrictions on exports and imports will all be very important in ensuring economic efficiency. As the economy grows, the energy demand will escalate in almost all economic sectors, which will trigger the need to supply more energy to meet the growing demand. The energy policy for this 'Economic Efficiency' scenario will therefore, be focused on expanding energy supply rather than reducing demand in order to support the economic growth. The need to increase production of indigenous fossil fuels will require the country to determine new oil and gas reserve findings and/or to enhance oil and gas recoveries. A new regulation on oil and gas (Oil and Gas Law no. 22/2002) that has recently been issued and agreed by the Indonesian Parliament will help open the opportunity for production increases of coal, natural gas and crude oil, as foreign investors are more welcome to participate in the oil and gas business. Equally important is that the 'Economic Efficiency' scenario requires a plentiful supply of relatively cheap fossil energy during the period, but still does not cause major environmental problems and does not induce controls on energy demand. The price of energy will need to be held constant to boost the economic activity and industrial development. The government should not issue new policies on energy conservation and environment that will hamper the productivity of manufacturing and commercial sectors.

The modelling exercise indicates the Indonesian economy will be more than triple in size over the scenario period of 1998-2020 (216 percent increase), under the 'Economic Efficiency' scenario. This is a significantly higher rate of economic growth compared to the other scenarios: Business-As-Usual (175 percent), Environmentally Beneficial (147 percent), Self-Sufficiency (160 percent) and Balancing the Trade-Offs (202 percent). Not surprisingly, this economic growth leads to a rapid increase (221 percent) in energy demand under the 'Economic Efficiency' scenario, but not to levels as high as the 'Business-As-Usual' scenario. This is because 'energy conservation' efforts assumed to take place under this scenario. The increase in $CO_2$ is very slightly higher than the 'Business-As-Usual' scenario at 190 percent, over the scenario period. The growth economy requires the expansion of energy supply infrastructure, which means that there is an increase in the total cost of energy supply from $US million 10,904 in 1998 to $US million 97,368 in 2020 (793 percent increase).

At the end of the scenario period, the 'economic efficiency' scenario, as expected has the highest level of economic growth of all of the scenarios. The performance of this scenario as measured against the other criteria is mixed. On a negative note, this scenario has the highest level of $CO_2$ emissions at 639,619 tonnes in 2020, and the highest total cost of energy supply and total cost of electricity supply. This scenario doesn't perform as poorly as expected against the energy demand and energy efficiency (both performing better than in the 'Business-As-Usual' scenario) due to 'efficiency' gains in the economy. The level of use of renewables is third highest of all of the scenarios.

***Self-Sufficiency Scenario:*** The focus on this 'Self Sufficiency' scenario, is more on reducing or making 'more efficient' the demand for energy so as not to require the country to rely on other countries to supply its domestic energy requirements. Pricing and energy conservation policies will consequently be needed to be carried out to encourage or promote more wise and rational use of energy, especially fossil fuel energy i.e. hydrocarbons and natural gas. The promotion of the use of abundantly available energy resources, such as coal and renewables will be encouraged. Population control also remains an important factor in the 'Self Sufficiency' scenario.

The government needs to internalise the true cost of energy by adjusting prices of hydrocarbons and natural gas and aiming at gradually removing subsidies for these fuels. An energy conservation policy is required that encourages the use of more efficient appliances through; providing incentives for investment in energy efficient products; introducing a scheme that will assist companies investing in energy efficient appliances and technologies in the form of tax incentives and soft loans, and a public information and assistance package to help companies gradually through the bureaucracy. Indigenous energy production both for renewable and non-renewable sources of energy needs to be increased. The government needs to reduce fossil fuel exports and to give priority to meeting domestic demand for energy. In this 'Self Sufficiency' scenario, the government needs to discontinue the 'foreign exchange' oriented policy and use indigenous fossil fuel products for meeting domestic energy demand. Government needs to introduce and promote the use CNG and LPG in transport to gradually replace hydrocarbons (which is still more than 98 percent) in this sector. Financial incentives and subsidy schemes also needs to be developed for promoting these fuels. Encouraging of research and development into local renewable energy technologies is also required.

The modelling results show that under this scenario, that there is an increase in energy efficiency (ie, a decrease in energy intensity) of 9.4 percent, over the 1998-2020 period. The energy self-sufficiency of Indonesia also shows least increases in both the percentage of non-wood renewables (215.8 percent) and total cost of energy supply (329.3 percent) over the period, compared to other scenarios. With this increase in energy efficiency and self-sufficiency performance, comes a relatively slow rate of increase in both energy demand (133.2 percent) and $CO_2$ emissions (91.9 percent). The model also indicates that the cost of energy supply will increase at the slowest rate of all of the five scenarios, although the rate of increase in electricity supply is mid-range of all of the scenarios.

At the end of the scenario period, the 'Self-Sufficiency' scenario performs best against the performance criteria of: percentage of renewables, total cost of energy supply and energy efficiency, as well as second best for energy demand and $CO_2$ emissions. This is at the apparent expense of lower than expected economic growth – second lowest next to the 'Environmentally Beneficial' scenario. Under this scenario the Indonesian economy will grow according to the model to Rupiah million 1998, 1,365,000 by 2020 (160 percent increase).

***Balancing Trade-Offs Scenario:*** This scenario adopts a more moderate approach to economic growth than the 'Economic Efficiency' scenario, which results in moderate energy demand growth, ensures adequate supply of energy and maintains a reasonable level of $CO_2$ emissions. This scenario also expects little disruption to the supply by prolonging as long as possible the 'net importing' status of the country. In order to achieve a sustained moderate economic growth, as in the case with 'Economic Efficiency' scenario, the government needs to create a conducive environment for economic growth by ensuring political and economic stability. The economy retains its market and trade oriented character under this scenario, and the government continues to adopt a market oriented approach more open to foreign capital investment. A steadily increasing private sector role in the economy should be guaranteed. Enhancement of the efficiency of state-owned companies will have to be encouraged and pursued to help avoid economic inefficiency. Demand will be moderately curtailed by energy conservation and efficiency efforts. Incentives and tax exemption programs for energy conservation efforts can be provided to enhance energy conservation implementation.

In the power-generating sector, the government will encourage the use of cheap fuels (like coal), but encourage Research and Development to provide efficient combustion technology to limit $CO_2$ emissions. The government will also need to promote the use of cheaper but much more abundant domestically available renewable resources such as hydro and geothermal which are free of carbon content. In the case of security of energy supply, a moderate growth of energy demand combined with a policy of energy conservation will be used to achieve this goal.

The modelling results show that the 'Balancing Trade Offs' scenario is indeed feasible, in that it achieves an effective compromise across the policy performance criteria. It achieves the second highest rate of increase in economic growth (next to the economic efficiency scenario) at 202.6 percent increase. But this is not achieved at the expense of the policy outcomes. The growth in energy demand, $CO_2$ emissions, total cost of energy supply and the total cost of electricity supply are kept at moderate levels (ranking second or third out of the five scenarios). The level of use of renewables is second highest of all the scenarios, at 8.8 percent of all primary energy use (excluding Wood and Biomass) in 2020.

## 10.2 Future Research Directions

This thesis represents a first attempt to construct a system dynamics model of the Indonesian energy system that integrates both economic and environmental factors into the model. Both the underpinning data (energy demand, energy supply, environmental data and economic data) as well as the model construction and its application could be further improved by additional research.

### 10.2.1 Energy Demand Analysis

Energy Demand analysis preliminary depended on using data on the delivered (or consumer) energy sector. In the model itself some differentiation of end-use energy demand was made according to three end-use categories: heat, transport and obligatory electricity To better understand the energy conservation and energy efficiency options available to Indonesia, future research could concentrate on a finer level quantification of end-use energy demand in Indonesia – eg, the New Zealand Energy Efficiency and Conservation Authority (1995) quantifies end-use energy according to 20 categories – eg, lighting, mechanical drive, heat (according to various temperature bands and end-uses), pumping, refrigeration, and so forth.

Typically, Indonesia like almost all other countries, collects energy demand data according to consumer (delivered) energy types. It can be argued that this only reflects 'derived demand', as consumers do not really require, for example, electricity rather the end-use services that are desired from electricity – eg, lighting, heating, refrigeration, air-cooling, and so forth.

Energy demand was analysed in Chapter 3, using regression modelling. Although this approach was quite successful, it could be further improved in a number of ways:

(1) the effect of other independent (exploratory variables) could be investigated, besides the dominant effect of GDP as a determinant of energy demand. In particular, the effect of price on energy demand, needs to be further investigated as the results as reported in Chapter 4 tended to be inconclusive. Lifestyle and technological effects could also be explicitly entered into the regression equations.

(2) with improved energy demand data, the regression models could be run at a finer level of sectoral disaggregation rather than at the crude four sector disaggregation.

(3) with improved end-use quantification of energy demand, the regression modelling approach could be applied to link consumer (delivered) energy use to end-use demand.

Energy demand was analysed in Chapter 5 using the divisia decomposition method, in order to quantify the structural and technical effects that explain changes in the Energy:GDP ratio. The analysis could be extended in a number of ways in further research:

(1) other factors in addition to structural and technical effects could be included in the decomposition – eg, energy quality effects as outlined in Jollands, Lermit and Patterson (2004). Without explicitly accounting for these effects, other factors tend to inappropriately measured by the technical effect factor.

(2) regression analysis could be used to explain the movements in the technical and structural effects, in order to build on the qualitative explanations for such movements already presented in Chapter 5.

### 10.2.2 Energy Supply Analysis

Although considerable amount of data on economic and technological energy supply options were collected in Chapter 8 of this thesis, it was not analysed to the same degree of mathematical rigour as energy demand. Difficulties were encountered in obtaining reliable economic data on energy supply options. Future research could focus on collecting such data and perhaps using it to construct supply curves for various future energy supply options. Given the uncertainty concerning future energy supply options, methods could be investigated for accommodating such uncertainty (and associated risk) into the analysis.

### 10.2.3 System Dynamics Model

With the improved data referred to above, the model can be extended to provide extra information on both energy demand and energy supply options. The model as it currently stands is reasonably generalised, and may need to contain more detailed data to explore particular policy issues. In particular, the level of structural detail in energy supply options may be insufficient for many decision-makers, and this may need to be improved if the model is to be used for a detailed analysis of energy supply options for Indonesia.

The current system dynamics model is based on coefficients and correlations that are often obtained from historical date (of past trends) of population, prices etc. These data are imported as exogenous data into the model. The future development should aim to endogenise the 'dynamics of these variables' into the core model. Without this development the model is incapable of fully simulating changes in the Indonesian energy system and is dependent on other models and processes. In particular, the drivers of sectoral activity in the economic module are based on regression-based trend analysis, whereas the model could benefit from understanding and modelling the 'dynamics of growth' that drive change in the sectors.

The economic module currently depends on an input-output model of the Indonesian economy. There are some limitations to this approach. That is, it is based on the well-known assumptions of input-output analysis (fixed coefficients, linearity, homogeneity of sector output) and furthermore it is an accounting framework rather than a dynamic modelling framework with feedbacks. The economic module could therefore be developed in a number of ways:

(1) reformulated as a computable general equilibrium model using the already existing input-output structures as the starting point.

(2) developing a model that reflects the key dynamics of the economy by operationalising growth theory ideas – eg, by utilising Solow growth theory or endogenous growth theory.

Unexpected future changes are difficult to accommodate in the modelling framework - eg political events, Asian financial crisis and the 2004 Tsunami. Further research could investigate ways of handling these 'uncertainties' within the modelling framework.

One issue that needs to be addressed in the future development of the model is the level of disaggregation of the model. A strength of the model is that it contains a minimum amount of structural detail to produce robust scenarios of Indonesia's energy future. As new policy issues arise, there will undoubtedly be calls to increase the detail in the model (more supply options, greater sectoral detail, greater spatial specificity). In particular, given the fact that Indonesia is an island archipelago, there may be a need to make the model more spatially explicit in order to obtain realistic results. These calls for greater detail, need to be balanced against the risk of the model becoming too unwieldy and unmanageable.

Finally, the issue of the uptake and use of this model needs to be addressed in future research. This model was developed by the author in a 'desk-top' fashion in New Zealand, as it is a research project, a partial fulfillment of the requirements for the degree of Doctor of Philosophy in Resource and Environmental Planning. The risk is that although the model is very user-friendly (through its graphical interface), it may be largely ignored by potential end-users in the Indonesian government. Future development of the model could adapt more participatory approaches to model development such as those advocated by van den Belt (2004).

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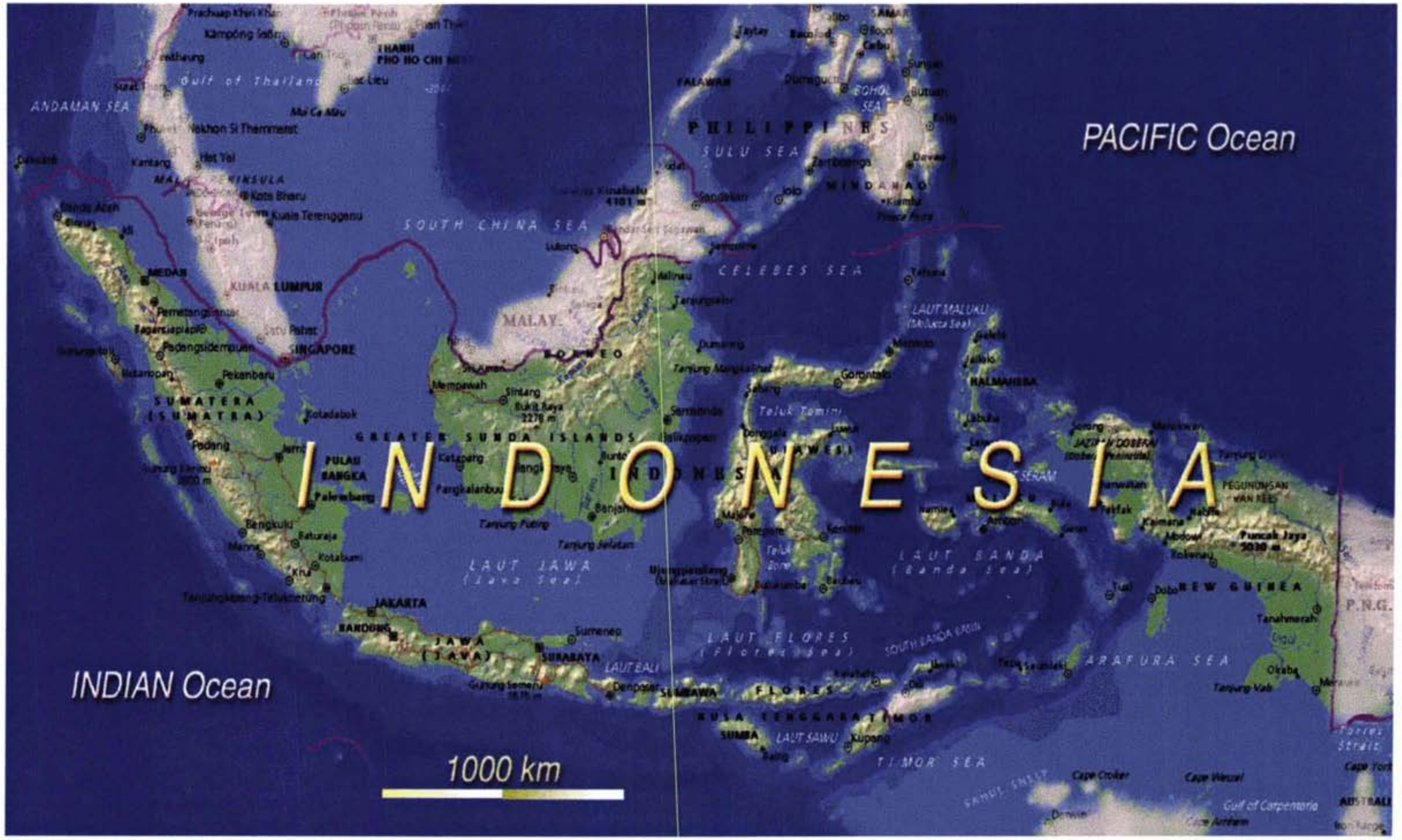
# APPENDICES

## APPENDIX A MAP OF INDONESIA




Indonesian Population: 221 Millions (2002)
Java: 140 Million : 67% of Total Population
Tribes: 300, Dialects : 300
Islands: approx. 17,500 islands

Figure A.1 Map of Indonesia

# APPENDIX B HISTORY OF INDONESIA AND ASSOCIATED ENERGY POLICY RESPONSES

| | DUTCH COLONIAL PERIOD<br>1600s – 1942 | JAPANESE PERIOD<br>1942 – 1945 | SUKARNO'S ERA<br>1945 – 1966 | SOEHARTO'S ERA<br>1966 - 1997 |
|---|---|---|---|---|
| **POLITICAL INFLUENCES** | • Brutalism, oppressive colonialism<br>• Racial discrimination<br>• Cultural, social and ideiological differences<br>• Divide and conquered<br>• Disruption of the traditional social order<br>• Increasing Indonesian/ Native nationalism | • The growing symphaty for Japan and antipathy toward the Dutch<br>• Regarded Japan as Liberators<br>• Encouraged Indonesian Nationalism<br>• Building the military means of resistance<br>• A much greater power of decision over their own affairs the release of nationalists and Indonesian soldiers.<br>• Giving Indonesians greater experience of Administrative power<br>• Fostered fighting spirit<br>• Insufficient communication between the authorities and the people<br>• Increased opposition toward Western imperialism | • Army was increasingly drawn into the political arena<br>• Conflicts between the Communist party and the Army<br>• The failures of legal principles, mounting demand for reform<br>• Increasing anti-Western attitudes<br>• Intrigue and conspiracy; cliques around the political elite<br>• Increasing arbitrary and irregularity og financial and legal systems<br>• Anti-imperialist move (Jakarta-Pnompenh-Hanoi-Beijing-Pyongyang) | • Increasing anti-communist forces, more Western oriented policy<br>• Authoritarian structure/political system, a controlled press etc.<br>• Political repression and political manipulations<br>• Leaders acted inconsistent with national ideology (Pancasila)<br>• Deeply rooted political, economy and legal structures<br>• Militarisation of the bureaucracy, ' a military bureaucratic state'<br>• The corrupt use of power for personal gain by the regime's leader<br>• Increasing socio-political role of military<br>• Military and bureaucratic control over society<br>• Patrimonial bureaucracy |
| **ECONOMIC INFLUENCES** | • Poor living standard of the native Indonesian / poverty<br>• Income gap between Europeans - Indonesian<br>• Corruption (VOC)<br>• Suppression of the cultivation elsewhere<br>• Unemployment of Western education<br>• Poor social well being<br>• World market dependence | • Exploitation of natural resources for war purpose<br>• Neglect economic issues<br>• Starvation and social ostracism<br>• Harsh economic conditions for the local people<br>• Serious decline in the people's health and malnutrition | • Strong action against American and British interests<br>• Refusal to accept American aid and IMF, foreign investment<br>• Mismanagement and corruption, lack of policy direction and planning<br>• Little prospect of rapid economic growth<br>• The contrast between rich and poor has sharpened<br>• Declining purchasing power of the Rupiah & inflation<br>• The social, political, and economic structure of the nation were near collapse | • 'Commercial orientation' of the officers 'bureaucratic capitalists'<br>• Combination of monopoly and lack of public accountability of many state enterpises<br>• Improvement in some economic and social indicators<br>• Increasing dependence on the Western-oriented groups of foreign creditors, like IGGI, World Bank and IMF.<br>• Low levels of efficiency and international competitiveness<br>• Dominant role of foreign capital in the economy, accumulation of debts<br>• Open door' encouragement to foreign corporate sector<br>• Disparity in income and livingstandard between rich and poor |
| **GOVERNMENT FORMAT** | • Colony<br>• United East India Company (VOC, Trading Companies)<br>• Governor - General<br>• Batavian Republic | • Japanese military administration<br>• No existing administrative structure anywhere<br>• Extension of Japanese Empire | • 1950 - 1957, Parliamentary Democracy, liberal politics & economy<br>• February 1957, Guided Democracy, establishing a traditional pattern of of authority based on indigenous concepts (mufakat) rather than one based on the will of the majority. | • New Order, military dominated regime<br>• Pancasila Democracy (a system in which political, economic and cultural life is inspired by Pancasila, based on belief in God, natio- nalism, democracy, social justice and humanitarian (decision making is to be reached through musyawarah rather than voting. |

**Figure B.1 History of Indonesia and Associated Energy Policy Responses**

| | DUTCH COLONIAL PERIOD 1600s – 1942 | JAPANESE PERIOD 1942 – 1945 | SUKARNO'S ERA 1945 – 1966 | SOEHARTO'S ERA 1966 - 1997 |
|---|---|---|---|---|
| **GOVERNMENT POLICIES (INSTITUTIONS)** | • Trading companies / supplies of spices<br>• Furnished agricultural products for the world market<br>• Regulate Production of spices<br>• Territorial expansion<br>• Reduction of independent states iinto depenpent state<br>• Territorial lands --> Source of revenue<br>• Monopoly --> Suppression of other cultivation elsewhere<br>• Liberalism (1850 - 1870) --> still export Indonesian products !!!<br>• Plantation system (large scale --> estate manager)<br>• Administration and political reform (1900) - Laisser-faire<br>• Decentralisation (1900s)<br>• Ethical Policy (1900) --> Welfare policy | • Maximum use of the existing administrative structure with minimum of interference with social and national customs.<br>• Avoiding giving rise to any premature moves for independence<br>• Occupation policies --> 'Replicas' of policies in Japan with ideology rather than expertise<br>• Expansion of military industry | • Prosperous society based on the Pancasila (five set of principles). i.e humanitarism, sosial justice, prosperity etc.<br>• The formulation & enactment of 1945 Indonesian Constitution<br>• Nationalism of Dutch enterprises and business offices<br>• Anti-Western propaganda<br>• Independency from foreign investment / loans / aids<br>• Eight year development plan | • Rehabilitation, recovery and stabilisation<br>• Five Year Development Plan (started in 1969)<br>• National economic developments, increase education and welfare<br>• Increase prosperity and modernity by employing technology and sound management (25 years of accelerated modernisation)<br>• Reform measures favoured by the World Bnk and IMF<br>• Open-door laissez-faire strategies to encourage foreign investment<br>• Reschedulling the foreign debt and obtaining new loan funds<br>• Stabilising the country's affairs and promoting economic recovery |
| **ENERGY POLICIES** | • Survey and exploration of Oil, natural gas and coal<br>• Exploitation of Oil, natura gas and coal<br>• Exporting oil and coal<br>• Setting up Dutch Companies and inviting other international inv.<br>• Monopoly of Oil and Gas production<br>• Law on Oil and Gas Venture (IMW) in 1899<br>• Establishment of Electric Power Business (1890)<br>• Construction of the first Hydro Power Plant (1927)<br>• The introduction of first biogas plant (1930)<br>• The establishment of the first mining and geological body Dienst van het Mijnwezen (1850), which latter changed into Dienst van den Mijnbouw (1922), and into Opsporing Dienst (which is the embryo of the current geological and mining body)<br>• The exploration and exploitation of geothermal resources (1928)<br>• 1870 --> Crops, coffee, sugar, etc --> 1930 --> Rubber, Oil export | • Exploitation of oil for the execution of the Greater East Asia War<br>• Geological survey and exploration activities<br>• Establishment of training schools for the oil industry for acceleration of exploitation activity<br>• Utilisation of oil and coal for war effort and for fulfiling Japanese domestic demand for oil<br>• The changing of Opsporing Dienst into Kogyoo Zimusho 1942, which later changed to Chisitsu Chosajo.<br>• The merger of all electric companies during the Dutch era, into one company called Jawa Denki Jigyuo Kosha<br>• Japanisation of all Dutch energy companies and Institution | • Taking over of all Dutch oil companies<br>• The implementation of article 33, para 2 and 3 of the 1945' Consitution regarding natural resources management (incl. oil, coal, gas and other energy resources)<br>• The continuation of the existing governmental bodies and regulations, including the old mining law (IMW, 1899)<br>• Cancellation mining rights, incl. oil, gas concession of private comp. and nationalisation of oil industry<br>• The formation of three Oil and Gas State Enterprises, the embryo of the State Oil and Gas Company (Pertamina)<br>• Prorata obligation (obliged to surrender part of their crude prod.) | • Strengthening army's role in the oil industry<br>• Policy reforms in mining and energy (private sectors investment)<br>• Reorganisation of State Mining Companies 1966-68 (Incl. Pertamina)<br>• Development of offshore oil and gas venture (1973)<br>• Enhancement of oil and gas export and oil-gas revenue<br>• Development of domestic oil refineries (1970 - 1990)<br>• Construction of two large LNG plants<br>• Renegositation of PSC (Contract agreement)<br>• Incentive packages to boost oil and gas investments<br>• Beginning of CNG and LPG utilisation for transport sector<br>• The merger of coal companies --> PN. Tambang Batubara<br>• Domestic coal development and utilisation |

**Figure B.1 History of Indonesia and Associated Energy Policy Responses (Continued)**

| | DUTCH COLONIAL PERIOD<br>1600s – 1942 | JAPANESE PERIOD<br>1942 – 1945 | SUKARNO'S ERA<br>1945 – 1966 | SOEHARTO'S ERA<br>1966 - 1997 |
|---|---|---|---|---|
| **ENERGY POLICIES (continued)** | | | • Introduction of a New Joint Venture type of production (PSC)<br>• Nationalisation of domestic oil supply and distribution in Indonesia<br>• The beginning of natural gas utilisation for fertilising industry (1964)<br>• The installation of LPG plant and it first production (1965)<br>• Reorganisation of Coal Mining and Geological Bodies<br>• Nationalisation of Dutch Electricity and Gas Companies<br>• The first regulation of electricity price (TDL 1966) | • Strengthening army's role in the oil industry<br>• Policy reforms in mining and energy (private sectors investment)<br>• Reorganisation of State Mining Companies 1966-68 (Incl. Pertamina)<br>• Development of offshore oil and gas venture (1973)<br>• Enhancement of oil and gas export and oil-gas revenue<br>• Development of domestic oil refineries (1970 - 1990)<br>• Construction of two large LNG plants<br>• Renegositation of PSC (Contract agreement)<br>• Incentive packages to boost oil and gas investments<br>• Beginning of CNG and LPG utilisation for transport sector<br>• The merger of coal companies --> PN. Tambang Batubara<br>• Domestic coal development and utilisation<br>• Beginning PSC for Coal industry<br>• Changes on Electricity tariff Structures (TDL 1967 to TDL 1994)<br>• Development of electricity infrastructure from 1969 to 1991<br>• Development of rural electrification program (1976 to 1994)<br>• Development of Indonesian electricity standards<br>• Development of Geothermal exploration / drilling activities<br>• Development of Geothermal ventures and power plants in Indonesia<br>• Exploration, exploitation and utilisation of Peat for Power Plant<br>• NRSE develepment and utilisation<br>• Development of National Energy Policy and Energy Planning Institutions<br>• Nuclear energy policy in Indonesia |



**Figure B.1 History of Indonesia and Associated Energy Policy Responses (Continued)**

| | DUTCH COLONIAL PERIOD 1600s – 1942 | JAPANESE PERIOD 1942 – 1945 | SUKARNO'S ERA 1945 – 1966 | SOEHARTO'S ERA 1966 - 1997 |
|---|---|---|---|---|
| **KEY ENERGY PROBLEMS/ISSUES** | • World wide economic depression (1930)<br>• Low Oil prices, US $ 5 - $ 7 per barrels (1996 price) in 1929-34<br>• Low income from oil, coal and gas exports<br>• The merger of De Koninklijke and Royal Dutch Sheell for efficiency<br>• Exploitation of oil and coal for Industrialisation in the Netherlands | • Large surpluses of oil export<br>• The decree of damage inflicted on oil production facilities unproven<br>• Exploitation of oil and coal for war effort and Japanese demand | • Decreasing oil prod. reaching the lowest levels (100,000 Bbl/d)<br>• The end of concession system, enactment of new Law no.44/1960<br>• The first Indonesian oil export by PN Pertamin<br>• The beginning of offshore oil and gas mining (1966)<br>• The establishment of a new shore baseline (3 miles terrt. Border)<br>• No significant development of coal during the period<br>• Rapid Increasing of electricity consumption --> Electricity tariff | • The crisis of domestic oil supply (1966)<br>• Oil fuel subsidy --> a great loss to the country's wealth<br>• Environmental problems in energy production and utilisation<br>• The Pertamina debacle in 1975 ( The state Oil Company's debts)<br>• Dutch Disseas (a false and frivolous sense of weath of oil windfall)<br>• Declining oil export and the falling of oil prices (in 1983, 1986, etc)<br>• Problems in NRSE development and utilisation (less than 0.1%)<br>• Rapid increasing of primary and final energy consumption and (high potential of energy saving, inefficient energy consump. sectors)<br>• Problems in Coordination of energy policy implementation<br>• Scarce oil resources: reserve vs production ratios |
| **ENERGY INDICATORS :**<br><br>** ENERGY/CAPITA (USE)*<br>** ENERGY/CAPITA (EXPORTS)*<br>** PRIMARY ENERGY CONSUMPTION* | • I Total Domestic Oil Production 162 thousand barrels per day (1940)<br>• I Electricity Consumption 6 kWh (1939) | | • Domestic Oil Production, about 500,000 barrels/day(1966).<br>• Per capita electricity production 17.7 kWh (during 1960s). | • Final Energy / Capita (Use) : 2.1(1970) to 25.2 (1997)PJ/Cap.<br>• Primary Energy Consumption : 251.6 (!970) to 5063.3 (1997) PJoule<br>• Energy / Capita (Export) : 12.5 (1970) to 22.2 (1997) PJoule/Cap.<br>• Per capita electricity production : 25 to 381 kWh (1970 - 1997)<br>• The role of oil to total cons.(-Biomass) : 87.7 to 60 %t (1970-97)<br>• Growth of final energy cons. : 12.5 per cent annually (1980 to 1997) (Conventional energy - no biomass)<br>• Crude oil Production 1.33 million barrels per day.(1991)<br>• Natural Gasl Production 800 billiion SCF per year (1994). |



**Figure B.1 History of Indonesia and Associated Energy Policy Responses (Continued)**

# APPENDIX C CONCEPTUAL FRAMEWORK OF THE INDONESIAN ENERGY MODEL

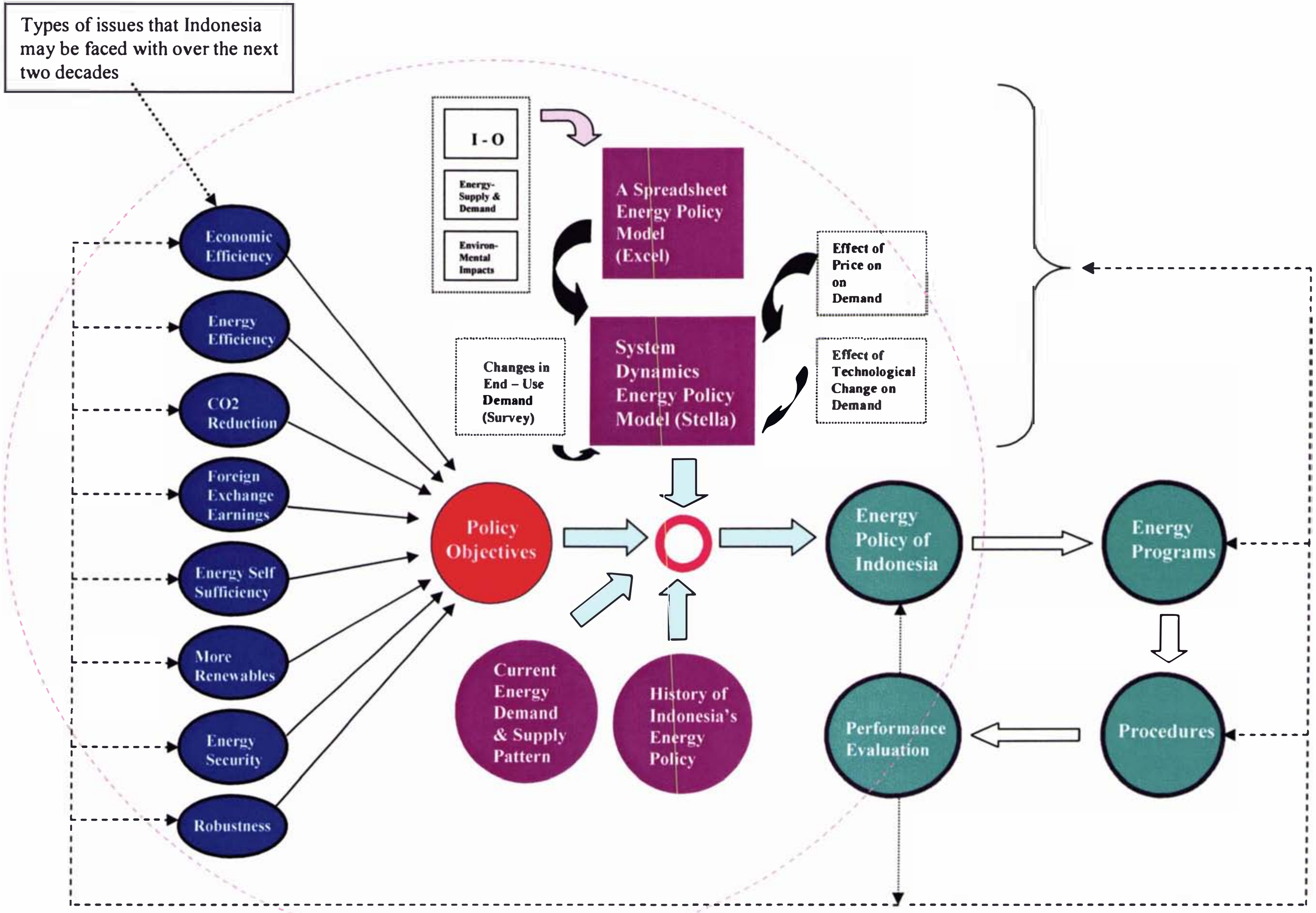



**Figure C.1 Conceptual Framework of Indonesian Energy Model**

# APPENDIX D MAGNITUDE OF THE KEY VARIABLES/MODULES IN THE INDONESIAN ENERGY MODEL, FOR EACH SCENARIO

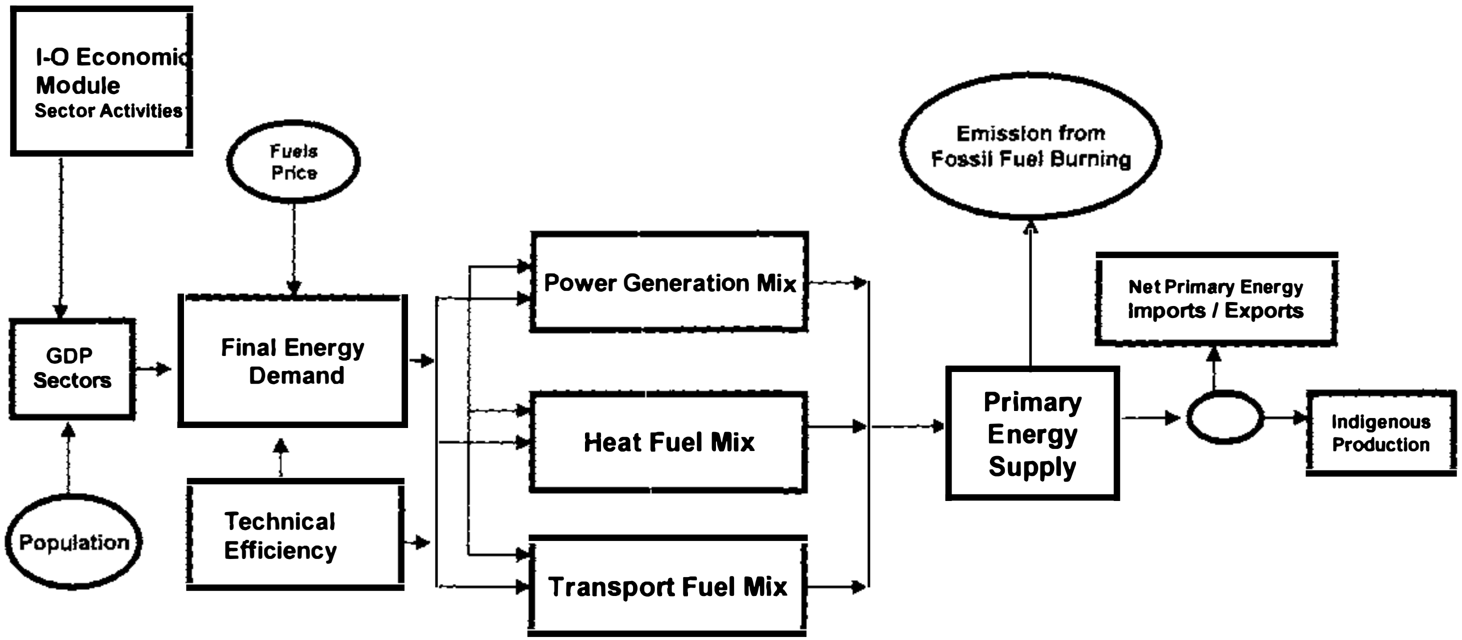



**Figure D.1 Key Variables and Modules in the 'Business as Usual' Scenario**

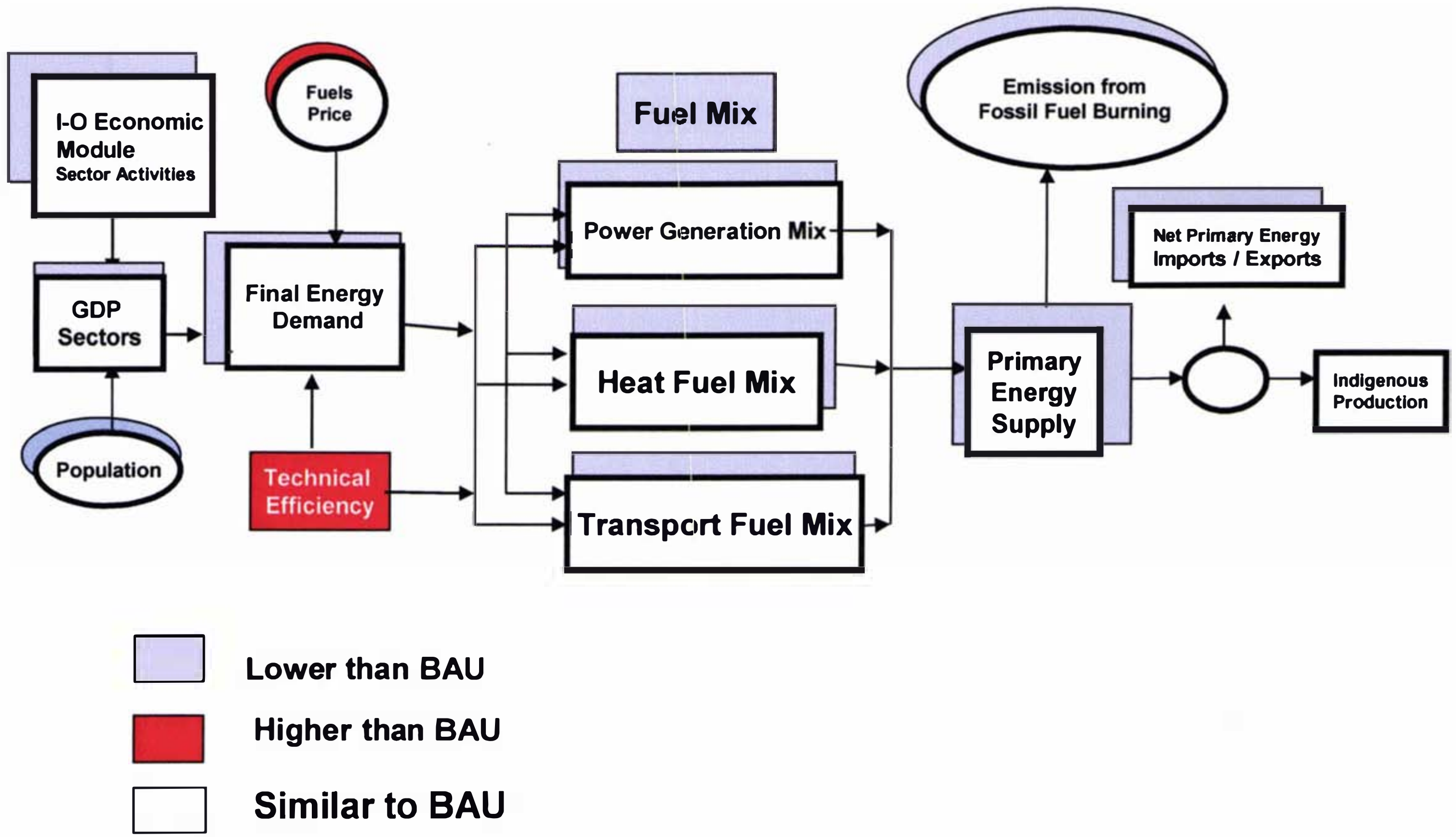



**Figure D.2 Magnitude of the Key Variables/Modules in the 'Environmentally Beneficial' Scenario**

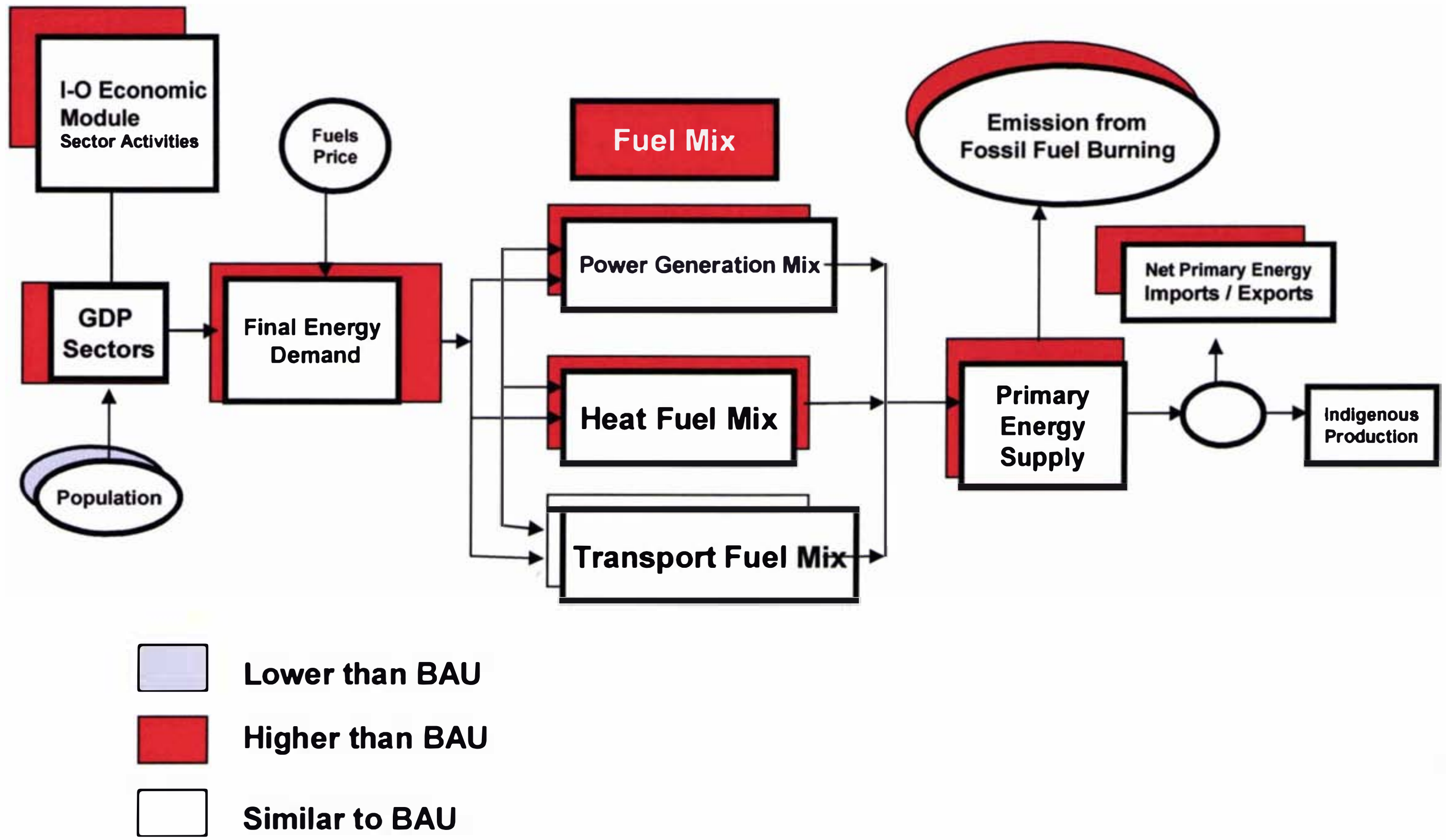



**Figure D.3 Magnitude of the Key Variables/Modules in the 'Economic Efficiency Scenario**

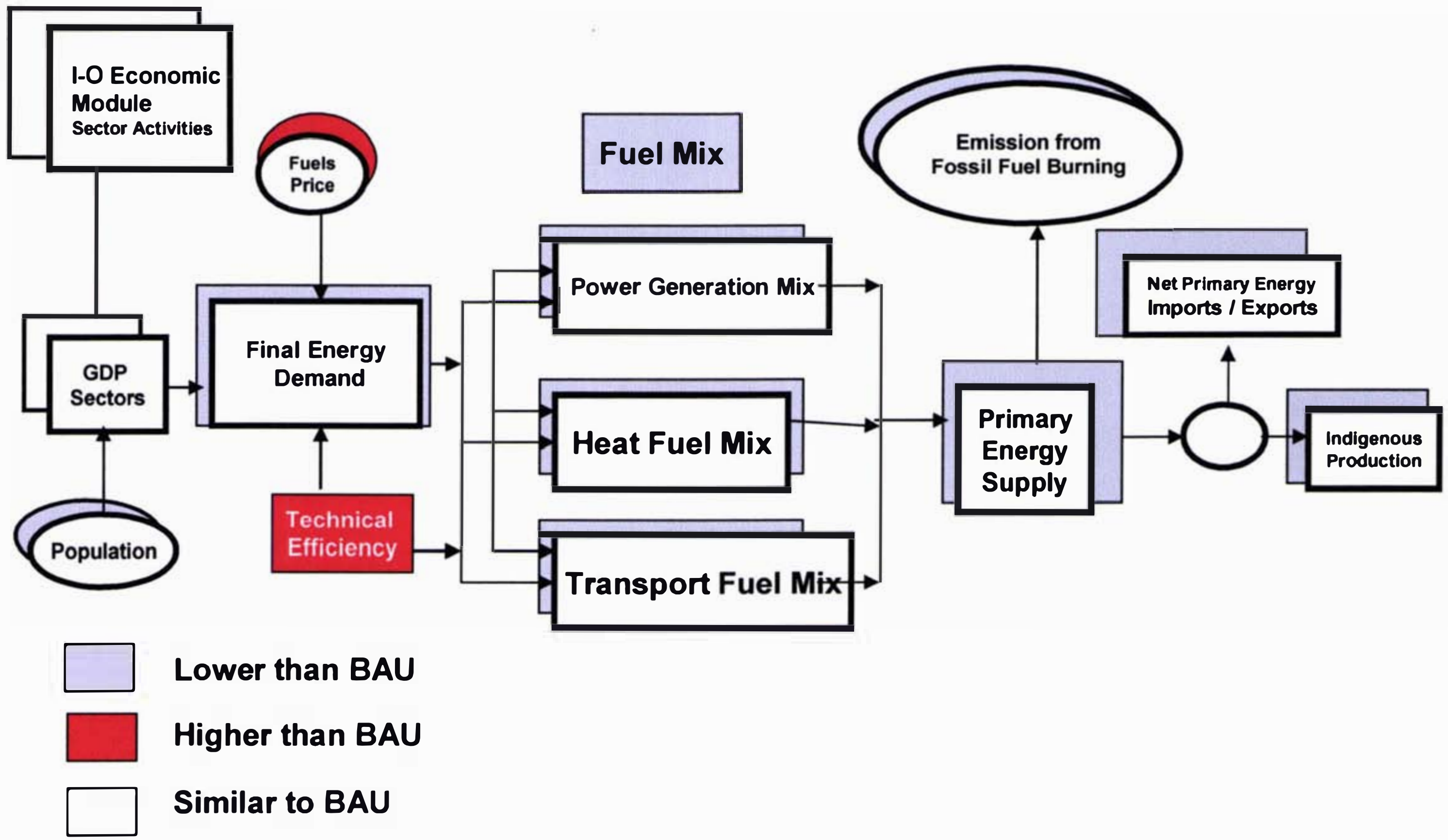



**Figure D.4 Magnitude of the Key Variables/Modules in the 'Self Sufficiency' Scenario**

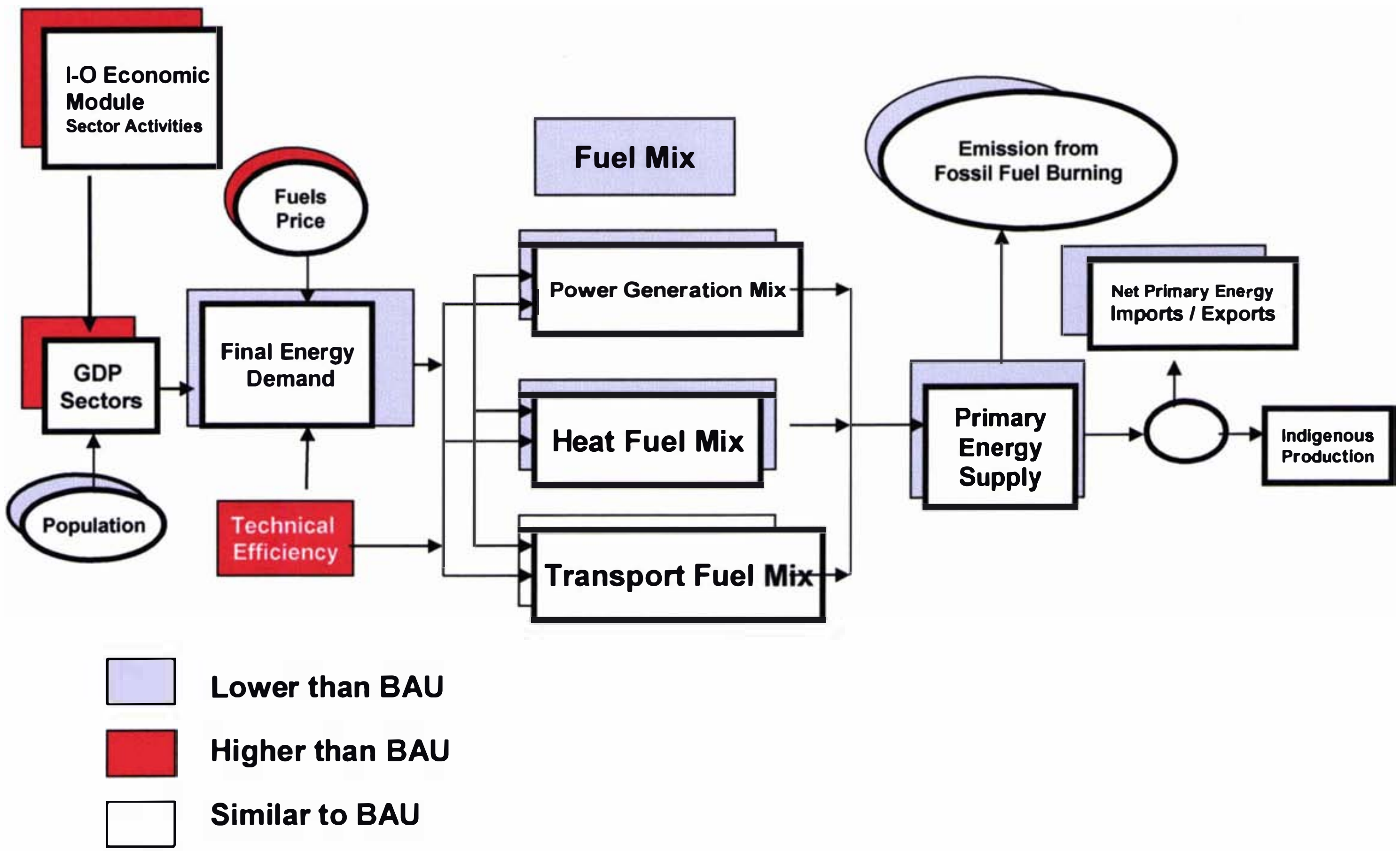



Figure D.5 Magnitude of the Key Variables/Modules in the 'Balancing Trade-Offs'' Scenario

# APPENDIX E KEY LINKAGES IN THE INDONESIAN ENERGY MODEL

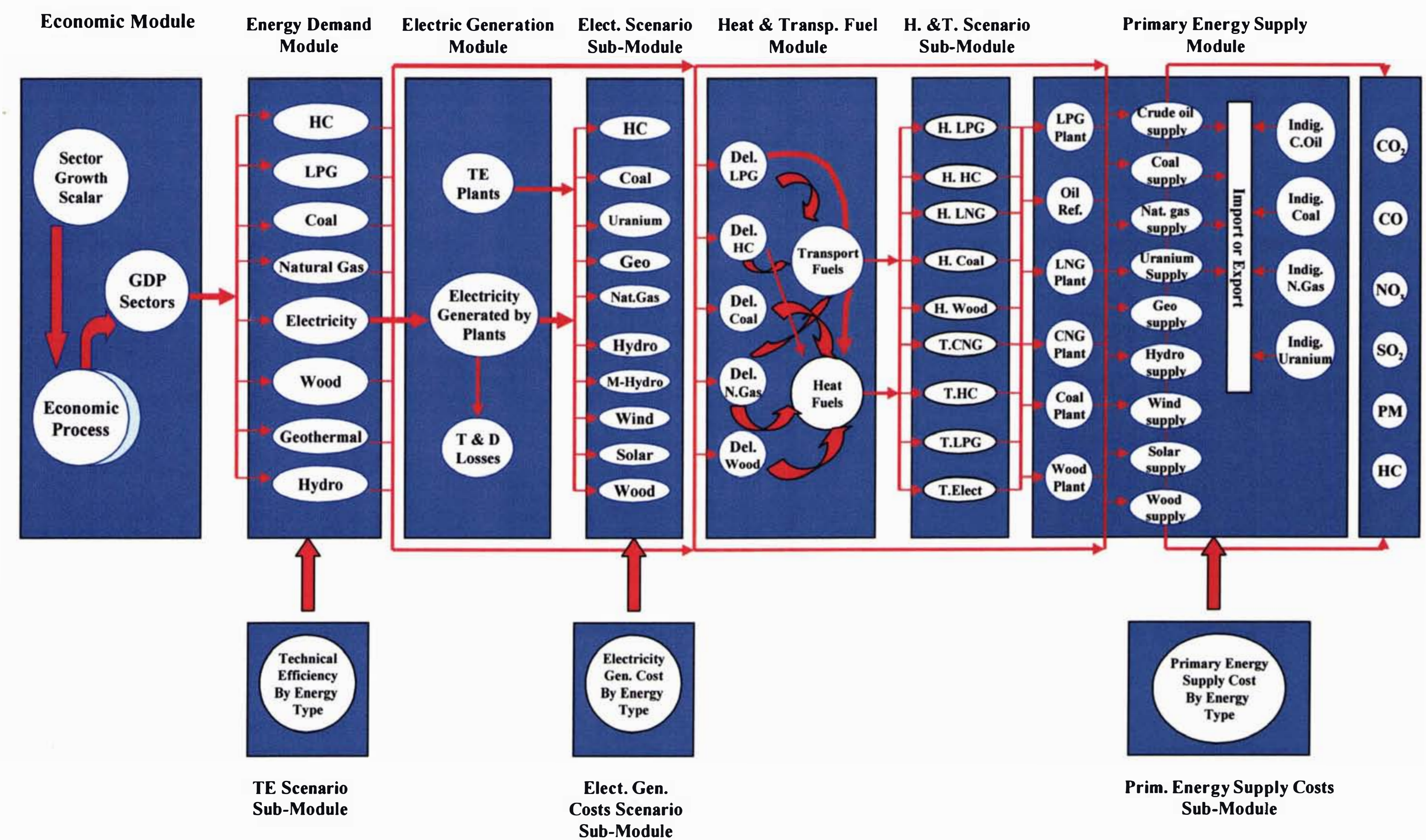



**Figure E** Key Linkages in and Between the Modules in the Indonesian Energy Model

# APPENDIX F SUMMARY OF POLICY DRIVERS, MAIN RESULTS AND INDICATORS FOR EACH SCENARIO

| | Business As Usual BAU | Environmentally Beneficial | Economic Efficiency | Self Sufficiency | Balancing Trade-Off |
|---|---|---|---|---|---|
| *GDP* | Follows the average trend of 5 selected countries', 20 years' ago = Current GDP Ind. | De-accelerated growth (-10 percent) from the Bussiness as Usual' trend over the period | Increased GDP growth by 15 percent from BAU's level, across the study period. | Follows 'Business as Usual' trends | Enconomy grows by 10 percent from 'Business as Usual' level. |
| *Population Growth* | Continuation of past trend, based on combination official data + UI 's study | Follows 'Business as Usual' trend | Follows 'Business as Usual' trend | Lower population growth -5 percent from Business as Usual' level across the study period. | Follows 'Business as Usual' trend |
| *EnergyConservation* | No major energy conservation efforts, continuation of the past efforts | Energy conservation efforts, promotional programs; campaign, labelling, training etc. | Energy conservation efforts, promotional programs; campaign, labelling, training etc. | Energy conservation efforts, promotional programs; campaign, labelling, training etc. | Energy conservation efforts, promotional programs; campaign, labelling, training etc. |
| *Energy Prices* | Continuation of historical increase/adjust inflation | Increased price of hydrocarbons for transport sector, 10 percent fron BAU's level. | Follows 'Business as Usual' price trend | Increased hydrocarbons price in transport sector by 10 percent to encourage shift of fuel use to LPG and CNG | Increased hydrocarbons price in transport sector by 20 percent from 'Business as Usual' level. |
| *Fuel Mix Power Generation* | Based on the existing operated power plants and utility company's plans and committed project. Nuclear starts in 2016 (BATAN's Plan) | Less carbon fuel to replace hydrocarbons and coal, use more nuclear, hydro and geothermal energy. | Utilisation of cheaper fuels like coal, hydro or geothermal in accordance to generation costs per production capacity of each fuel. | Use of more coal and abundant fuels available in the country like geothermal and hydro. | Utilisation of cheaper fuels like coal, hydro or geothermal in accordance to generation costs per production capacity of each fuel (follows 'Economic Efficiency' Scenario) |
| *Fuel Mix Primary Energy (Heating & Transport)* | Continuation of the past trends, follows the economic activities/GDP's trends | Hydrocarbons and coal for heating gradually replace by natural gas and LPG, wood/biomass use follows the past trend, hydrocarbons use in transport sector gradually replaced by CNG, LPG and Elect. | Reduce the use of hydrocarbons for heating purpose with cheaper fuels like coal. Biomass use follows the BAU's trend. Hydrocarbons for transport also follows the past trend. | Use more coal to replace hydrocarbons for heating purpose in manufacturing, household sectors | Follows 'Business as Usual' trends |
| *Production of Fossil Fuels (Net Import or Export of Energy)* | Production plan in accordance to the UI Research Center's Study and MEMR<br>Net importing status as BAU | Follows the BAU's fossil-fuel production scenario<br><br>Net importing status as it is | Increase indigenous production to support the economic growth. Coal, natural gas and crude oil production to be increased 50 percent of BAU production level.<br>Net importing status will be prolonged | Increased coal, hydrocarbons, natural gas production started from 2005. Coal (75-100 percent), crude oil and natural gas (50-75 percent), from BAU's production level.<br>Net importing status will be avoided | Increased coal production by 50 percent, natural gas and crude oil production by 25 percent from 'Business as Usual' production level, started from 2005 across the study period.<br>Net importing status will be prolonged |



**Figure F.1 Policy Drivers for Each Scenario**

SUMMARY OF POLICY OBJECTIVES, MAIN RESULTS/INDICATORS FOR EACH SCENARIO AND POLICY OPTIONS/IMPACTS

| *MAIN RESULTS INDICATOR VARIABLES* | **Business As Usual BAU** | **Environmentally Beneficial** | **Economic Efficiency** | **Self Sufficiency** | **Balancing Trade-Off** |
|---|---|---|---|---|---|
| ***GDP (Billion Rupiahs, 1995 Price)*** | | | | | |
| -Beginning (2000), Billion Rupiahs, 1995 Price | 553,164.07 | 553,164.07 | 553,164.07 | 525,607.51 | 553,164.07 |
| -End (2020), Billion Rupiahs, 1995 Price | 1,441,485.08 | 1,297,336.57 | 1,657,707.84 | 13,64259.70 | 1,585,633.59 |
| ***Energy Demand Growth (average % per year)*** | 5.7 | 4.2 | 5.6 | 4.7 | 5.3 |
| ***Percentage of Renewables (%)*** | | | | | |
| *- Wood/Biomass included (%), (2000 - 2020)* | 62.8 - 42.2 | 60.4 - 47.5 | 62.8 - 42.1 | 63.2 - 43.2 | 63.2 - 43.4 |
| *-Non-Wood/Biomass (%), (2000-2020)* | 1.2 - 7.6 | 1.1 - 9.7 | 1.2 - 8.1 | 1.3 - 3.8 | 1.3 - 8.8 |
| ***Cost of Energy Supply (Million US$), 2000-2020*** | 11,456 – 93,8923 | 11,762 – 5,1059 | 25,866 – 97,368 | 10,460 – 46,812 | 11,243 – 67,207 |
| *-Cost of Electricity Supply (Million US$),2000-2020* | 2,130 – 9,326 | 2,130 – 17,686 | 2,119 – 29,051 | 1,794 – 17,780 | 2,119 – 23,724 |
| *-Cost of Primary Energy (Million US$),2000-2020* | 9,326 – 49,271 | 9,631 –33,370 | 23,747 – 68,316 | 8,666 – 29,030 | 9,124 – 43,481 |
| ***Total Energy Efficiency (T-Joule/Billion Rupiahs)*** | | | | | |
| *-Beginning (2000), T-Joule/Billion Rupiahs* | 15.4 | 16.0 | 15.4 | 15.3 | 15.0 |
| *-End (2020), T-Joule/Billion Rupiahs* | 18.7 | 13.9 | 16.2 | 12.9 | 15.8 |
| ***Net Primary Energy Import/export (P-Joule)*** | 2.9 | 0.8 | 2.2 | exporting energy | 2.4 |
| *-Start Importing (Year)* | 2010 | 2011 | 2013 | | 2013 |
| ***Total CO2 Emissions (Million Tons)*** | | | | | |
| *-Beginning (2000), Million Tons* | 227,761 | 236,367 | 227,747 | 215,157 | 226,393 |
| *-End (2020), Million Tons* | 638,689 | 407,439 | 639,620 | 423,481 | 589,959 |



**Figure F.2 Main Results and Indicators for Each Scenario**

# APPENDIX G GLOSSARY

**ACE:** ASEAN Centre for Energy

**ADO:** Automotive Diesel Oil

**AEEMTRC:** ASEAN-EC Energy Management Training and Research Centre

**AFBC:** Atmospheric Fluidised Bed Combustion

**APERC:** Asia Pacific Energy Research Centre

**API:** The American Petroleum Institute, a trade association

**AFBC:** Atmospheric Fluidized-Bed Combustion

**API Gravity:** An arbitrary scale expressing the gravity or density of liquid petroleum products. The measuring scale is calibrated in terms of degrees API. A lighter, less dense product has a higher API gravity.

**Aviation Gasoline:** A complex mixture of relatively volatile hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in aviation reciprocating engines. Fuel specifications are provided in ASTM Specification D910 and Military Specification MIL-G-5572.

**ARCO:** American Oil Company, Atlantic Richfield Company Inc.

**ASEAN:** Association of Southeast Asian Nations

**Barrel (Petroleum):** A unit of Volume equal to 42 U.S. gallons

**Barrels per Day (Operable Refinery Capacity):** The maximum number of barrels of input that can be processed during 24-hour period after making allowances for the following limitations: the capability of downstream facilities to absorb the output of crude oil processing facilities of a given refinery (no reduction is made when a planned distribution of intermediate streams through other than downstream facilities is part of a refinery's normal operation); the types and grades of inputs to be processed; the types and grades of products to be manufactured; the environmental constraints associated with refinery operations; the reduction of capacity for scheduled downtime, such as routine inspection, mechanical problems, maintenance, repairs, and turn-around; and the reduction of capacity for unscheduled downtime, such as mechanical problems, maintenance, repairs, and turnaround; and the reduction of capacity for unscheduled downtime, such as mechanical problems, repairs, and slowdowns.

**BAKOREN:** Badan Koordinasi Energy Nasional (National Energy Coordinating Body of Indonesia)

**BAPPENAS:** Badan Perencanaan Pembangunan Nasional (National Development Planning Agency, Indonesia)

**BATAN:** Badan Tenaga Atom Nasional, The National Nuclear Energy Agency (Indonesia)

**Bituminous Coal:** A dense coal, usually black, sometimes dark brown, often with well defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications.

**Biomass:** Organic non-fossil material of biological origin constituting a renewable energy source

**BOE:** Barrels of Oil Equivalent

**BPM:** De Bataafsche Petroleum Maatschappij

**BPPT:** Badan Pengkajian dan Penerapan Teknologi (The Agency for Assessment and Applications of Technology, Indonesia)

**BPS:** Biro Pusat Statistik (Central Bureau of Statistic of Indonesia)

**BPU-PLN:** Board of Directors of PLN (State Electricity Company) (Indonesia)

**BSCF:** Billion Standard Cubic Feet

**BTU**: British Thermal Unit, the quantity of heat needed to raise the temperature of 1 pound of water by $1^{\circ}$ F at near $60^{\circ}$ F and 1 atm.

**CAES:** Compressed Air Energy Storage

**CALTEX:** American Oil Company, a joint venture between Chevron and Texaco Oil Company established in 1949, which reoperated their concession and mobilized its drilling activities in Central Sumatra.

**CC:** Combined Cycle

**CESUI:** Centre for Energy Study of University of Indonesia

**CHP:** Combined heat and power generation

**CIA:** The Central Intelligence Agency of the United States

**CNG:** Compressed Natural Gas

**CO2:** Carbon dioxide

**CSIRO:**

**Dem.Pro:** Demonstration Project

**DGEED:** Directorate General of Electricity and Energy Development (Indonesia)

**DGEEU:** Directorate General of Electricity and Energy Utilisation (Indonesia)

**DGENE:** Directorate General of Electricity and New Energy Development (Indonesia)

**DGM:** Directorate General of Mining (Indonesia)

**DGOG:** Directorate General of Oil and Gas (Indonesia)

**Divisia or Decomposition Method:** The method used in this study for identifying technical and structural factors that cause changes in energy efficiency patterns by decomposing the effects of *energy: GDP* ratio into structural effect and intensity or technical effect for each individual sector.

**ECE:** The Economic Commission for Europe

Electriciteies Vergunning

**Electrical System Energy Losses:** The amount of energy lost during generation, transmission, and distribution of electricity, including plant and unaccounted-for uses.

**Electricity Generation:** The process of producing electric energy or transforming other forms of energy into electric energy. Also, the amount of electric energy produced or expressed in watt-hours.

**Electric Power Plant:** A Station containing prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or fission energy into electric energy.

**End-Use Sectors:** The residential/household, commercial, industrial/manufacturing, and transportation sectors of the economy.

**Energy:** The capacity for doing work as measured by the capacity of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatthours, while heat energy is usually measured in British Thermal Units.

**Energy Consumption:** The use of energy as a source of heat or power or as an input in the consuming sector.

**EMA:** Electricity and Gas Company, established by the Dutch in Ambon (1 September 1953).

**Etatism:**

**FCCC:** Framework Convention on Climate Change

**FGD:** Flue-Gas Desulfurization

**Fossil Fuel:** any naturally occurring organic fuel formed in the earth's crust, such as petroleum, coal and natural gas.

**Gas-Turbine Electric Power Plant:** A plant in which the prime mover is a gas turbine. A gas turbine typically consists of an axial-flow air compressor and one or more combustion chambers where liquid or gaseous fuel is burned. The hot gases expand to drive the generator and then are used to run the compressor.

**GBHN:** Garis Besar Haluan Negara,

**Gross Domestic Product (GDP):** The total value of goods and services produced by labour and property located in Indonesia. As long as the labour and property are located in Indonesia, the supplier (that is, the workers and, for property, the owners) may be either Indonesian residents or residents of foreign countries.

**GHG:** Greenhouse gas

**GWh:** Giga Watt-hours

**Hydrocarbon:** all forms of petroleum products, an organic chemical compound of hydrogen and carbon in the gaseous, liquid, or solid phase. The molecular structure of hydrocarbon compounds varies from the simplest (methane, a constituent of natural gas) to the very heavy and very complex.

**Hydroelectric Power Plant:** A plant in which the turbine generators are driven by falling water.

**HSD:** High Speed Diesel Oil

**IDO:** Intermediate Diesel Oil

**IEA:** International Energy Agency

**IGCC:** Integrated Gasification Combined Cycle

**IGGI:** The Inter-Governmental Group on Indonesia which was established by foreign creditors of Indonesia in early 1967 which aimed at giving vast credits a moratorium on debt repayments.

**IMF:** International Monetary Fund

**IMW:** Indische Mijnwet, mining regulation established in 1899 in Indonesia by the Dutch colonial government

**Indicated Resources, Coal:** Coal for which estimates of the rank, quality, and quantity are based partly on sample analyses and measurements and partly on reasonable geologic projections. Indicated resources are computed partly from specified measurements and partly from projection of visible data for a reasonable distance on the basis of geologic evidence.

**Industrial Sector:** Manufacturing industries, which make up the largest part of the sector ranging from energy intensive industries to small scale industries cement, steel mills, pulp and papers, textiles, food-beveries to companies like assembling electronic components.

**I-O:** Input Output Matrix Coefficient

**IPCC:** Intergovernmental Panel on Climate Change

**ISTIG:** Intercooling Steam Injected Gas Turbine

**IUK:** Ijin Usaha Kelistrikan, Electricity Venture Permit

**IUKS**: Ijin Usaha Kelistrikan untuk Pemakaian Sendiri, Electricity Producing Permit for Own Use

**JICA:** Japan International Cooperation Agency

**JIOC:** Japan Indonesian Oil Company

**JOA:** Joint Operating Agreement, a form of joint agreement on oil and gas matters between private companies and PERTAMINA.

**JOB:** Joint Operation Body; a form of cooperation between PERTAMINA with private companies for oil and gas exploration and exportation.

**Kerosene:** A light petroleum distillate that is used in space heaters, cook stoves, and water heaters and is suitable for use as a light source when burned in wick-fed lamps. Kerosene has a maximum distillation temperature of 400°F at the 10-percent recovery point, a final boiling point of 572°F, and a minimum flash point of 100°F. Included are No. 1-K and N0. 2-K, the two grades recognised by ASTM Specification D3699 as well as all other grades of kerosene called range or stove oil, which have properties similar to those of No. 1 fuel oil and have gravity of about 43 degrees API and a maximum endpoint of 625°F.

**KEP:** Kelompok Energi Perdesaan, Rural Energy Group

**KEPPRES:** Keputusan Presiden, Presidential Decrees

**KONEBA:** Konservasi Energy Abadi, Energy Consulting Company (Indonesia)

**KUBE:** Kebijaksanaan Umum Bidang Energi, General Energy Policy Guidelines

**KUD:** Koperasi Unit Desa, Rural Cooperatives Unit

**Kilowatthour (kWh):** A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kilowatthour is equivalent to 3,412 Btu.

**Lignite:** The lowest rank of coal, often referred to as brown coal, used almost exclusively as fuel for steam-electric power generation. It is brownish-black and has a high inherent moisture content, sometimes as high as 45 percent. The heat content of lignite ranges from 9 to 17 million Btu per short ton on a moist, mineral-matter-free basis.

**Liquefied Natural Gas (LNG):** Natural gas (primarily methane) that has been liquefied by reducing its temperature to –260°F at atmospheric pressure.

**Liquefied Petroleum Gases (LPG):** Ethane, ethylene, propane, propylene, normal butane, butylene, and isobutane produced at refineries or natural gas processing plants, including plants that fractionate new natural gas plant liquids.

**LWB:** Lands Waterkracht Bedrijven (LWB)" established by The Dutch colonial government in 1927, a State Electricity Company, which ran Hydro Power Plants (PLTA) in Indonesia during the Dutch era.

**MAED:** Model for Analysis of Energy Demand

**MARKAL:** Market Allocation for Energy Supply Analysis

**MEMR:** Ministry of Energy and Mineral Resources (Indonesia)

**MH:** Micro-Hydro

**MHD:** Magneto Hydro Dynamics

**MHTGR:** The modular High-Temperature Gas-Cooled Reactor (Nuclear)

**MME:** Ministry of Mines and Energy (Indonesia)

**MPR:** Majelis Permusyawaratan Rakyat, the People Consultative Assembly

**Musyawarah:** Is a consensus being reached by a group of people after a debate or discussion

**MWh:** Mega Watt Hours

**Naphtha:** A generic term applied to a petroleum fraction with an approximate boiling range between 122° and 400° F.

**Natural Gas:** A mixture of hydrocarbons (principally methane) and small quantities of various non-hydrocarbons existing in the gaseous phase or in solution with crude oil in underground reservoirs.

**Natural Gas Liquids (NGL):** Those hydrocarbons in natural gas that are separated as liquids from the gas. Natural gas liquids include natural gas plant liquids (primarily ethane, propane, butane, and isobutane) and lease condensate (primarily pentanes produced from natural gas at lease separators and field facilities).

**NATO:** Non Align Treaty Organisation

**New Order:** The so called 'a new regime' under Soeharto's presidency

**NGO:** Non Governmental Organisation

**NKPM:** De Koninklijke Nederlandsche Maatschappij tot Exploitatie van Petroleumbronnen, an oil company in Dutch Indies.

**NOMISMA:** A Study on energy efficiency in industrial, commercial, agriculture, transport and residential carried out by the Italian government

**$NO_x$:** Nitrogen Oxide

**NRSE:** New and Renewable Sources of Energy

**NV NIAM:** Nederlands Indische Aard-Olie Maatschpij, Joint venture enterprise established by the Dutch colonial government

**NV NIGM:** Nederlands Indische Gas Maatschappij, Dutch private company,. The company previously run gas business and then was expanded to supply electricity for the public during the Dutch colonial era.

**OECD:** Organization for Economic Cooperation and Development): Current members are Australia, Austria, Belgium, Canada, Czech Republic, Denmark and its territories (Faroe Islands and Greenland), Finland, France, Germany, Greece, Greenland, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States and its territories (Guam, Puerto Rico, and Virgin Islands).

**OECD, Europe:** includes Austria, Belgium, Czech Republic, Denmark, Faroe Islands, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

**Oil Windfalls**: the escalating oil and gas exports' revenue caused by the rise of world oil prices

**OPEC:** Organization of Petroleum Exporting Countries, countries that have organized for the purpose of negotiating with oil companies on matters of oil production, prices, and future concession rights. Current members are Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela.

**ORNL:** The Oak Ridge National Laboratory, US

**OTA:** The Office of Technology Assessment, US Congress

**OTEC:** Ocean Thermal Energy Conversion

**Pancasila:** The government system that was based on belief in God, nationalism, Democracy, Social Justice and Humanitarian. Pancasila stipulates that democracy decision is not based merely on the formal power of the majority or voting, but it should be based on 'consensus' or 'musyawarah' through control.

**PERMIGAN:** Perusahaan Minyak dan Gas Negara, Oil and Gas State Owned Company

**PERTAMIN:** Perusahaan Tambang Minyak Negara, Oil State Owned Company

**PERTAMINA:** Perusahaan Pertambangan Minyak dan Gas Nasional, Oil and Gas State Owned Company, in Indonesia.

**Premium Gasoline:** Gasoline having an antiknock index i.e. octane rating greater than 90.

**Petroleum:** A generic term applied to oil and oil products in all forms, such as crude oil, lease condensate, unfinished oils, petroleum products, natural gas plant liquids, and non-hydrocarbon compounds blended into finished petroleum products.

**Petroleum Products:** Products obtained from the processing of crude oil (including lease condensate), and other hydrocarbon compounds. Petroleum products include unfinished oils, pentanes plus, aviation gasoline, motor gasoline, naphtha-type jet fuel, kerosene, distillate fuel oil, residual fuel oil, petrochemical feedstock's, special naphtha's, lubricants, waxes, petroleum coke, asphalt, road oil, still gas, and miscellaneous products.

**Photovoltaic Energy:** Direct-current electricity generated from sunlight through solid-state semiconductor devices that have no moving parts.

**Photovoltaic Module:** A group of photovoltaic cells (Cells are solid-state devices that produce electricity when exposed to sunlight). The electricity is used primarily in applications requiring remote power, such as radio communication, cathodic protection, and navigational aids.

**PFBC:** Pressurized Fluidised Bed Combustion

**PGN:** Perusahaan Umum Gas Negara, State Owned Gas Transmission and Distribution Company, in Indonesia.

**PKI:** Partai Komunis Indonesia, Indonesian Communist Party

**PLN:** Perusahaan Listrik Negara , State Owned Electricity Company (Indonesia).

**POKKORLAK P4BA:** Coordination Group on Bukit Asam Coal Development and Transportation (Indonesia)

**PANKORBANG Batubara:** Coordinating Committee on Coal Development (Indonesia_

**Price Deflator**: A measure used to convert nominal prices to real prices.

**PRISM:** The Power Reactor Inherently Safe Module (Nuclear)

**PUSRI:** Pupuk Sriwijaya, Sriwijaya Fertilising Plant (Indonesia)

**PP:** Peraturan Pemerintah, Government Regulation

**Production Sharing Contract (PSC):** A form of cooperation between PERTAMINA and private companies in accordance with Law no. 44 Prp of 1960 jo Law No. 8 of 1971.

**Proven Reserves, Crude Oil:** The estimated quantities of all liquids defined as crude oil that geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.

**Proven Reserves, Condensate:** The volumes of condensate expected to be recovered in future years in conjunction with the production of proved reserves of natural gas based on the recovery efficiency of lease and/or field separation facilities installed.

**Proven Reserves, Geothermal:** The estimated quantities of geothermal steam that geological, geochemical, geophysics, and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.

**Proven Reserves, Natural Gas:** The estimated quantities of natural gas that analysis of geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions.

**PSKSK:** Small Scale Private Power Generator and Cooperatives

**PTE:** Panitia Teknis Sumber Daya Energy, Technical Committee on Energy. A committee established under BAKOREN who supports BAKOREN and deals with the technical matter of energy policy analysis.

**R&D:** Research and Development

**R/P:** Reserves to Production ratio

**Renewable Energy:** Energy obtained from sources that are essentially inexhaustible (unlike, for example, the fossil fuels, of which there is a finite supply). Renewable sources of energy include conventional hydroelectric power, wood, waste, geothermal, wind, photovoltaic, and solar thermal energy.

**Repelita:** Rencana Pembangunan Lima Tahun, Five Year Development Plan (Indonesia)

**Residential Sector:** All private residences, whether occupied or vacant, owned or rented, including single-family homes and multifamily housing units. Secondary homes, such as holiday homes, are also included. Institutional housing, such as school dormitories, hospitals, and military barracks, generally are not included in the residential sector. They are included in the commercial sector.

**Res-Com:** Residential-Commercial Sector

**SAS:** A multi-variable regression methodology used for the analysis of the determinant of demand for energy in this study

**Small Power Producer:** A small power producer generates electricity by using waste or renewable energy (biomass, conventional hydroelectric, wind, solar, and geothermal) as a primary energy source.

**Solar Collector:** Equipment that actively concentrates thermal energy from the sun. The energy is usually used for space heating, for water heating, or for heating swimming pools. Either air or liquid is the working fluid.

**Steam-Electric Power Plant:** A plant in which the prime mover is a steam turbine. The steam used to drive the turbine is produced in a boiler where fossil fuels are burned.

**Sub-bituminous Coal:** A coal whose properties range from those of lignite to those of bituminous coal and used primarily as fuel for steam-electric power generation. It may be dull, dark brown or black, soft and crumbly, at the lower end of the range, to bright, jet black, hard, and relatively strong, at the upper end. Sub-bituminous coal contains 20 to 30 percent inherent moisture by weight. The heat content of sub-bituminous coal ranges from 17 to 24 million Btu per short ton on a moist, mineral-matter-free basis.

**SCF:** Standard Cubic Feet

**SHS:** Solar Home System

**SNI:** Standar Nasional Indonesia, Indonesian National Standard

**$SO_x$:** Sulphur Oxide

**STELLA:** is a computer software with a multi-level hierarchical environment for constructing and interacting with models. The environment consists of two major layers: the high-level mapping layer and the model construction layer. An equations view is provided to view the entities on the model construction layer in a list format, for rapid modification of variable definitions, and for easy reporting of equations from the model.

**STIG:** Steam-Injected-Gas Turbine

**Supersemar:** Surat Perintah Sebelas Maret, The Instruction letter dated on $11^{th}$ of March 1965

**System Dynamics:** A field for understanding how things change through time. System dynamics deals with how the internal feedback-loops within the structure of a system create behaviour. Computer simulation models are used to achieve better understanding of system behaviour over time. With a better comprehension of systems, one can redesign structure or policies to improve the behaviour. The field of system dynamics was created by Jay W. Forrester beginning in 1956.

**TBE:** Tariff Biaya Exploitasi, Exploitation Cost

**TCE:** Ton of Coal Equivalent

**TDL:** Tariff Dasar Listrik, The Basic Electricity Tariff (Indonesia)

**TOE:** Ton of Oil Equivalent

**TPES:** Total Primary Energy Supply

**Transportation Sector:** Private and public vehicles that move people and commodities. Included are automobiles, trucks, buses, motorcycles, railroads, and railways (including streetcars), aircraft, ships, barges, and natural gas pipelines.

**UI:** University of Indonesia

**UN:** United Nations

**UNEP:** United Nations Environment Program

**UNFCCC:** United Nation Framework Convention on Climate Change

**US:** United States

**US DOE:** United States Department of Energy

**UU:** Undang-Undang, Acts or Law

**VFDs:** Variable Speed AC Drives

**VOC:** The East India Companies (VOC) established by the Dutch government in 1602, which were not purely private endeavours (sponsored by the State and the Civic Corporations).

**WB:** World Bank

**Wind Energy:** The kinetic energy of wind converted into mechanical energy by wind turbines (i.e., blades rotating from a hub) that drive generators to produce electricity.

**Wood Energy:** Wood and wood products used as fuel, including round-wood (cord wood), limb wood, wood chips, bark, sawdust, forest residues, charcoal, pulp waste, and spent pulping liquor.