An Energy-Economy Model to Evaluate the Future Energy Demand-Supply System in Indonesia

1994年度 工学修士学位請求論文

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The present level of energy demand in Indonesia is still very low and it is expected to continue to increase. To fulfill the demand, some energy resources such as coal, gas, oil and renewable energy are available. These energy resources are characterized by limited oil reserves, sufficient gas reserves and abundant coal reserves. Therefore, it is important to make optimal strategies for the national energy demand-supply system for the long future. Energy-economy model is one of the tools for the energy decision maker to perform it.

The objective of this study is to develop an energy- economy model for Indonesia to evaluate the future energy demand-supply systems. Because there is increasing concern about environmental problem recently and for the energy decision maker, the relation among energy, economy and environment become a new consideration, this model also consider environmental aspect.

The model contains five types of primary energy sources: coal, natural gas, crude oil, biomass and other renewable energy which involves hydropower and geothermal energy. The primary energy sources are transformed into secondary energy sector which consists of electricity and non-electricity. Demand sector is disaggregate into three sectors: industry, transportation and other sectors. The whole country is divided into four regions: Java, Sumatera, Kalimantan and other islands with transportation of fossil energy: coal, natural gas and crude oil. The model is benchmarked against 1990 base year statistics. The evaluations cover four ten-year time intervals extending from 2000 through 2030. The model is designed as an non-linear optimization model with various components of quantitative framework to make the model useful device for analysis. A software that called General Algebraic Modeling System (GAMS) is used to solve the problem of the model on 486 compatible personal computer.

According reference case result, abundant coal reserves make coal attractive as the major domestic energy supply in Indonesia. These huge amounts using coal seem to create high emission of air pollutants. The second major energy supply is natural gas and followed by crude oil. Crude oil supply is expected not growing significantly due to limited of resource.

On the regional perspective, coal is attractive for the energy supply in Java and Sumatera due to the high growth of energy demand in these regions. In Kalimantan natural gas has a significant share for energy supply in a long term. In the other islands, area is extensive and the energy demands are fewer but much more spread out. Therefore, renewable energy such as hydropower and geothermal energy are attractive in these regions.

Sensitivity analysis is performed by varying the discount rate from 5% to10 % and varying the domestic transportation cost of fossil energy from 50% to 150% of domestic transportation cost of fossil energy in the reference case. At a higher discount rate, the total income decreases and also the energy demand declines in a long term. A cheaper domestic transportation cost makes increase of the total energy demand. The increasing demand will be supplied by an expansion of coal and natural gas production. Supply of crude oil will grow if the domestic transportation cost goes up.

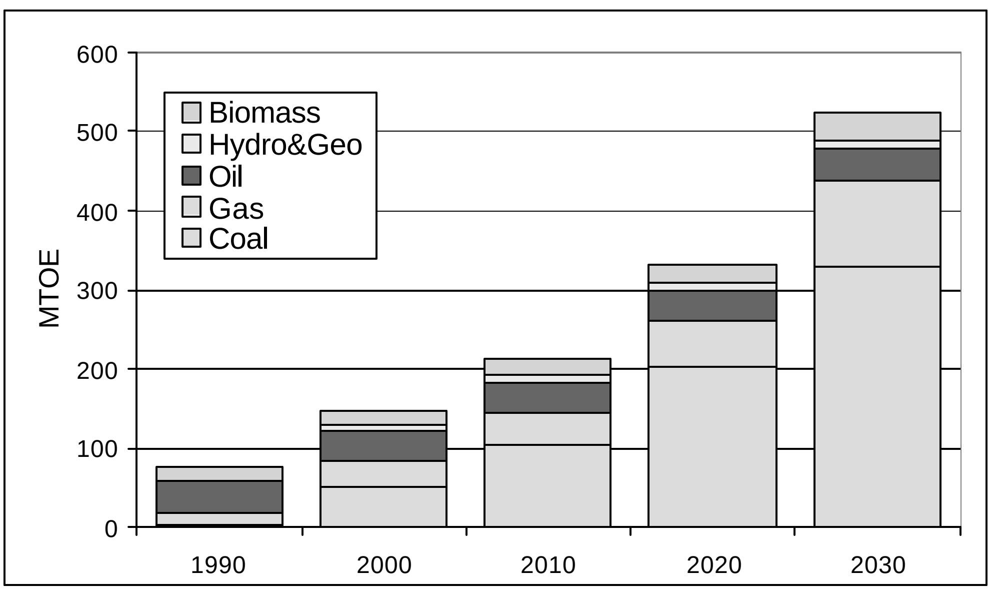

Fig. Total primary energy supply projection

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1. Introduction

The present level of energy demand in Indonesia is still very low and it is expected to continue to increase. To fulfill the demand, some energy resources such as coal, gas, oil and renewable energy are available. These energy resources are characterized by limited oil reserves, sufficient gas reserves and abundant coal reserves. Therefore, it is important to make optimal strategies or planning for the national energy demand-supply system for the long future.

The term of energy planning is in wide use now since the fear of energy shortage has emerged after the energy crisis in 1973-1974. Mathematical model has usually been used in energy planning to capture the engineering details of specific energy technology. The energy models can be categorized according to their scope. Its range from supply-oriented models of single fuel to models encompassing the overall energy system coupled to the economy. Four major groups of models can be distinguished: sectoral model, industry market model, energy system model and energy-economy model.

The sectoral models defined as relating to some specific energy process or activity forming a part of a specific energy industry market. Typically, the models focus on either the supply or the demand side of the market. Process models are used most often for characterizing energy supply and capacity expansion, whereas econometric models are used to characterize demand. The industry market model include process and econometric model, which characterize both the supply and the demand for a specific of energy products. Such models are very useful and are applicable to all energy-use categories. The modeling in the field of energy system models is very difficult with regard to methodologies and design of models. Generally, simulation and optimization methodologies are applied due to the set of questions addressed by the models. Most of the sectoral and energy system models require that the energy demands must be specified exogenously as input parameters. Most of them create energy demand-supply balances and can be categorized in economic terms as partial equilibrium models. The energy-economy models consist in the coupling of energy system models with models of the overall economy such as macroeconomic and input-output models.

This study is modeling in the field of energy-economy models with the object to develop an energy-economy model for Indonesia and to evaluate the future energy demand-supply systems. The whole country is divided into four regions. The model is benchmarked against 1990 base year statistics. Evaluations cover four ten-year time intervals extending from 2000 through 2030. Because there is increasing concern about environmental problem recently and for the energy decision maker, the relation among energy, economy and environment become a new consideration, this model also consider the environmental aspect. The model is designed as an non-linear optimization model with various components of quantitative framework to make the model useful device for analysis.

2. Background on Indonesia

2.1 Geography

Indonesia, the world's largest archipelago, stretching from 94°45' to 141°5' east longitude and 6°8' north latitude to 11°15' south latitude, is bordered in the west and the south by Indian Ocean. In the east by the Pacific Ocean and in the north by the South China Sea. Indonesia is located in the Southeast Asia, between the Asian Continent in the north, and the Australian Continent in the south. Indonesia extends about 5,150 km from east to west and about 1,770 km from north to south.

The Indonesian archipelago consists of no less than 13,700 islands. Around 6,000 islands are inhabited, but only about 3,000 islands have substantial settlements. The total area is about 9.8 million squares kilometers with the sea area is four times larger than its land area (including exclusive economic zone). The land area is generally covered with thick tropical rain forest and predominantly mountainous.

The largest islands are Kalimantan (previously known as Borneo) which area of about 539,460 square km, Sumatera with 473,605 square km, Man Jaya (previously called West New Guinea, hording on Papua New Guinea) with 421, 981 square km, Sulawesi (previously called Celebes) with 189,216 square km and Java including Madura, with a land area of about 132,187 square km.

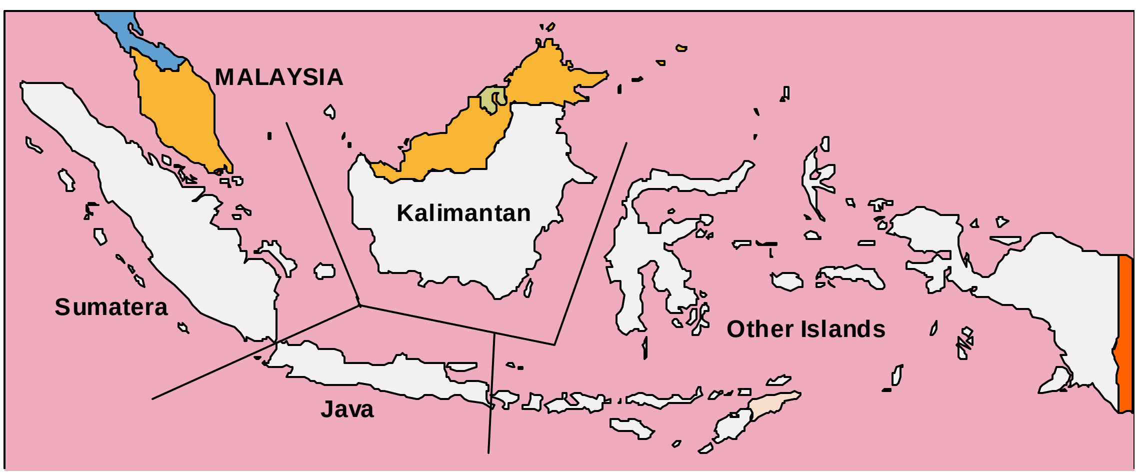

Fig. 2-1. Indonesia and regional divisions of the model

2.2 Population and economic indicators

According to the 1990 census the population has reached 179.3 million, which is the third largest group in Asia after People's Republic of China and India. The population growth rate has declined from 2.2% per annum in the early eighties to 1.8% at present due to the success with the family planning program. Compared to other countries, and in particular to industrialized countries, this growth rate is considered very high.

The most serious situation is found on Java. The island covers only 7% of the land area but 60% of the Indonesian population lives there. The population density is 842 inhabitants per square km.

In the 1970, the country experienced relatively high economic growth of around 7.8% per annum mainly due to the high oil prices in the international market. Average economic growth rate for the last 10 years is about 6% per annum. In early 1983, a series of economic reforms were undertaken to develop and promote exports of agricultural, forestry, and manufacturing that aggregatedly designated as non oil and gas commodities. Strong international competition and the economic momentum of previous achievements prompt Indonesia to broaden industrial base. Indonesia is actively preparing for economic take-off around 1995 with the best chance of success against increasingly global competition.

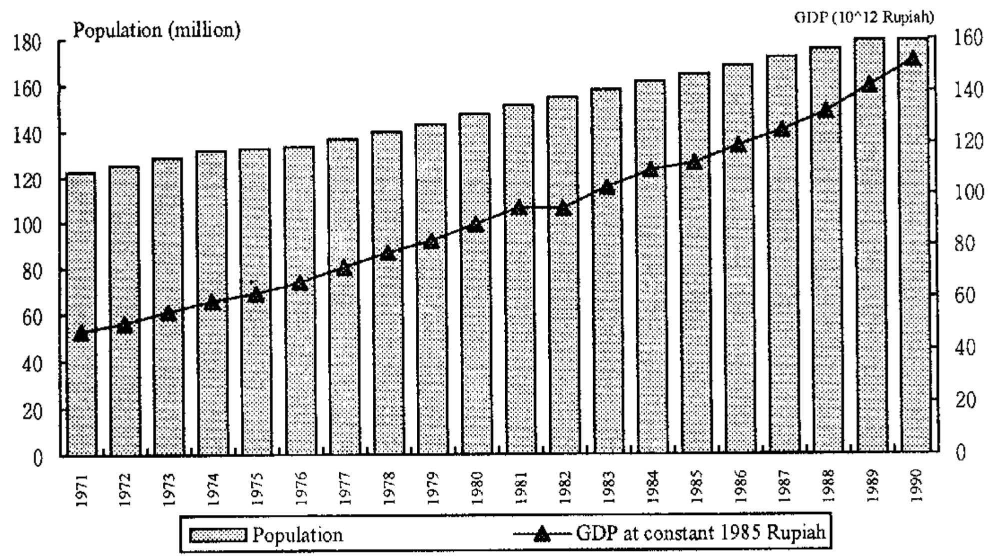

Fig. 2-2. Population and GDP growths[7,11)]

2.3 Energy

The energy sector is one of the most importance sub-sectors in Indonesia because it has been a major source of technological development, to drive economic activity and also as an export commodity. It accounted for slightly over 20% of GDP in 1990 and approximately 40% of the export earnings.

Table 2-1 summarizes the energy resource compared to utilization in 1990. The situation of the fossil energy reserves is characterized by limited oil reserves, sufficient gas reserves and abundant coal reserves. The Indonesia's oil reserves were estimated by Minister of Mine and Energy to be 10.731 billion barrels. Petroleum geologists believed that the not yet explored basins within the Indonesian archipelago contain resources of 30 to 40 billion barrels. The possible oil reserves may be located in remote areas or in the deep sea. High risk exploration and intensive capital investment may be necessary to prove at least part of these resources.

The proven and potential gas reserves are estimate at about 101.8×10^{12} scf. Unfortunately, the most of the reserves have a 70% CO_2 content that need large investments to develop the field, to process the gas, and to dispose CO_2 into the reservoir.

Table 2-1. Energy reserves compared to utilization in 1990[8)]

	Oil 10^9 Barrel	Natural Gas 10^{12} scf	Coal 10^9 ton	Hydropower GW	Geothermal GW
Java	1.325	12.4	0.061	4.2	7.80
Sumatera	8.324	64.1	24.776	15.6	4.90
Kalimantan	1.002	24.4	9.361	21.6	-
Other islands	0.080	0.9	0.107	33.6	3.40
Total reserves	10.731	101.8	34.305	75.0	16.10
Production in 1990	0.470	2.1	0.011	-	-
Installed in 1990	-	-	-	2.2	0.17

Coal is found predominantly in east and south Kalimantan and central and south Sumatera. The total resources are estimated in 1992 at 34.305 billion tonnes. More than 65% of Indonesian coal is lignite, most is found in south Sumatera. The rest is primarily classified as sub-bituminous and bituminous, although a small amount of anthracite is found in Sumatera. Most of coal reserves have characteristic a low ash, low sulphur and high volatile matter content. Lignites have lower calorific value, higher moisture content and hence higher transportation costs than sub-bituminous, bituminous and anthracite coals.

Indonesia has a large hydropower potential of 75 GW. Until 1990, only 2.2 GW was used for electricity generation. Most of the reserves are located in thinly populated areas where the demand is too low to justify large scale investment. The total geothermal has been estimated to be 16 GW. Intensive exploration must be carried out in order to develop geothermal reserves. A constraint is also geothermal steam pricing. Therefore, up to now only 140 MW has been used in Kamojang and 220 MW are under development.

The domestic primary energy supply in 1991 was accounted around 52 MTOE and was dominated by crude oil with 41% and by biomass, as a traditional form of energy, which contributed 31%. Natural gas supplied 18% of the domestic energy consumption. The remainder was shared by coal (6%) and hydropower together with geothermal energy (4%) as shown in Fig. 2-3. The main consumption of biomass is in the rural and urban peripheral residential sector.

Considering the current energy reserves and utilization situation, the general feeling that within 20 years time Indonesia will have to be a net oil importer to satisfy its demand if no new discoveries were made. Natural gas and coal may be then become the dominant energy supply. For the past five years, the production and use of coal has been accelerating. Coal is mainly used in power generation and the cement industry. With increasing environmental actions, the use of natural gas also be expected to grow at a steadily increasing pace.

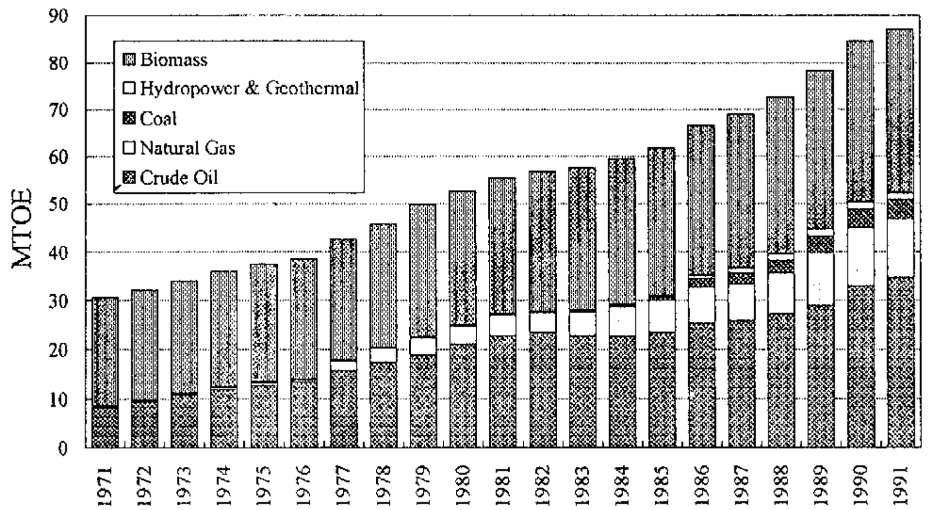

Fig. 2-3. Primary energy supply[10)]

As shown in Table 2-1 that most of the energy resource are located out of Java, but the demand of energy is concentrated in Java. Therefore the regional transportation of energy will be an important factor for the future of energy demand-supply projection.

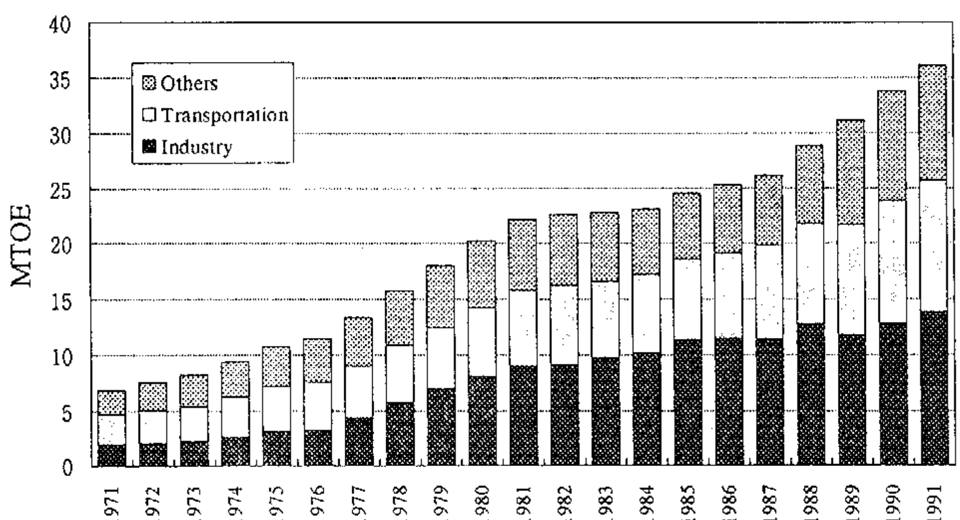

Fig. 2-4. The commercial energy consumption[10)]

The present level of energy consumption in Indonesia is still very low and it is expected to continue to increase, as in the most developing countries. An overview of the sectoral commercial energy consumption is given in Fig. 2-4. The industry sector has the highest share of commercial energy consumption. For the last 10 years, the commercial energy consumption in industry sector increased by 3.6%. In transportation sector increased by 5% and the other sectors that includes household, government and commerce sub-sectors, increased by 4.9%.

3. Background on Energy-Economy Model

3.1 Existing energy modeling

Recently many integrated approaches of energy models, involving interaction among energy, economy, and environmental, has been developed to analysis the future of energy policy and technology options. Some of the models were described in this section and some of that emphasize on planning of future for mitigating global warming.

3.1.1 MARKAL

MARKAL(MARKet ALlocation) was developed in a co-operative effort between Brookhaven National Laboratory (BNL), USA and Nuclear Research Center (KFA), Germany. About 15 countries belonging to the International Energy Agency (IEA) contributed to the joint effort within the framework of the Energy Technology Systems Analysis Project.

Fig. 3-1 shows the energy flows modeled by MARKAL and the basic categories of technologies are :

- resource technologies such as mining, import and export;
- processes which transform energy carrier into one another;
- conversion technologies which produce electricity or district heat or both; and
- end-use technologies which change some forms of energy into useful services such as motive power, space heat and transportation.

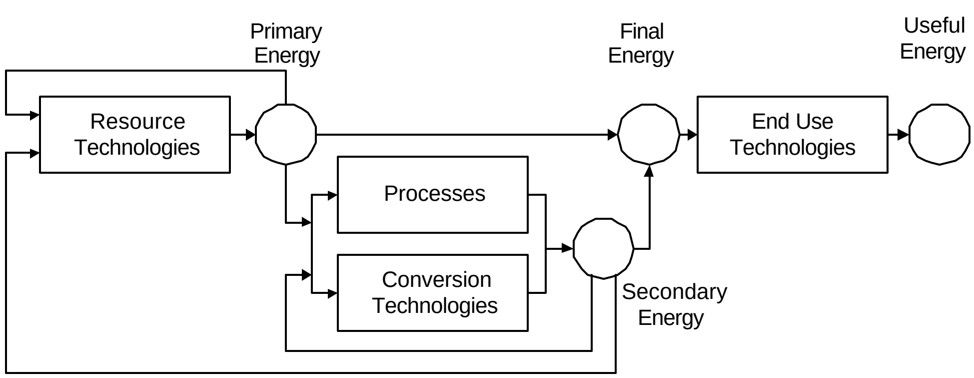

Fig. 3-1. Basic energy flows and technology categories[14)]

MARKAL focuses on the energy sector and linkages to the rest of a nation's economy through the exogenous specification of useful energy demands. Its describes the energy system by means of a data base and provides software tools which select the variables, constraints, right-hand sides and calculate the numeric values needed. MARKAL is multi-period and linear programming model. Its takes exogenously supplied useful energy projections and determines the optimal energy supply and end-use network that can meet the demand. An optimal solution is obtained from a collective optimization over the whole set of time periods. The mathematical formulation is shown in equation 3-1, 3-2 and 3-3.

$$\text{minimize} \quad \sum_i c_i x_i \quad i = 1,\ldots,n \tag{3-1}$$

$$\text{subject to} \quad \sum_i a_{ji} x_i \le b_j \quad j = 1,\ldots,m \tag{3-2}$$

$$\text{and} \quad x_i \ge 0 \tag{3-3}$$

The coefficients for the objective function (c_i), the coefficients (a_{ji}) and the value of right-hand side (b_j) are known parameters. The variables (x_i) are the unknown quantities to be found. The number of variables is n and the number of constraints is m.

3.1.2 Edmonds-Reilly

Edmonds-Reilly model published in 1983 is a global framework for energy assessment that involves nine global regions. The model can be thought of as consisting of four parts: supply, demand, energy balance and CO_2 emissions. The first two modules determine the supply and demand for six major primary energy categories (oil, gas, solids, resource constrained renewable, nuclear, and solar) in each of regions. The energy balance module assures global equilibrium in each global fuel market and the computations needed to develop projected CO_2 emissions. The current terminal analysis date of the model framework is 2050 with the base year 1975.

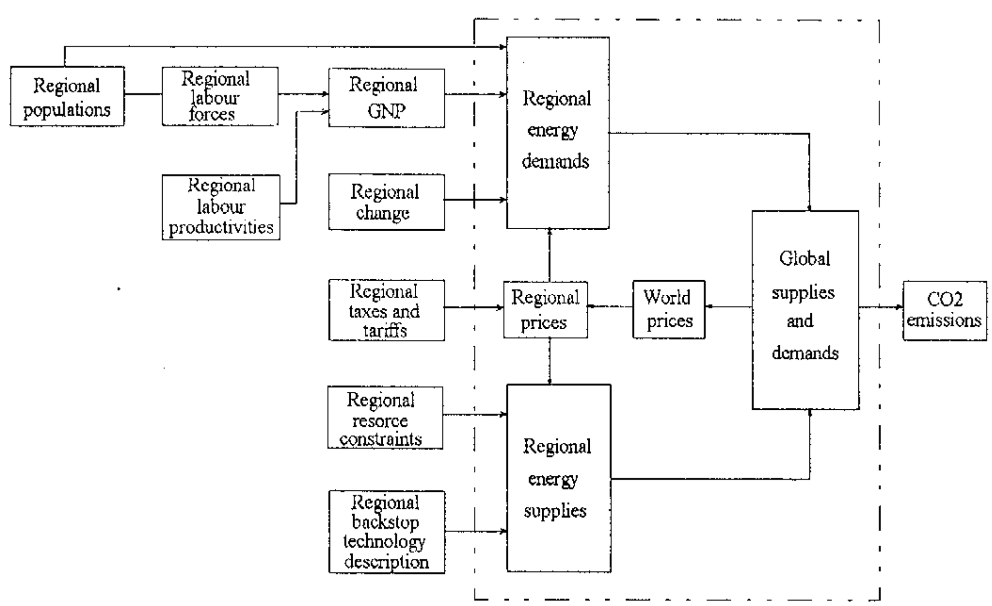

Fig. 3-2. Framework of Edmonds-Reilly model[12)]

In this model, supply is determined by a simple extrapolation model. Production of the constrained resource is handled conventionally via a logistics function. The key inputs to determination of the demand are the level of population, level of economic activity (GNP) and prices of primary energy types. World energy price and demand are determined to meet the world energy supply functions.

Since the program source code of this model is opened for any researcher, it has been modified. Until now it has often provided base case scenarios in many discussions. The base case scenario result of global final energy use by fuel is shown in Fig. 3-3. Among the four primary fuel categories, electricity production expands most rapidly over the period, averaging nearly 6% per year. Primary solids use grows moderately (3.1% per year), while the use of oil and gas grows more slowly. This is due partly to rising prices of oil and gas

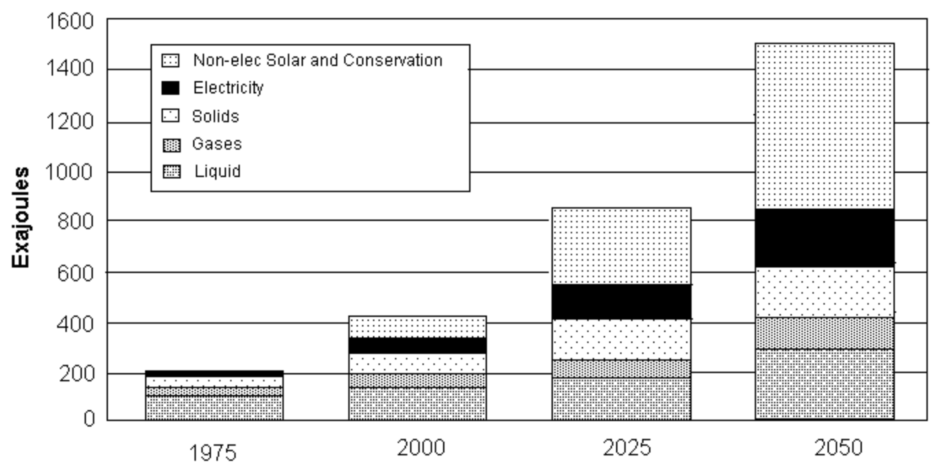

Fig. 3-3. Projected final energy use[13)]

3.1.3 New Earth 21

New Earth 21 model was developed by Yasumasa Fujii to evaluate economic and technological feasibility of energy technology combinations with several physical constraints such as supply-demand balances. The whole world is divided into 10 regions with time horizon from 1990 to 2050 at intervals of 10 years. The principal characteristics of the models is as follows:

- Final energy demands will be given exogenously.
- Supply-cost functions of various energy supplies will be given with probabilities of occurrence.
- The model determines the optimum energy-demand pattern, given final demands and
- supply cost functions of energy supplies.

The model consists of 10 regional sub-models which optimize the energy flows within the respective regions, and one main-model which manages the interregional energy balances among the sub-models (see Fig. 3-4). The sub-models are linked each other by interregional trade items : natural gas, coal, oil, hydrogen, methanol, ethanol, electricity and recovered CO_2.

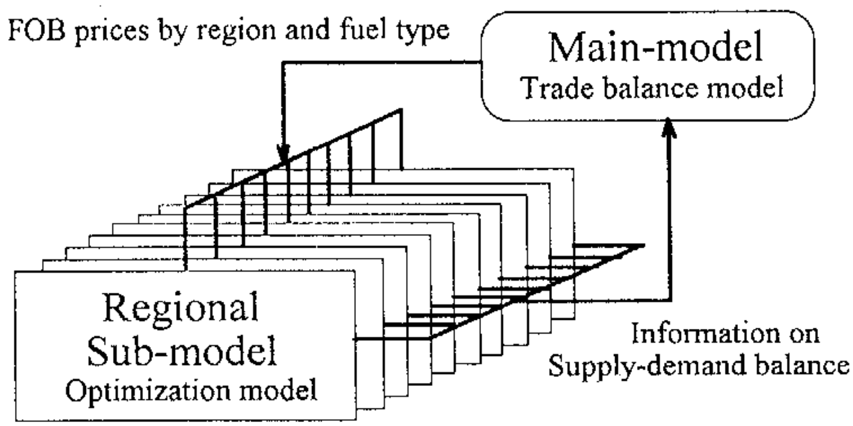

Fig. 3-4. The structure of New Earth 21 model[23)]

The sub-model is formulated as non-linear optimization problem with inequality and/or equality linear constrains. The constraints represent supply-demand balances and mass-energy balances in various type of energy plants.

- Objective function:

  Cost for n-th region = Energy system cost in n-th region
  + carbon tax × regional carbon emissions (3-4)

- Subject to:

$$A^n u^n = b^n, \qquad u^n \geq 0 \tag{3-5}$$

- Where:

  u^n: the control variables that represented energy supply
  A^n: system matrix of n-th region
  b^n: constant (energy demands and existing capacities).

The main model which seeks an equilibrium of the world energy trades is formulated on the basis of the maximum principle of discrete type.

3.1.4 Global 2100

A.S Manne and R.G. Richels developed Global 2100 in 1990. The model is an extended version of ETA-MACRO model developed in 1970's that linkages between the energy sector and the balance of the economy. This is a merger between ETA (a process model for energy technology assessment) and MACRO (a macroeconomic production function) that provides for substitution between capital, labor, and energy inputs. ETA-

MACRO is a tool for integrating long-term supply and demand projection. Figure 3-5 provides an overview of the principle static linkages of ETA-MACRO. Electric and non-electric energy are supplied by the energy sector to the rest of the economy. Gross output depends on the inputs of energy, labor and capital. In, turn, output is allocated among current consumption, investment in building up the stock of capital, and current payments for energy cost.

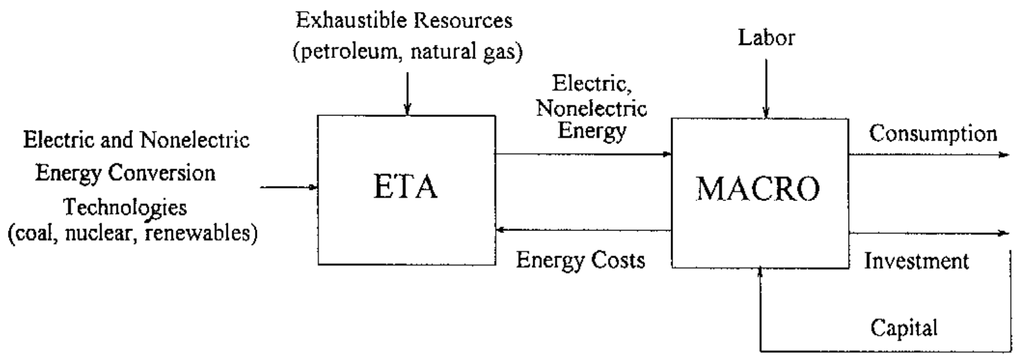

Fig. 3-5. An overview of ETA-MACRO[4)]

ETA-MACRO simulates a market or a planned economy over time. There is a single representative producer-consumer. Supplies, demands, and prices are matched through a dynamic non-linear programming model. A partial equilibrium reasoning applied to a single energy form in a single time period. Consumers' willingness to pay is shown as a smoothly decreasing function of the amount of energy available of them, and producers' incremental cost are shown as a rising step functions of the amount to be supplied (Fig. 3-6). These functions represent energy demands through a stepwise linear physical process model. Supplies and demands matched through an equilibrium price. It is as though the economy were attempting to maximize the size of the shaded area (net economic benefits).

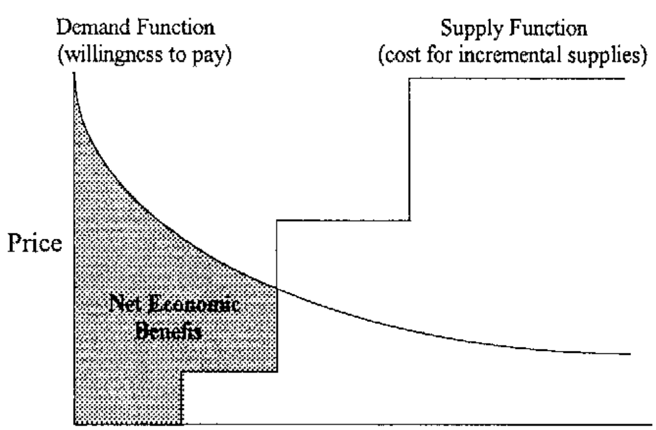

Fig. 3-6. Market mechanisms and maximization[4)]

The first version of Global 2100 deals with five major geopolitical regions : the United States, other OECD nations, the Soviet Union, China, and the rest of the world (ROW). The model is intertemporal with a base year of 1990 and projections cover ten-year time intervals from 2000 through 2100. The national economic activities aggregate into one production function involves various energy technologies.

Table 3-1 identifies the alternative sources of electricity supply. The first five technologies represent existing sources: hydroelectric and other renewables, gas-fired, oil-fired and coal-fired units, and nuclear power plants. The second group of technologies includes the new electricity generation options that are likely to become available. They differ in terms of their projected costs, carbon emission rates, and dates of introduction.

Table 3-1. Electricity generation technologies[4)]

Technology name	Earliest possible introduction date	Identification
Existing:		
HYDRO		Hydroelectric, geothermal, and other renewables
GAS-R		Remaining initial gas fired
OIL-R		Remaining initial oil fired
COAL-R		Remaining initial coal fired
NUC-R		Remaining initial nuclear
New:		
GAS-N	1995	Advanced combined cycle, gas fired
COAL-N	1990	New coal fired
ADV-HC	2010	High-cost carbon free
ADV-LC	2020	Low-cost carbon free

It is expected that new gas-fired capacity for base load electricity will take the form of combustion turbine combined cycle plants that have a high thermal efficiency, low carbon emissions, and low capital cost. If natural gas prices remain at their 1990 levels, this technology would represent an attractive source of electricity; however, as natural gas resources gradually become exhausted, fuel prices are likely to rise. With an increase of this magnitude, gas-fired electricity would lose its competitive advantage over coal.

Table 3-2 identifies the nine alternative sources of nonelectric energy. Crude oil price is crucial to any near or medium-term projections of energy supplies and demands. All other carbon-based fuels are ranked in ascending order of their cost per GJ of crude oil equivalent. The least expensive domestic source is CLDU that uses in industries such as steel and cement. Next in the merit order are domestic oil and gas.

Table 3-2. Nonelectric energy supplies[4)]

Technology name	Description	Unit cost per GJ of crude oil equivalent (1990 Dollars)
OIL-MX	Oil imports minus exports	4.00 in 1990 rising to 8.40 from 2040 onward
CLDU	Coal - direct uses	2.00
OIL-LC	Oil - low cost	2.50
GAS-LC	Natural gas - low cost	2.75
OIL-HC	Oil - high cost	6.00
GAS-HC	Natural gas - high cost	6.25
RNEW	Renewables	8.20
SYNF	Synthetic fuels	8.33
NE-BAK	Nonelectric backstop	16.67

The rate of GDP is a key determinant of energy demands. This rate depends on both population and per capita productivity trends. In parallel with the slowing of population growth during the twenty-first century, there will be a diminishing rate of growth of GDP and, hence, a slowdown in the demand for energy. Energy consumption need not grow at the same rate as the GDP. Over the long run, they may be decoupled. In Global 2100, these possibilities are summarized through two macroeconomic parameters: *ESUB* (the elasticity of price-induced substitution) and *AEEI* (autonomous energy efficiency improvements).

The energy supply projection under business-as-usual conditions is described in Fig. 3-7 (for electric energy) and Fig. 3-8 (for nonelectric energy). With increasing gas price, gas-fired electricity would lose its competitive advantage over coal. The other low cost alternative to coal is the carbon-free technologies, ADV-LC. If it were introduced in 2020, it would take on an increasing share of electric load thereafter.

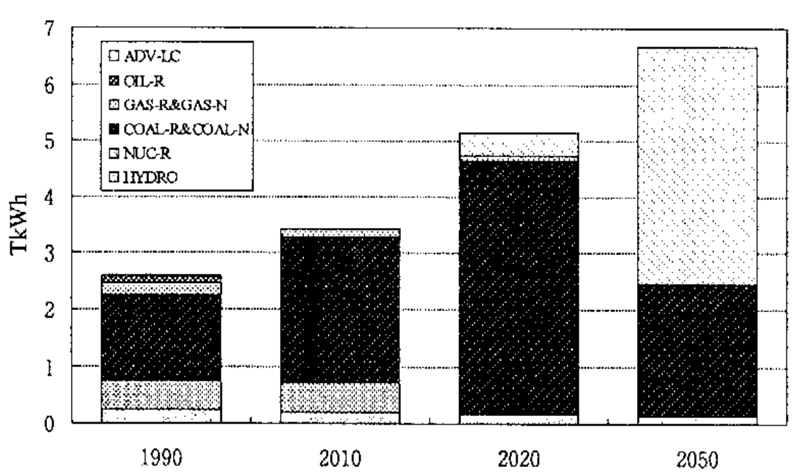

Fig. 3-7. Electric energy[4)]

On the nonelectric side, new energy sources become attractive due to increasing crude oil prices. These sources are grouped into two broad categories : SYNF (coal and shale based synthetic fuels) and RNEW (low-cost carbon-free renewables such as ethanol from biomass)

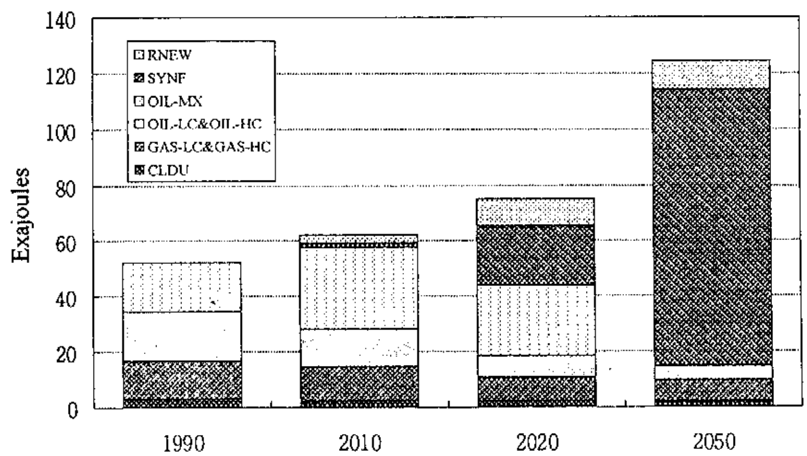

Fig. 3-8. Nonelectric energy[4)]

3.1.5 MARIA

Multi-regional Approach for Resource and Industry Allocation (MARIA) model, developed by Shunsuke Mori in 1994, is a version of DICE model. W. Nordhaus developed the DICE model to see the long term interactions between human activities and global warming damages on the world economic growth. Due to the lack of energy flow in DICE model, MARIA model impose energy flows upon the DICE model. This model can estimate the energy technology options for the long future as well as the international trade prices of fossil fuels and the tradable carbon emission permit under the certain constraints. The model disaggregated primary energy resources into : coal, oil, natural gas, nuclear, biomass, and other renewable sources which involves hydropower, geothermal and solar energy. Secondary energy sector consists of electric and nonelectric energy. Final consumption sectors are classified into three sectors : industry, transportation and others. The world is divided into three region : Japan, other OECD countries and others.

Figure 3-9 described the structure of MARIA model. The model is a non-linear programming model like Global 2100 model. When a CES type production function is used in Global 2100 model, this model employs a Cobb-Douglas type production function with capital, labor, electric and nonelectric energy. The model used Negishi-weight in the objective function to guarantee the compatibility between local (national) optimization behavior and international trade price mechanism. Mathematically, Negishi-weight is given by the inverse of Lagrange multiplier of budget constraint which is proportional to the consumption per capita of each region.

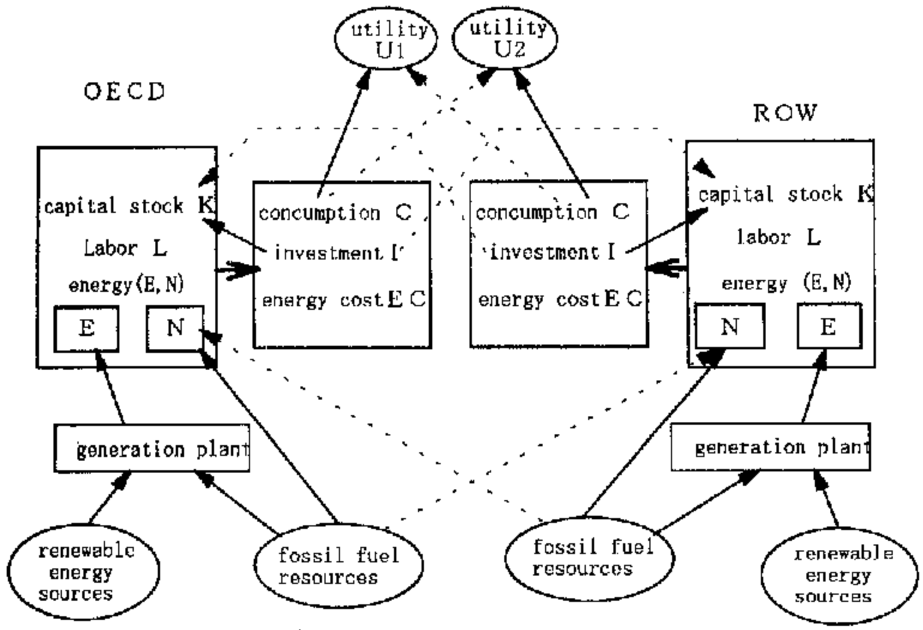

Figure. 3-9. Structure of MARIA model[19)]

3.2 Energy technology and resources[24)]

The primary energy resources are basically divided into nonrenewable and renewable energy resources. The first group of depletable character includes the fossil energy resource: coal, crude oil and natural gas. The group of renewable resources is base on geothermal energy, solar energy, hydro power, wind power and biomass. This section only discuss the main characteristic of crude oil, natural gas, coal, geothermal, hydropower and biomass energy that were used in this model.

3.2.1 Crude oil

With the rare exception of being burned directly, the major part of crude oil is processed into petroleum derivatives. The efficiency of modern petroleum refineries is, in general, around 90% with peak performances. Petroleum refineries consist of crude tankage, a system of separation and conversion process, individual product tanks, interconnecting lines among the process and tankage, and a system of utilities that provide and distribute the required supply of steam, power, and cooling. Overlying this equipment are process control systems that assure proper flows, temperatures, and pressures; safety systems that assure the equipment equipment design pressure cannot be exceeded and that discharges are flared in a controlled manner; and environmental system that assure clean refinery effluents.

Crude oil is the feed to refineries. Crudes come in many types, ranging from light crude, which contains higher fractions of gasoline and jet fuel, to heavy crudes containing more heavy oil and asphalt. Sour crudes contain more nitrogen and sulfur compounds than sweet crudes.

The objective of a refinery is to manufacture products ranging from the lightest propane, through gasoline, jet fuels, heating oils, and lumbricating oils to heaviest products, asphalt and coke. The variability in crudes, product characteristic, and demands requires that the equipment be flexible enough to operate over a wide range conditions.

Petroleum products are by far the most versatile and useful energy resources available at present. It is characterized by low costs and ease of transportation. Almost all the needs of the transportation sector and mobile equipment are currently met by petroleum product. Kerosene and LPG are the favored cooking fuels and the former is the major lighting fuel in area where is no electricity.

3.2.2 Natural gas

Natural gas is a kind of hydrocarbon usually predominantly by methane. They may occur alone (non-associated gas) or in conjunction with crude oil (associated gas). Production of associated gas dissolved in oil depends on oil production, and is therefore interrupted whenever the latter is shut down for economic or other reasons. Non-associated gas production depend on the structure and characteristics of the reservoir.

Natural gas may contain substantial proportions of non-hydrocarbon gases as impurities. Most of these contain small proportions of heavier hydrocarbons, beside methane, which can readily be reduced to liquid form at the surface by refrigeration or compression. These so-called wet gases can be processed to produce natural gas liquids (NGL), otherwise know as natural gasoline and liquefied petroleum gases (LPG) consisting of propane and butane.

Historically, crude oil had fundamental advantages over gas as fuel. It could be transported easily and could be processed into petroleum derivatives which could serve different markets. The physical characteristics of natural gas, particularly, difficult to be transported that make limited its share in the growth of international trade until techniques for ocean transport of liquefied natural gas (LNG) were developed in the 1960s. Hence make natural gas competitive with oil products.

The utilization of gas may also extended to non-traditional uses, such as transport fuels. Compressed natural gas is already being used as a fuel for vehicle in some countries. Methanol, a chemical derivative of natural gas, is eminently suitable for spark plug engines either as a straight fuel or as an mixture to gasoline. Natural gas can also be converted into gasoline although the cost of conversion is high. Another utilization of natural gas is in fertilizer industry. It is excellent feedstock for nitrogenous fertilizer and a wide range of basic chemicals. A significant percentage of gas consumption, is represented by these non-energy uses. However, chemical and fertilizer plants themselves are large consumers of energy. Up to 40% of the gas consumed by these installations may be use as an energy input, rather than as feedstock.

If the deposits of natural gas are large and in remote locations, gas production are used exclusively for export in the form of LNG. In this form, however, these resources do not make any contribution to the energy balances of the producer country.

3.2.3 Coal

The technology for mining, moving and using of coal is well established and steadily improving. Technological advances in combustion, gasification, and liquefaction will greatly widen the scope for the environmentally acceptable use of coal in 1990s and beyond. The utilization of coal is mainly in industry sector and for the generation of electricity.

The most common classification of coal is calorific content. Hard coal is distinguished from brown coal and peat, which have less heating values. Within the class of hard coal one can distinguish between steam coal for electric power generation and coking coals, used primary as reductants in steel making. Other important parameters for the classification of coals are contents of water, volatile matter and ash. This parameters have a large range of variation according to their geological deposit.

Table 3-3. Approximate calorific values of various grades of coal

Grade of coal	MJ/kg
Hard coal :	
Steam coal :	
- Anthracite	33.3
- Bituminous	29.1
- Sub-bituminous	24.7
Coking coal	27.8
Brown coal and lignite	14.7
Peat	8.0

3.2.4 Geothermal

Temperatures in excess of 1000°C exist deep in the earth. The resulting thermal gradient creates a heat flow to the surface which is the source of geothermal energy. Geothermal energy is continuously generated by the flow of heat from the earth's core. It is, therefore, a renewable form of energy.

Geothermal energy can be classified into high level energy and low level energy. The temperature of geothermal system is normally in the range of 175-315°C, which is considered low-quality heat by fossil fuel standards. For this reason, the most efficient utilization of geothermal energy would be for the purpose of process heat in industrial applications. But the distance over which the energy can be transported economically is very limited. By far the largest industrial application of geothermal energy today is the generation of electric power. A pound of steam coming from a man-made boiler fired by conventional fuel is indistinguishable from a pound of steam coming from the earth's boiler, and the steam turbine does not know the difference. Accepting, then, that electric power can be generated and transported over a transmission system. The electricity generating cost of geothermal energy compare with the other technologies is shown in Fig. 3-10.

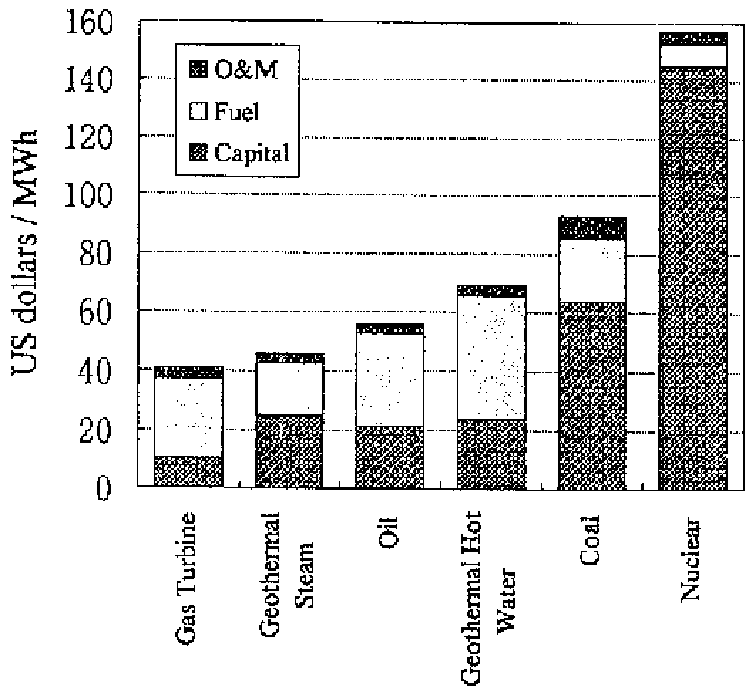

Fig. 3-10. Electricity generation cost[9)]

Exploration for geothermal energy requires a relatively heavy investment in drilling. If the deep drilling does not result in a commercial discovery, the investment will have to be written off as a loss. This is a risk which not all decision makers can take, unless they have a specific guarantees or insurance, even though the success ratio of geothermal exploration is higher than that of oil exploration.

3.2.5 Hydropower

Hydropower technology utilizes the difference of potential energy between different parts of a water body at a rate which is roughly proportional to the product of water level difference, commonly refered to as head, and the discharge. Hence, hydropower design and development is directed towards increasing these two quantities both by proper site selection and construction measures.

With regard to the development of head and control of discharge, different plant types can be distinguished:

- River power plant, where the head is created by weirs or low dams,

- Diversion power plant, which basically utilize naturally available heads,
- Run-of-river power plant, which little or no control of discharge, and
- Storage power plant, which high dam and large reservoir for flow regulation.

The theoretical annual hydropower potential of a river depends on the precipitation it received annually in its catchment area and the quantity of water remaining on the earth surface and running down from its altitude to sea level. Since certain portions of the river cannot technically be harnessed, the technical or usable potential, usually, is lower about 50% than the theoretical potential.

3.2.6 Biomass

Biomass is a product of photosynthesis due to the capability of the chlorophyll of plants to absorb the light energy from the sun and to use CO_2 of the air for producing sugar and carbohydrates under release of O_2 The most important biomass source are: agricultural crop residues, forest residue, animal manures, standing vegetation, aquatic biomass and solid wasted. Fuel wood, by far the most important biomass from is an important energy especially those living in the rural and urban areas of developing countries. The fuel wood, as a traditional energy is used in residential sector, such as cooking and heating.

There are many technique for advanced utilizing of biomass that convert biomass to useful energy. Generally the process is classified into three category:

- Mechanical and thermomechanical process:
  - o Feedstock preparation
  - o Extraction
- Thermochemical process:
  - o Direct combustion
  - o Pyrolysis
  - o Gasification
  - o Liquefaction
- Biological process:
  - o Biomethanation
  - o Fermentation.

3.3 Production function[17)]

Table 3-4. Historical data[7,10,11]

Year	Energy Consumption (1000 TOE)	Income (million US dollar)	Population (million)
1971	6736	30.75	122.53
1972	7440	32.72	125.64
1973	8068	35.58	128.80
1974	9322	38.02	132.00
1975	10697	39.95	132.67
1976	11354	42.97	133.53
1977	13266	46.63	136.63
1978	15579	50.13	139.80
1979	17689	52.92	143.04
1980	19996	57.47	147.49
1981	21993	62.25	151.31
1982	22427	62.86	154.66
1983	22666	68.42	158.08
1984	23099	72.69	161.58
1985	24389	74.69	164.63
1986	25084	79.29	168.35
1987	25922	82.91	172.01
1988	28281	88.72	175.59
1989	30337	95.30	179.14
1990	33013	100.40	179.30

$$\ln\left(\frac{P}{L}\right)_t = \alpha \times \ln\left(\frac{Y}{L}\right)_t + \beta \times \ln\left(\frac{P}{L}\right)_{t-1} + A \qquad (3\text{-}14)$$

The calculation result show in Equation 3-15 and Table 3-5.

$$\ln\left(\frac{P}{L}\right)_t = 0.169417 \times \ln\left(\frac{Y}{L}\right)_t + 0.829419 \times \ln\left(\frac{P}{L}\right)_{t-1} + 1.025627 \qquad (3\text{-}15)$$

Table 3-5. The result of regression analysis

回帰分析の結果：		
Y 切片		1.025627
Y 評価値の標準誤差		0.042305
R 2 乗		0.987026
標本数		19
自由度		16
X 係数	0.169417	0.829419
X 係数の標準誤差	0.169603	0.104051

Using the parameter a, b and A from regression analysis result, the regional data of income and population in 1990 and using Equation (3-16), the energy-demand regional in 1990 can be calculated as below (i: Java, Sumatra, Kalimantan, and other island).

$$\ln\left(\frac{P}{L}\right)^{i}_{1990} = \frac{\alpha}{1-\beta}\ln\left(\frac{Y}{L}\right)^{i}_{1990} + \frac{A}{1-\beta} \tag{3-16}$$

Table 3-6. Data and calculation results

Region (i)	Y (million \$)	L (million)	P (1000 TOE)
Java	60.307	110.359	24738.547
Sumatera	26.719	36.507	10938.564
Kalimantan	5.935	9.100	2431.590
Others	7.448	23.413	3066.685
Total	100.409	179.379	41175.386

From the aggregate data, the total energy demand in 1990 is 33.013 MTOE and from the regression result the total energy demand in 1990 is 41.175 MTOE that will be acceptable. As shown in Table 3-6 the energy demand in Java is 24.738 MTOE, Sumatera is 10.938 MTOE, Kalimantan is 2.432 MTOE and other island is 3.067 MTOE.

The share of electricity and non-electricity energy in each regions were calculated using the same technique.

4. Model Overview

Some of the existing energy-economy models were described in Chapter 3. These techniques are commonly classified into three categories :

- Linear programming model
- Simulation of the economy under the assumption of various alternative policies
- Computable general equilibrium, such that consumers maximize their utility function.

The last technique is used in this model.

4.1 Energy-Economy flow

The many islands of Indonesia show a significantly non-uniform distribution of energy resource and of energy consumption and a different status of development. Taking this into account, the whole country is divided into four regions: Java, Sumatera, Kalimantan and other islands (see Fig. 4-1) with transportation of fossil energy: coal, crude oil and natural gas (see Fig. 4-2)

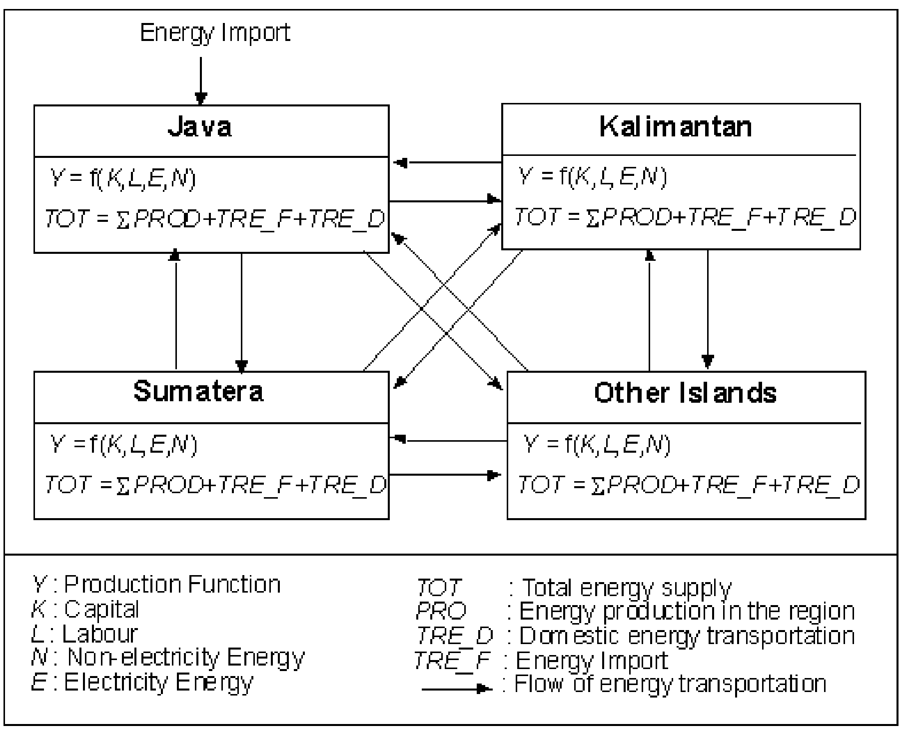

Fig. 4-1. Block diagram of the regionalized model

The real energy flow is represented by a complex network of all relevant energy technologies interconnected by energy carrier from supply side to demand side. In this study an aggregate of energy flow has been used to avoid the complexity of the model. Each of the region has an energy flow as shown in Fig. 4-2. These individual regions are linked in the model by inter-regional flows such as coal, crude oil and natural gas shipping but is assumed no migration of labor or population.

The model contains five types of primary energy sources: coal, natural gas, crude oil, biomass and other renewable energy which involves hydropower and geothermal energy. The primary energy sources are transformed into secondary energy sector which consists of electricity and non-electricity. Demand sector is disaggregate into three sectors : industry, transportation and other sectors.

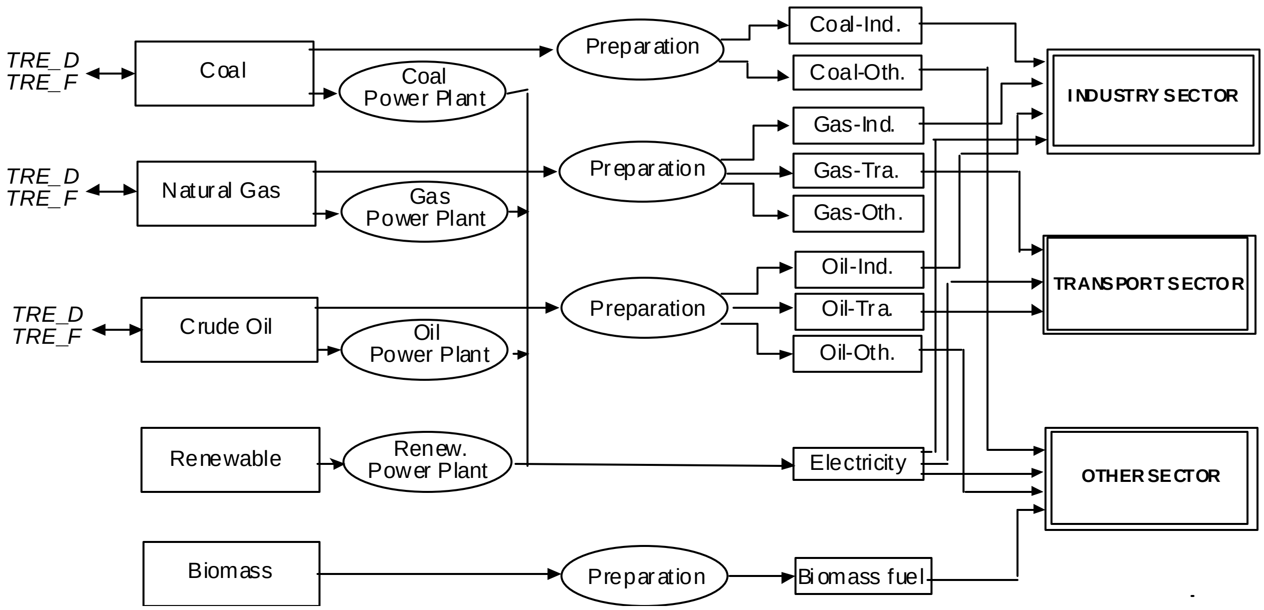

Fig. 4-2. Structure of regional energy flow model

4.2 Mathematical formulation

The model is formulated as an intertemporal optimization model with two-way linkages between the energy sectors and the balance of the economy. The basic formulation to calculate the energy demand is the Cobb-Douglas type production function. Y is the production function in each region r with time period t.

$$Y_{t,r} = A_{t,r} \left[K_{t,r}^{KPVS} L_{t,r}^{(1-KPVS)} \right]^{(1-ESUB)} \left[E_{t,r}^{ELVS} N_{t,r}^{(1-ELVS)} \right]^{ESUB} \qquad (4\text{-}1)$$

Where E and N denote the production of electricity and non-electricity energy for the industry sector. Unit measurement for the energy production is MTOE. L is a population assumed as an exogenous variable. K denote capital stock and A is a technical progress factor. The macroeconomics parameters on the above equation are adopted from Global 2100 model[4)] where $ESUB$ is production value share of energy, $KPVS$ and $ELVS$ are capital value share parameter and electricity value share parameter.

Table 4-1. The production function parameters

	Java	Sumatera	Kalimantan	Other
ESUB	0.30	0.12	0.12	0.30
KPVS	0.30	0.30	0.30	0.30
ELVS	0.40	0.40	0.40	0.40

The energy demand in the transportation sector is calculated using equation (4-2). The supplies of nonelectric and electric energy must be adequate to cover the demands.

$$N_{t,r} + \frac{E_{t,r}}{EF_{t,r}} \geq B_{t,r} Y_{t,r}^{a} L_{t,r}^{(1-a)} \tag{4-2}$$

where a is a value share of income in the transportation sector, *EF* is the electricity use efficiency and *B* is a constant. In the other sectors of demand a similar set of energy demand constraint is employed. The other constraints are the energy resources limit as summarized in Table 2-1. For the fossil energy (coal, natural gas and crude oil) these constraints also calculate the energy transportation to each regions as shown is equation (4-3).

$$\sum_{t} \left(E_{t,r} + N_{t,r} - TRE\_D_{t,r} - TRE\_F_{t,r} \right) \leq RES_{r} \tag{4-3}$$

where *TRE_D* and *TRE_F* are domestic transportation of energy and import of energy. RES_r denote the limit of fossil energy resource of region *r*. The total domestic transportation of fossil energy must be balanced and is expressed with:

$$\sum_{r} TRE\_D_{t,r} = 0 \tag{4-4}$$

In this model, fossil energy resources assume as a static resources with no new discoveries were made along the time horizon. For the biomass energy and other renewable energy, the resources are renewable in each time period and the production of these energy type are limited by the resources as shown in equation (4-5) and (4-6).

$$E_{t,r} \leq RESREN_{r} \tag{4-5}$$

$$N_{t,r} \leq RESBIO_{r} \tag{4-6}$$

where *RESREN* and *RESBIO* is a other renewable energy resource and biomass energy resource in each region *r*.

The gross value of production is to be distributed among consumption, investment for build up the capital stock and interindustry payments for energy cost (*EC*),

$$Y_{t,r} = C_{t,r} + I_{t,r} + EC_{t,r} \tag{4-7}$$

where *C* is consumption and *I* is investment.

Table 4-2. Energy production cost[4,18)]

	US Dollar per TOE				
	Crude Oil	Natural Gas	Coal	Renewable	Biomass
Electricity	500	480	550	600	-
Nonelectricity	105	73	84	-	50

The energy cost consists of energy production cost and energy transportation cost. The energy production cost was shown in Table 4-2 and the energy transportation cost was shown in Table 4-3. Distance from one region to each others is assumed 1000 km.

$$EC_{t,r} = (E_{t,r} \times ECST + N_{t,r} \times NCST + TRE\_D_{t,r} \times CTRD + TRE\_F_{t,r} \times CTRF) \times n \tag{4-8}$$

Where *ECST* and *NCST* denote electricity and nonelectricity energy production cost, *CTRD* and *CTRF* denote domestic transportation cost of fossil energy and energy import cost, *n* denote time horizon interval.

Table 4-3. Energy transportation cost[23)]

Transportation Cost	$/TOE/1000 km
LNG	4.79
Natural Gas Pipeline	19.00
Oil	0.67
Coal	0.98
Electricity line	170.11

The total capital stock surviving from one period to the next was expressed with:

$$K_{t+1,r} = (1-d)K_{t,r} + n \times I_{t,r} \tag{4-9}$$

where d is depreciation rate and n denote time horizon intervals. At the end of the planning horizon, a terminal constraint is applied to ensure that the rate of investment is adequate.

To avoid excessively rapid expansion of new technologies, there are expansion rate constraints of the following form. The electricity energy production expansion rate constraint is expressed in equation (4-10) and for the nonelectricity energy in equation (4-11).

$$E_{t+1,r} \geq (1-d)^n E_{t,r} \tag{4-10}$$

$$N_{t+1,r} \geq (1-d)^n N_{t,r} \tag{4-11}$$

The model maximizes a social welfare function that is the discounted sum of the utility of per capita consumption. In the mathematical formulation can be expressed as:

$$\text{Max} \sum_{t,r} \left(S_r \times L_{t,r} \times \log\left[\frac{C_{t,r}}{L_{t,r}}\right] \times [1-d]^t \right) \tag{4-12}$$

where d is the discount rate and C denote consumption. S is share of regional income per capita. In this model depreciation rate and discount rate is set to be 10% and 5% per year.

The energy sector, which includes energy production, transport, conversion and end-use in the sector of industry, transportation and other sectors, is the main contributor to man-made air pollution. The main pollutants are CO_2, CO, particulate matter, NO_X, SO_2, volatile hydrocarbons and some heavy metals.

Table 4-4. CO_2 release in the production and combustion of fuels[12)]

Fuels	Ton Carbon/TOE
Coal	0.996
Crude Oil	0.804
Natural Gas	0.574
Renewable	0

In this study only CO_2 emission will be analyse. CO_2 emission is associated with the consumption of coal, crude oil, and natural gas. The value for CO_2 emission coefficients for any type of fuels shown in Table 4-4. The CO_2 emissions directly estimated if the quantity of each fuel consumed is known. If ECH and NCH are CO_2 emission coefficients for fuel use in electricity and nonelectricity then the total CO_2 emission is calculated as:

$$CO2_{t,r} = (E_{t,r} \times ECH + N_{t,r} \times NCH) \tag{4-13}$$

4.3 Population and income data

The major factors influencing energy demand are population growth and the economic growth. This section describes the regional growth of population and income.

Table 4-5. Regional population and income

	Population (Million)		Income (Billion US $)	
	1980	1990	1980	1990
Java	91.22	107.57	37.51	56.53
Sumatera	28.00	36.46	20.15	27.21
Kalimantan	6.72	9.11	6.25	9.88
Other Islands	21.90	26.18	5.57	7.15
Total	147.84	179.32	69.48	100.77

Each region has a different growth rate of population. For the last 10 years, Kalimantan has the highest population growth rate which about 3.1% per annum followed by Kalimantan (2.7%), other islands (1.8%) and Java (1.7%).

Indonesia has income per capita in 1990 about 560 US dollar. Kalimantan and Sumatera have higher income per capita than the other regions due to oil production. In decreasing order of the growth rate of income in US dollar base are Kalimantan (4.7%), Java (4.2%), Sumatera (3.0%) and other islands (2.5%).

4.4 Sensitivity analysis[17)]

Sensitivity analysis is conducted to determine how the optimum path would change if the problems were formulated differently. Doing a sensitivity analysis is a key part of the design process, equal in importance to the optimization process itself.

The significance of sensitivity analysis stems from the fact that solution of the mathematical problem in any optimization is only an approximation of the real problem. The exact solution that was obtained and used to represent reality is thus not an exact solution to the real problem of design. At the best, the optimization process provides a good approximation to the best design of a real system.

None of the mathematical models will ever represent system exactly. All these representations are approximations in some way. They each differ from reality in any or all the following three ways:

- Structurally, because the overall nature of the equations does not correspond precisely to the actual situation.
- Parametrically, as that all coefficients not able determined precisely.

- Probabilistically, in typically assume that the situation is deterministic when it is generally variable.

Structural differences arise as a matter of course in the modeling process. The mathematical model of a system is typically constructed to imagine some form that believes is appropriate or useful, and then to match the real situation to this structure.

The discount rate and the transportation cost of fossil energy are the main parameters of sensitivity analysis in the model in this study.

4.5 The GAMS software

The model is an non-linear programming model. A software that called General Algebraic Modeling System (GAMS) is used to solve the problem on 486 compatible personal computer. It is generally more difficult to find the solution of non-linear problem than that of linear one. With non-linear model, it is important to keep the formulation as simple as possible and the model as small as possible. Development of the model should be incremental. Most non-linear problems can be solved more easily if some initial information is provided for the value of important variables. This can be implemented in the GAMS using initial values, bounds and scaling of variables.

The GAMS[1)] can solve both linear and nonlinear programming problems. The GAMS solves linear programming using reliable implementation of the standard simplex method that first developed by G. Danzig in the 1940s. The problem with nonlinear constraints are solved using projected Lagrangean algorithm, base on a method due to S.M. Robinson. When objective function is nonlinear, GAMS solves such problem using a reduced gradient developed by P. Wolfe in 1962 combined with quasi-Newton algorithm developed by W.C. Davidon in 1959.

5. Result

Selected highlights of the model results are presented in this section. This model is run with reference case and sensitivity analysis is performed.

5.1 Aggregate of supply

Energy demand-supply grows in line with economic activities and population expansion, In the model population is assumed as an exogenous variable. A continued decline of the population growth rate is expected because Indonesia family planning policy is attempting to further reduce the growth rate. The total population growth rate until the year 2000 is about 1.8% per annum and 1% per annum for the long term. The population growths during the whole time horizon until 2030 are presented in Fig. 5-1

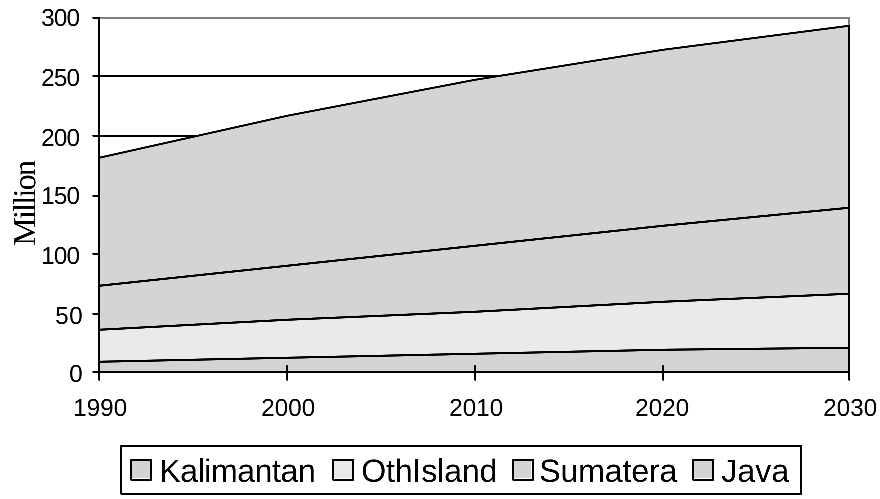

Fig. 5-1. Population growths

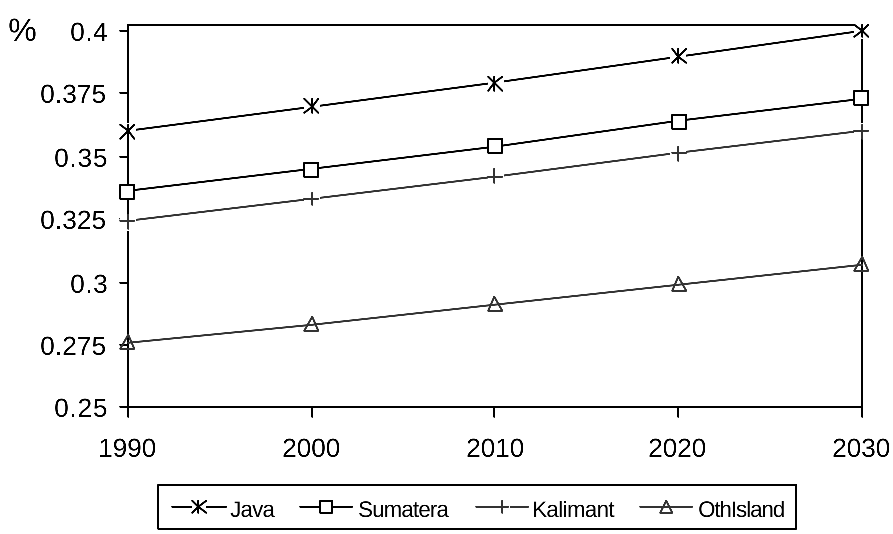

Fig. 5-2. Electricity conversion efficiency

The other major factors influencing energy demand, addition to population growth and economic growth, are the efficiency with which energy is used. This parameter is also assumed as an exogenous variable. Fig. 5-2 shows the electricity conversion efficiency projection. The efficiency in Java is higher than the others due to availability of electricity networks in this region.

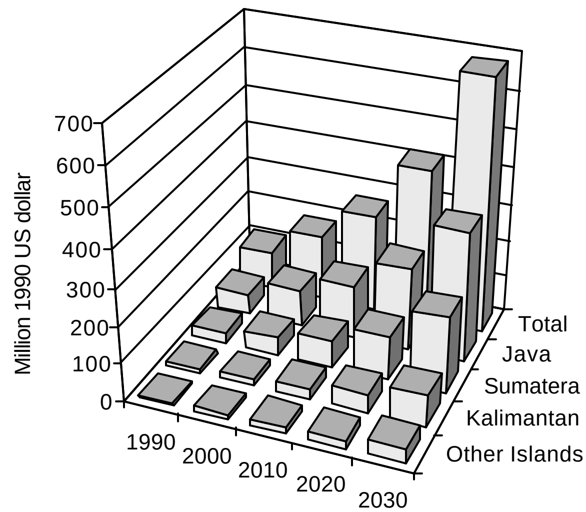

Fig. 5-3. Income growths

With reference case, the income growths are projected and summarized in Fig. 5-3. In 2000 the average annual income growth rate is 5.7 % and 4.6 % until the end of the time horizon. Taking into account the population, in 2000 the income per capita growth rate is 3.9 % per annum. Because the population is still increasing, the income per capita grows at lower rate of 3.5 % per annum for a long term.

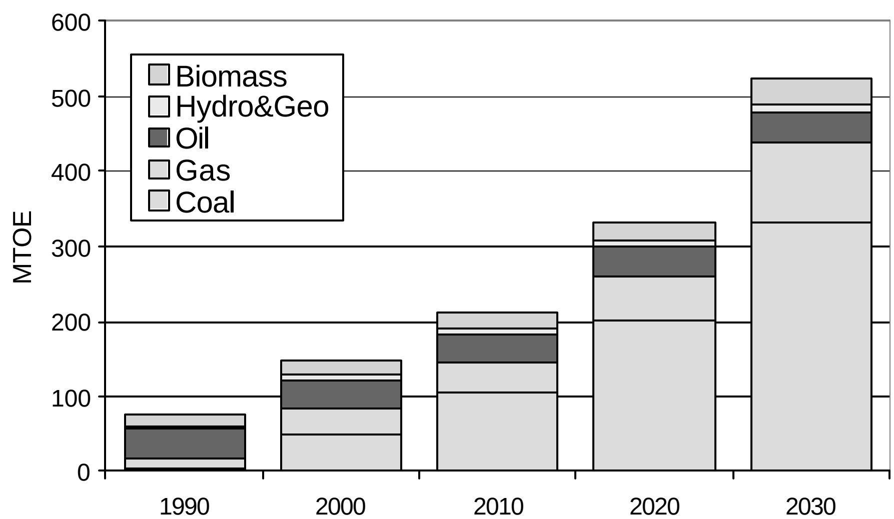

Fig. 5-4. Total primary energy supplies

The future of total primary energy supplies of the reference case was shown in Fig. 5-4. In 2000 the share of coal supply comes to about 34 % of the total primary energy supply that is almost same to the share of crude oil and natural gas supply. In 2010 and 2020 the share of primary energy supply in decreasing order is coal, natural gas, crude oil, biomass and renewable energy. The renewable energy is not growing significantly because the production cost is expensive than the other technologies.

5.2 Regional perspective

On the regional perspective, coal is attractive for the energy supply in Java and Sumatera due to the high growth of energy demand in these regions. In Kalimantan natural gas has a significant share for energy supply in a long term. In the other islands, area is extensive and the energy demands are fewer but much more spread out. Renewable energy such as hydropower and geothermal energy are attractive in these regions. All of the regional energy supply were shown in Fig. 5-5 for Java, Fig. 5-6 for Sumatera, Fig. 5-7 for Kalimantan and Fig. 5-8 for other islands.

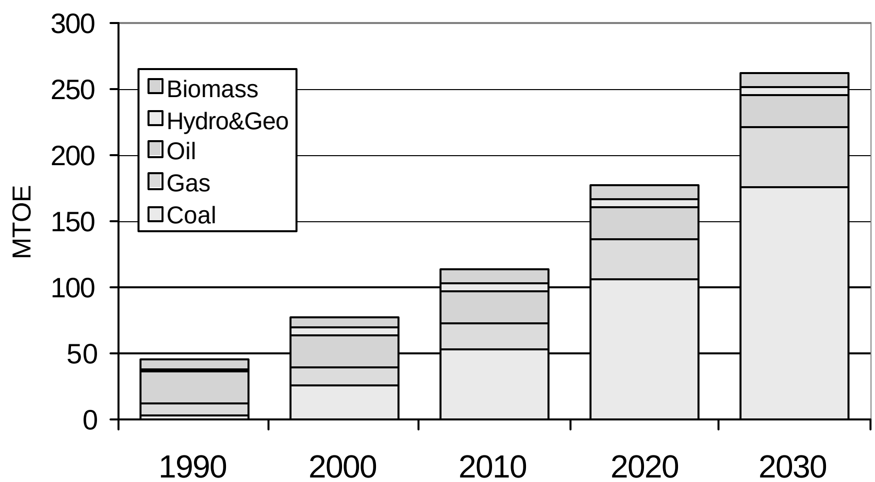

Fig. 5-5. Primary energy supply : Java

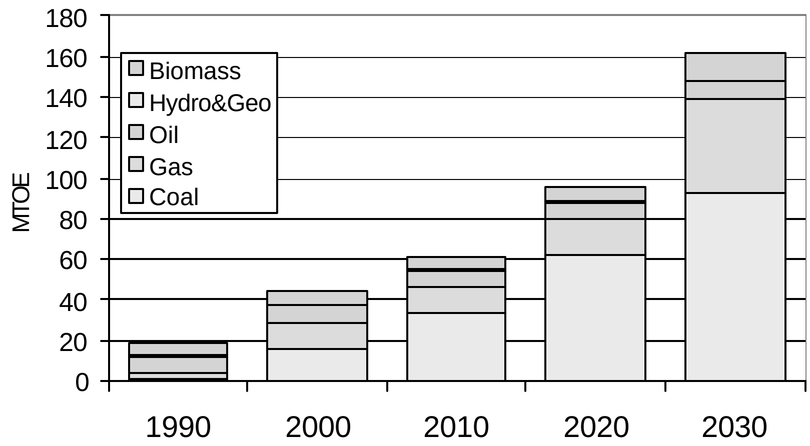

Fig. 5-6. Primary energy supply : Sumatera

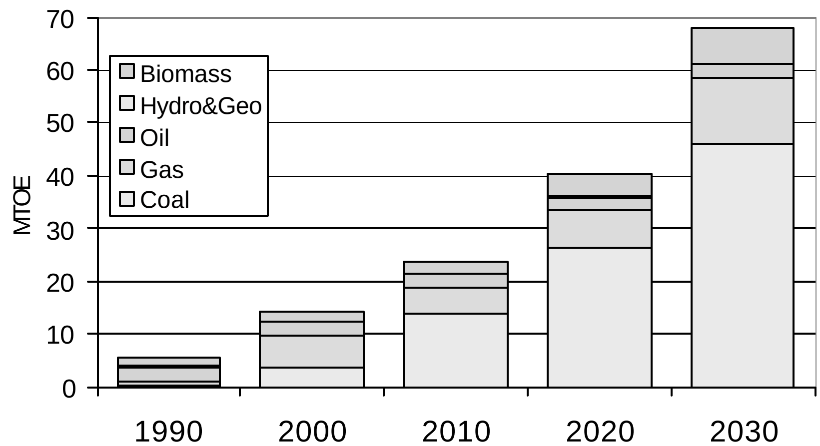

Fig. 5-7. Primary energy supply : Kalimantan

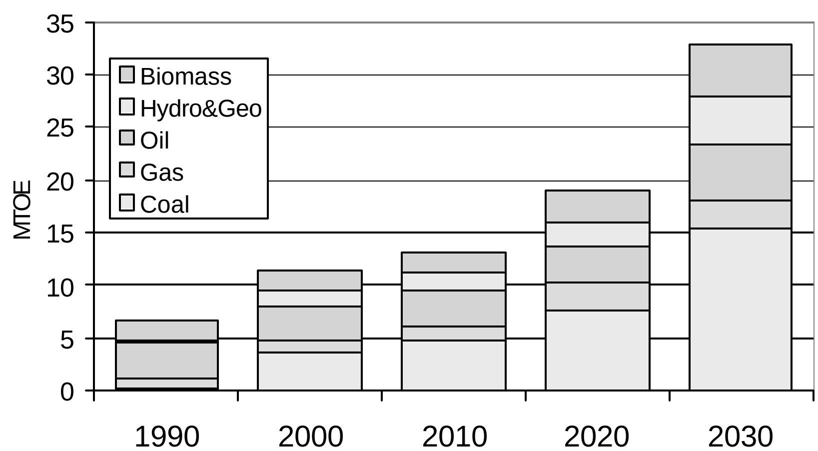

Fig. 5-8. Primary energy supply : Other islands

5.3 Emission

Air pollution resulting from coal combustion is probably the most significant environmental impact associated with the coal fuel cycle and is the topic that generates the greatest amount of international concern. Three main type of emission are involved : sulphur dioxide (SO_2), nitrogen oxide (NO_X) and paniculate matter.

Increasing used of coal and other fossil energy for the long future in Indonesia seem to create high emission of air pollutions. Therefore, it need to reduce emission in end-use sector (industry, transportation, household) and in power plant using new technology with low emission rate. For example : in industry sector use the dust control system in the new plants, using electrostatic precipitator and using coal clean technology in power plant. In transportation sector can be use catalytic converters for new car.

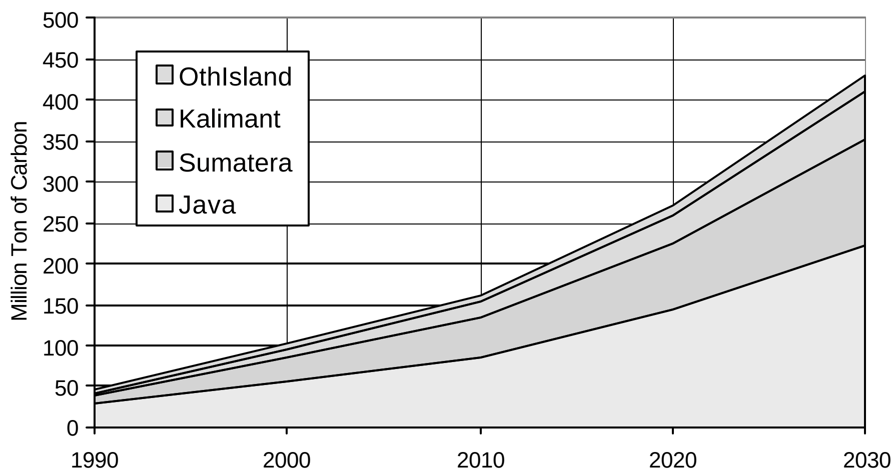

Fig. 5-9. CO_2 emission

The other emission from energy-used is CO_2. Although the CO_2 emission in Indonesia is still low comparing with total CO_2 emission in the world, Indonesia is aware of this issue. As one of the 150 signatory states of the Rio Convention, Indonesia agreed to report on the status and tendency of CO_2 emission in its territory. The CO_2 emission expected by 2030 has been estimated as is shown in Fig. 5-9.

5.4 Sectoral energy demand

The energy demand in industry sector, transportation sector and other sectors are shown in Fig. 5-10. The industry sector has by far the highest energy demand. The growth rate until the year 2030 in industry sector is about 6.7% per annum, in transportation sector is 4.1% per annum and in other sector is 2.0% per annum.

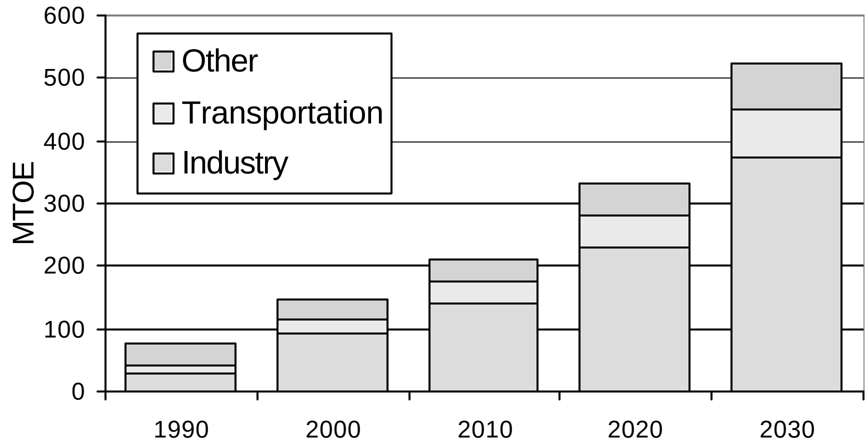

Fig. 5-10. Sectoral energy demand

5.5 Transportation of fossil energy

Domestic transportation and import of fossil energy was shown in Fig. 5-11 to Fig. 5-17. The domestic import means that this region received fossil energy from other regions. The domestic export means that this region transported fossil energy to other regions. The term of fossil energy import from other countries is indicated by foreign import.

Java and other islands received fossil energy from other regions. This energy is supplied from Sumatera and Kalimantan for coal and natural gas; and from Sumatera only for crude oil. Indonesia will begin import crude oil from other countries in the year 2010 due to the limit of domestic crude oil resources.

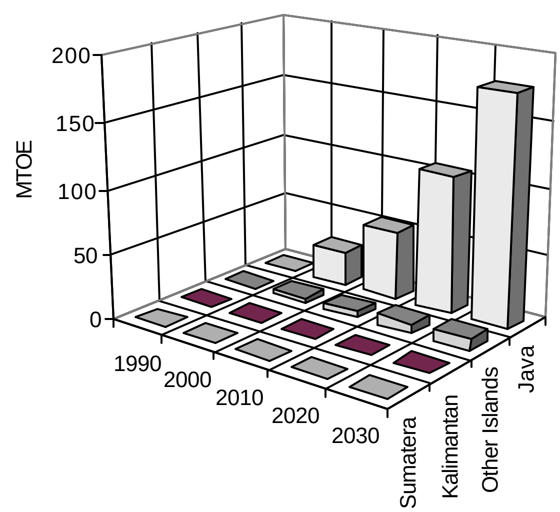

Fig. 5-11. Domestic import of coal

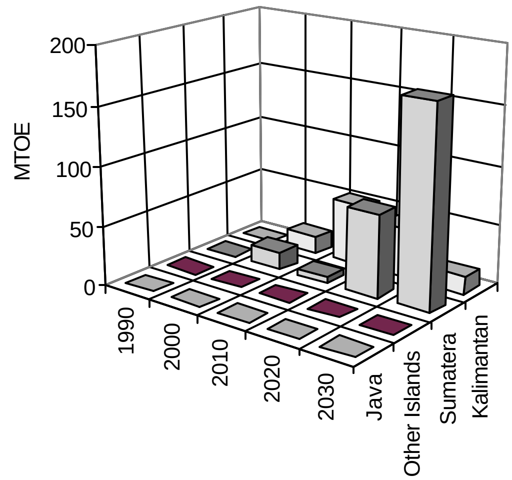

Fig. 5-12. Domestic export of coal

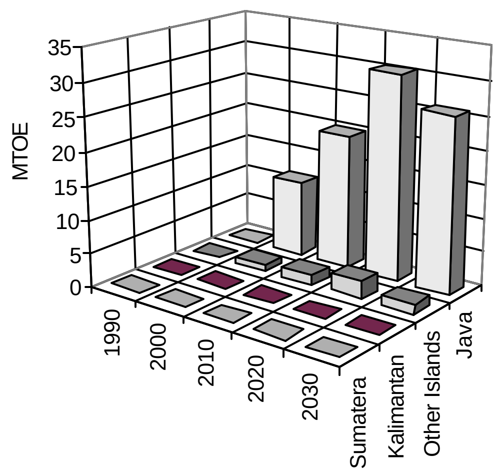

Fig. 5-13. Domestic import of natural gas

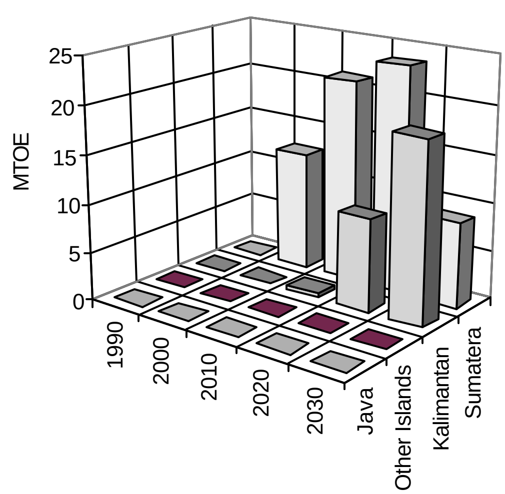

Fig. 5-14. Domestic export of natural gas

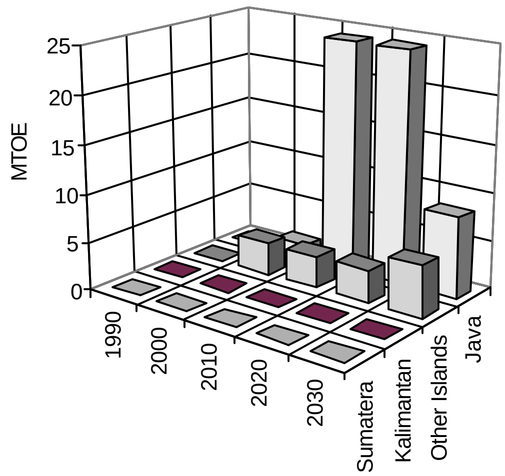

Fig. 5-15. Domestic import of crude oil

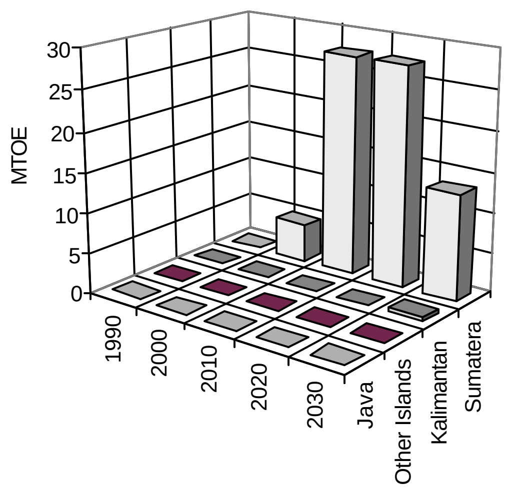

Fig. 5-16. Domestic export of crude oil

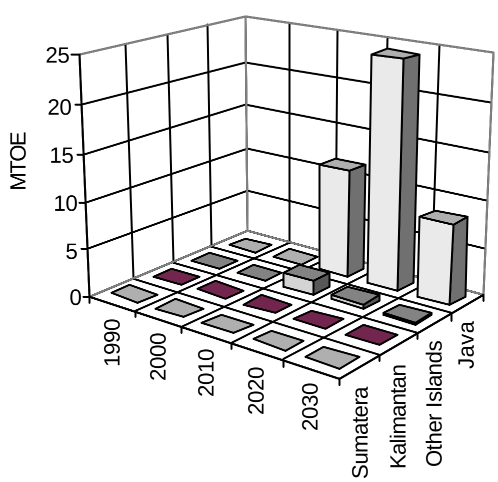

Fig. 5-17. Foreign import of crude oil

5.6 Electric energy

Fig. 5-18 summarized the electric energy growths compare to nonelectric energy growths for the long future. The total energy supply was dominated by nonelectric energy. The growth rate of electric energy is about 5.2% per annum and 4.8% per annum for nonelectric energy.

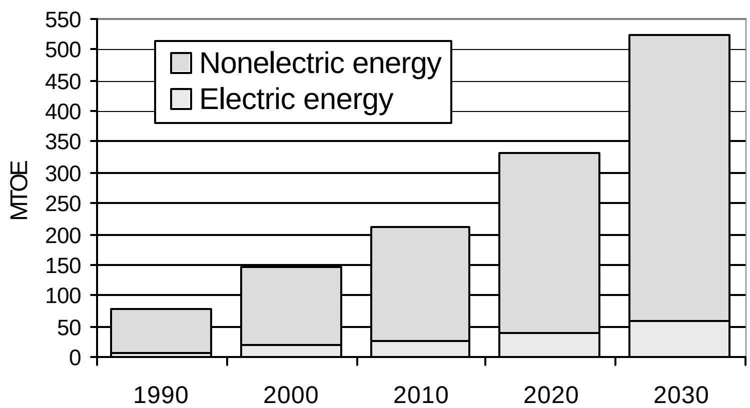

Fig. 5-18. Electric and nonelectric energy

5.7 Sensitivity analysis

Sensitivity analysis is performed by varying the discount rate from 5% to 10% and varying the domestic transportation cost of fossil energy from 50% to 150% of domestic transportation of fossil energy in the reference case. The result is shown in Fig. 5-19, Fig. 5-20 and Fig. 5-21 for varying discount rate and Fig. 5-22, Fig. 5-23 and Fig 5-24 for varying domestic transportation cost of fossil energy.

- **Discount rate**

At a higher discount rate, the total income decreases and also the energy demand declines in a long term. The import of crude oil from other countries will be delayed from the year 2010 to 2020 at a higher discount rate.

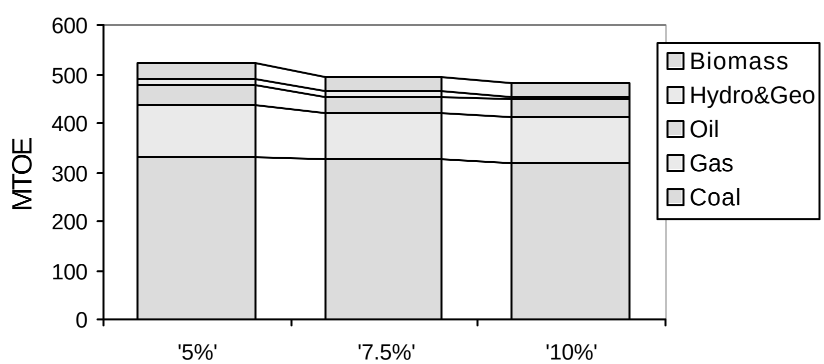

Fig. 5-19. Total primary energy supply

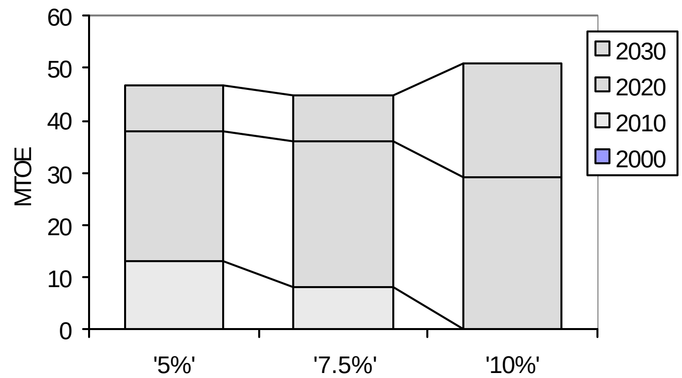

Fig. 5-20. Import of crude oil

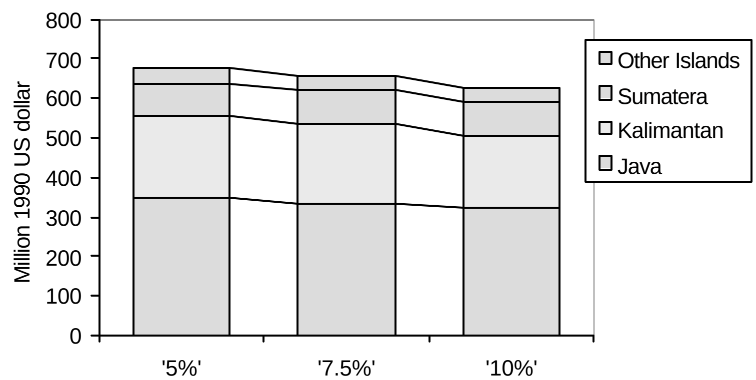

Fig. 5-21. Regional income

- **Domestic transportation cost**

A cheaper domestic transportation cost makes increase of the total energy demand. The increasing demand will be supplied by an expansion of coal and natural gas production. Supply of crude oil will grow if the domestic transportation cost of fossil energy goes up.

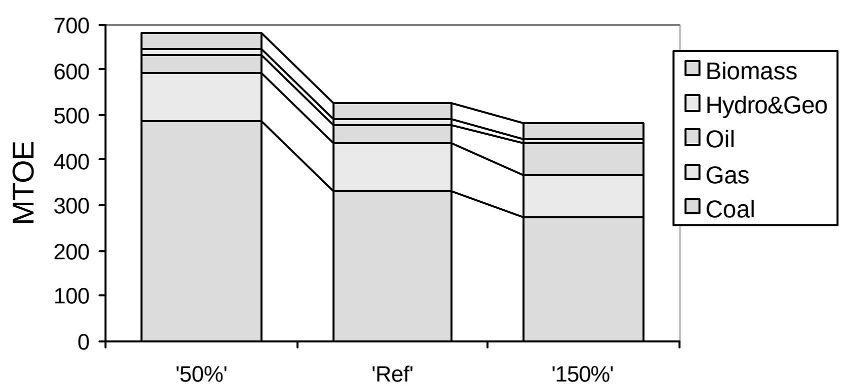

Fig. 5-22. Total primary energy supply

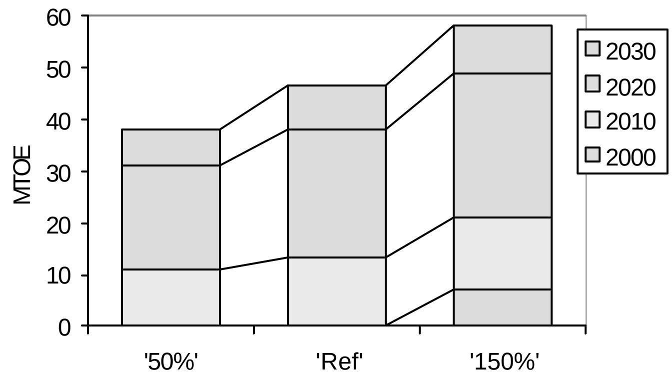

Fig. 5-23. Import of crude oil

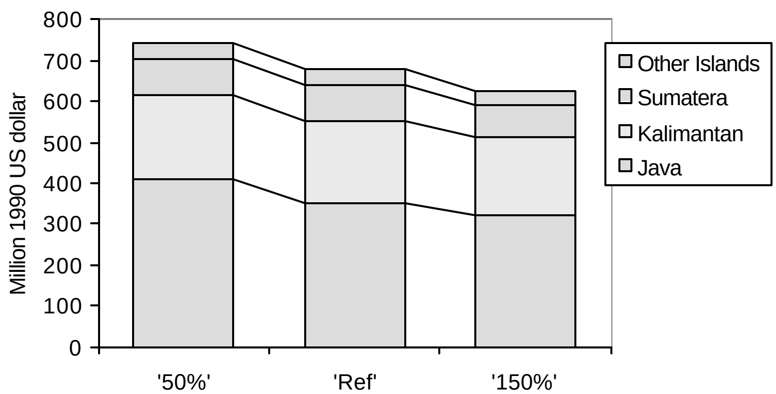

Fig. 5-24. Regional income

6. Concluding remarks

Abundant coal reserves make coal attractive as the major domestic energy supply in Indonesia. These huge amounts using coal seem to create high emission of air pollutants. The second major energy supply is natural gas and followed by crude oil. Crude oil supply is expected not growing significantly due to limited of resource.

On the regional perspective and a long term, in Java and Sumatera the energy supply is dominated by coal. In Kalimantan, however is dominated by natural gas. Renewable energy such as hydropower and geothermal energy are attractive in other islands.

Doing sensitivity analysis shows the total income and energy demand will decline at a higher discount rate. A cheaper domestic transportation cost make increasing the energy demand and it supplied by an expansion of coal and natural gas production. Supply of crude oil will grow if the domestic transportation cost goes up.

When one considers the increasing of electricity consumption, it would be desirable to extent this model with electricity energy transportation to the other regions, such as using submarine cable from Sumatera, that abundant of fossil fuel, to Java that shows rapidly increase of energy demand in the future study.

Acknowledgments

I particularly thanks to Professor Dr. Shunsuke Mori for guidance and advice. I also thanks to Dr. Harada Taku for valuable discussion and to all Mori-Laboratory members, who helped while I have been living in Japan.

I am much indebted to Professor. Dr. Yoichi Kaya and all members of Kaya-Hori Laboratory, who helped when I studied at Tokyo University.

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APPENDIX A

GAMS SOURCE PROGRAM

```
* An Energy-Economy Model to Evaluate the Future Energy Demand-Supply System
*                              in Indonesia
*                         Author : Agus Sugiyono
*                              January 1995

$OFFSYMXREF OFFSYMLIST OFFUELLIST OFFUELXREF
FILE FSAVE /EEBAS.OUT/;
PUT FSAVE;
PUT "* BASE CASE *" /;

SETS
  T          Time period   /1990, 2000, 2010, 2020, 2030/
  TFIRST(T) First period
  TLAST(T)  Last period
  RG         Region        /JAV, SMT, KAL, OTH/
  ITR        Iteration     /1*3/

  AT All Technology
    /COA-I  Coal to Industry Sector
     COA-O  Coal to Other Sector
     GAS-I  Gas to Industry Sector
     GAS-T  Gas to Transportation Sector
     GAS-O  Gas to Other Sector
     OIL-I  Oil to Industry Sector
     OIL-T  Oil to Transportation Sector
     OIL-O  Oil to Other Sector
     BIO-O  Biomass Fuel to Other Sector
     COA-P  Electric from Coal
     GAS-P  Electric from Gas
     OIL-P  Electric from Crude Oil
     HYDRO  Electric from Hydropower
     GEOTR  Electric from Geothermal
     /

  ET(AT) Electricity Technology
    /COA-P, GAS-P, OIL-P, HYDRO, GEOTR/

  NT(AT) Nonelectric Technology
    /COA-I, COA-O, GAS-I, GAS-T, GAS-O, OIL-I, OIL-T, OIL-O, BIO-O/

  TCOA(AT) Coal Base Technology
    /COA-I, COA-O, COA-P/
  TGAS(AT) Gas Base Technology
    /GAS-I, GAS-T, GAS-O, OIL-P/
  TOIL(AT) Oil Base Technology
    /OIL-I, OIL-T, OIL-O, GAS-P/

  FOSS Fossil fuel for regional transportation
    /COAL, NGAS, COIL/

  EDM Electricity Sectoral Demand
    /ELE-I, ELE-T, ELE-O/

  NIND(AT)  Nonelectricity in Industry Sector
    /COA-I, GAS-I, OIL-I/
  NTRA(AT)  Nonelectricity in Transportation Sector
    /GAS-T, OIL-T/
  NOTH(AT)  Nonelectricity in Other Sector
    /COA-O, GAS-O, OIL-O, BIO-O/

SCALARS
  NYPER  Number of years per period             /10./
  BET    Discount factor                        /0.95/
  DK     Depreciation rate on capital per year  /0.10/
```

```
  A0     Initial level of total factor productivity     /1.0/
  GA0    Initial growth rate for technology per decade  /0.25/
  DELA   Decline rate of technology change per decade   /0.08/

  PFPF   Proportional factor of production function    /0.10/
  PFEC   Proportional factor of energy cost            /6500/
  PFFC   Proportional factor of foreign transp. cost   /900/
  PFDC   Proportional factor of domestic transp. cost  /90/

PARAMETERS
  R(RG) Rate of social time preference per year
    /JAV  .025
     SMT  .020
     KAL  .020
     OTH  .025/

  K0(RG) Initial capital (Billion 1990 US dollar)
    /JAV  107.86
     SMT   86.74
     KAL   29.52
     OTH   25.75/

  I0(RG) Initial investment (Billion 1990 US dollar)
    /JAV  23.477
     SMT  10.402
     KAL   2.306
     OTH   2.900/

  C0(RG) Initial consumption (Billion 1990 US dollar)
    /JAV  5.729
     SMT  2.539
     KAL  0.563
     OTH  0.708/

  N0(RG) Initial nonelectric energy
  E0(RG) Initial electric energy
  L0(RG) Initial population

  Y0(RG) Initial productivity (Billion 1990 US dollar)
    /JAV  56.53
     SMT  27.21
     KAL   9.88
     OTH   7.15/

  ESUB(RG) Production value share of energy
    /JAV  0.30
     SMT  0.12
     KAL  0.12
     OTH  0.30/

  KPVS(RG) Capital value share
    /JAV  0.30
     SMT  0.30
     KAL  0.30
     OTH  0.30/

  ELVS(RG) Elasticity of electricity in industry
    /JAV  0.40
     SMT  0.40
     KAL  0.40
     OTH  0.40/

  A(RG) Output scaling factor

  RESBIO(RG) Limit of biomass use per annum (MTOE)
```

```
  /JAV  10.0
   SMT  14.0
   KAL  15.0
   OTH   8.0/

RESGEO(RG) Limit of geothermal use per annum (MTOE)
  /JAV  4.113
   SMT  2.585
   KAL  0.001
   OTH  1.792/

RESHYD(RG) Limit of hydropower use per annum (MTOE)
  /JAV   2.215
   SMT   8.226
   KAL  11.390
   OTH  17.718/

EATRN(RG) Income elasticity in transportation sector
  /JAV  0.403
   SMT  0.403
   KAL  0.403
   OTH  0.403/

EAPUB(RG) Income elasticity in others sector
  /JAV  0.312
   SMT  0.312
   KAL  0.312
   OTH  0.312/

EFF0(RG) Final electric conversion efficiency
  /JAV    3.0
   SMT    2.8
   KAL    2.7
   OTH    2.3/

EFFA(RG) Constant term of electric conversion eff.
  /JAV  7.3333
   SMT  7.3333
   KAL  7.3333
   OTH  7.3333/

EFFB(RG) Time dependence term of electric conversion eff.
  /JAV  -0.003
   SMT  -0.003
   KAL  -0.003
   OTH  -0.003/

GL0(RG) Population after 2100
  /JAV  161
   SMT  103
   KAL   27
   OTH   75/

GLA(RG) Constant term of population
  /JAV  0.490
   SMT  1.788
   KAL  1.788
   OTH  1.788/

GLB(RG) Time dependence term of population
  /JAV  -0.056
   SMT  -0.037
   KAL  -0.049
   OTH  -0.025/
```

```
  CH(AT) Carbon Emission Coefficient (Ton Carbon per TOE)
    /COA-I  1.000
     COA-O  1.000
     GAS-I  0.578
     GAS-T  0.578
     GAS-O  0.578
     OIL-I  0.825
     OIL-T  0.825
     OIL-O  0.825
     BIO-O  0.000
     COA-P  1.000
     GAS-P  0.578
     OIL-P  0.825
     HYDRO  0.000
     GEOTR  0.000/

  BETA(T)     Annual discount factor
  AL(T)       Technical progress
  L(T,RG)     Level of population (Million)
  EFF(T,RG)   Electric power conversion efficiency
  DKT         Depreciation rate per decade
  SHARE       Income per capita in 1990
  NEGISHI(RG) Share of income percapita
  ;

TABLE RESF(FOSS,RG) Resource of fossil fuel (MTOE)
          JAV    SMT    KAL    OTH
  COAL     39  15762   5955     68
  NGAS    306   1580    601     22
  COIL    185   1161    140     11
  ;

TABLE ECST(ET,RG) Electricity cost coefficient (Dollar per TOE)
             JAV      SMT      KAL      OTH
  COA-P  550.000  550.000  550.000  550.000
  GAS-P  480.000  480.000  480.000  480.000
  OIL-P  500.000  500.000  500.000  500.000
  HYDRO  600.000  600.000  600.000  600.000
  GEOTR  580.000  580.000  580.000  580.000
  ;

TABLE NCST(NT,RG) Nonelectric cost coefficient (Dollar per TOE)
             JAV      SMT      KAL      OTH
  COA-I   83.720   83.720   83.720   83.720
  COA-O   83.720   83.720   83.720   83.720
  GAS-I   62.790   62.790   62.790   62.790
  GAS-T   62.790   62.790   62.790   62.790
  GAS-O   62.790   62.790   62.790   62.790
  OIL-I  104.650  104.650  104.650  104.650
  OIL-T  104.650  104.650  104.650  104.650
  OIL-O  104.650  104.650  104.650  104.650
  BIO-O   60.000   60.000   60.000   60.000
  ;

TABLE CTRD(FOSS,RG) Domestic transport. cost of fossil (Dollar per TOE)
          JAV    SMT    KAL    OTH
  COAL  0.980  0.980  0.980  0.980
  NGAS  4.790  4.790  4.790  4.790
  COIL  0.670  0.670  0.670  0.670
  ;

TABLE CTRF(FOSS,RG) Foregin transport. cost of fossil (dollar per TOE)
          JAV    SMT    KAL    OTH
  COAL  1.960  1.960  1.960  1.960
  NGAS  9.580  9.580  9.580  9.580
```

```
  COIL  1.340  1.340  1.340  1.340
  ;

TABLE PRO0(AT,RG) Energy production in 1990 (MTOE)
            JAV      SMT      KAL      OTH
  COA-I   2.442    0.422    0.015    0.022
  COA-O   0.132    0.011    0.002    0.002
  GAS-I   3.852    0.942    0.542    0.582
  GAS-T   0.404    0.017    0.002    0.005
  GAS-O   2.604    1.102    0.002    0.003
  OIL-I   8.455    3.342    1.142    1.152
  OIL-T   8.708    2.570    1.073    1.782
  OIL-O   6.876    2.642    0.452    0.402
  BIO-O   7.130    6.342    1.642    1.924
  COA-P   0.612    0.322    0.107    0.112
  GAS-P   0.173    0.031    0.023    0.031
  OIL-P   2.708    0.712    0.409    0.442
  HYDRO   0.678    0.335    0.137    0.142
  GEOTR   0.868    0.012    0.001    0.022
  ;

TABLE DMD0(EDM,RG) Lower bound of electricity energy (MTOE)
            JAV      SMT      KAL      OTH
  ELE-I   0.792    0.154    0.015    0.103
  ELE-T   0.005    0.000    0.000    0.000
  ELE-O   0.672    0.125    0.015    0.103
  ;

TABLE IMD0(FOSS,RG) Lower bound of domestic import of fossil (MTOE)
           JAV     SMT     KAL     OTH
  COAL   0.000   0.000   0.000   0.000
  NGAS   0.000   0.000   0.000   0.000
  COIL   0.000   0.000   0.000   0.000
  ;

TABLE EXD0(FOSS,RG) Lower bound of domestic export of fossil (MTOE)
           JAV     SMT     KAL     OTH
  COAL   0.000   0.000   0.000   0.000
  NGAS   0.000   0.000   0.000   0.000
  COIL   0.000   0.000   0.000   0.000
  ;

TABLE IMF0(FOSS,RG) Lower bound of foreign import of fossil (MTOE)
           JAV     SMT     KAL     OTH
  COAL   0.000   0.000   0.000   0.000
  NGAS   0.000   0.000   0.000   0.000
  COIL   0.000   0.000   0.000   0.000
  ;

TFIRST(T) = YES$(ORD(T) EQ 1);
TLAST(T)  = YES$(ORD(T) EQ CARD(T));
DISPLAY TFIRST, TLAST;

EFF(T,RG) = EFF0(RG)/(1+EFFA(RG)*EXP(EFFB(RG)*NYPER*(ORD(T)-1)));
L(T,RG)   = GL0(RG)/(1+GLA(RG)*EXP(GLB(RG)*NYPER*(ORD(T)-1)));
L0(RG)    = L('1990',RG);

BETA(T)     = BET**(NYPER*ORD(T));
BETA(TLAST) = BETA(TLAST)/(1-BET);

E0(RG) = SUM(ET, PRO0(ET,RG));
N0(RG) = SUM(NT, PRO0(NT,RG));
A(RG)  = Y0(RG)/((K0(RG)**KPVS(RG) * L0(RG)**(1-KPVS(RG)))**(1-ESUB(RG)) *
         (E0(RG)**ELVS(RG) * N0(RG)**(1-ELVS(RG)))**ESUB(RG));
```

```
DKT   = (1-DK)**NYPER;
AL(T) = A0 * EXP((GA0/DELA) * (1.-EXP(-DELA*(ORD(T)-1))));

SHARE = SUM(RG, Y0(RG)/L0(RG));
NEGISHI(RG) = (Y0(RG)/L0(RG))/SHARE;

DISPLAY E0, N0, BETA, A, AL, L, L0, EFF, DKT;

VARIABLES
  PRO(AT,T,RG)   Energy production (MTOE)
  DMD(EDM,T,RG)  Energy demand (MTOE)
  EC(T,RG)       Energy cost
  TDC(T,RG)      Domestic transport cost
  TFC(T,RG)      Foreign transport cost
  EE(T,RG)       CO2 emission (Billion Ton of Carbon)

  IMD(FOSS,T,RG)  Domestic import of energy
  EXD(FOSS,T,RG)  Domestic export of energy
  IMF(FOSS,T,RG)  Foreign import of energy

  K(T,RG)        Capital stock
  C(T,RG)        Consumption
  I(T,RG)        Investment
  Y(T,RG)        Output (Million 1990 US dollar)
  UTILITY        Objective
  ;

POSITIVE VARIABLE
  K, C, I, Y, PRO, DMD, EC, EE, IMD, EXD, IMF
  ;

EQUATIONS
  ECOST(T,RG)  Energy cost equation
  TDCOST(T,RG) Domestic transportation cost equation
  TFCOST(T,RG) Foreign transportation cost equation
  EEM(T,RG)    Carbon emission equation

  LMCOA(RG)    Limit of coal reserve
  LMGAS(RG)    Limit of gas reserve
  LMOIL(RG)    Limit of oil reserve
  LMBIO(T,RG)  Limit of biomass reserve
  LMGEO(T,RG)  Limit of geothermal reserve
  LMHYD(T,RG)  Limit of hydropower reserve

  IEDBAL(FOSS,T) Balance of regional transport. of fossil

  EBAL(T,RG)        Electricity balance
  PRDUP(AT,T,RG)    Upper bound of energy production
  DMDUP(EDM,T,RG)   Upper bound of electricity energy
  EXDUP(FOSS,T,RG)  Upper bound of domestic export
  IMDUP(FOSS,T,RG)  Upper bound of domestic import
  IMFUP(FOSS,T,RG)  Upper bound of foreign import

  IXCOA(T,RG)  Maximum domestic import of coal
  IXOIL(T,RG)  Maximum domestic import of oil
  IXGAS(T,RG)  Maximum domestic import of gas

  MXCOA(T,RG)  Maximum foreign import of coal
  MXOIL(T,RG)  Maximum foreign import of oil
  MXGAS(T,RG)  Maximum foreign import of gas

  CC(T,RG)  Capacity constraint
  KK(T,RG)  Capital balance
  TM(T,RG)  Terminal condition
  YY(T,RG)  Output equation
```

```
  TRNDMD(T,RG)   Demand on transportation sector
  PUBDMD(T,RG)   Demand on other sectors

  UTIL  Objective function equation
  ;

ECOST(T,RG)..  EC(T,RG) =E= (SUM(ET, ECST(ET,RG)*PRO(ET,T,RG)) +
               SUM(NT, NCST(NT,RG)*PRO(NT,T,RG)) + PFFC*TFC(T,RG) +
               PFDC*TDC(T,RG) )*NYPER/PFEC;

TDCOST(T,RG).. TDC(T,RG) =E= SUM(FOSS, (CTRD(FOSS,RG)*IMD(FOSS,T,RG) +
               CTRD(FOSS,RG)*EXD(FOSS,T,RG)));
TFCOST(T,RG).. TFC(T,RG) =E= SUM(FOSS, CTRF(FOSS,RG)*IMF(FOSS,T,RG));

EEM(T,RG)..    EE(T,RG) =E= SUM(AT, CH(AT)*PRO(AT,T,RG));

LMCOA(RG)..    SUM(T, (SUM(TCOA, PRO(TCOA,T,RG)) -
               IMD('COAL',T,RG)+EXD('COAL',T,RG)-IMF('COAL',T,RG) )*
               NYPER) =L= RESF('COAL',RG);
LMGAS(RG)..    SUM(T, (SUM(TGAS, PRO(TGAS,T,RG)) -
               IMD('NGAS',T,RG)+EXD('NGAS',T,RG)-IMF('NGAS',T,RG) )*
               NYPER) =L= RESF('NGAS',RG);
LMOIL(RG)..    SUM(T, (SUM(TOIL, PRO(TOIL,T,RG)) -
               IMD('COIL',T,RG)+EXD('COIL',T,RG)-IMF('COIL',T,RG) )*
               NYPER) =L= RESF('COIL',RG);

LMBIO(T,RG)..  PRO('BIO-O',T,RG) =L= RESBIO(RG);
LMGEO(T,RG)..  PRO('GEOTR',T,RG) =L= RESGEO(RG);
LMHYD(T,RG)..  PRO('HYDRO',T,RG) =L= RESHYD(RG);

IEDBAL(FOSS,T).. SUM(RG, IMD(FOSS,T,RG)-EXD(FOSS,T,RG)) =E= 0;

EBAL(T,RG)..   SUM(EDM, DMD(EDM,T,RG)) =E= EFF(T,RG)*SUM(ET, PRO(ET,T,RG));
PRDUP(AT,T+1,RG).. PRO(AT,T+1,RG) =G= PRO(AT,T,RG)*DKT;

DMDUP(EDM,T+1,RG).. DMD(EDM,T+1,RG) =G= DMD(EDM,T,RG)*1.05;

EXDUP(FOSS,T+1,RG).. EXD(FOSS,T+1,RG) =G= EXD(FOSS,T,RG)*DKT;
IMDUP(FOSS,T+1,RG).. IMD(FOSS,T+1,RG) =G= IMD(FOSS,T,RG)*DKT;
IMFUP(FOSS,T+1,RG).. IMF(FOSS,T+1,RG) =G= IMF(FOSS,T,RG)*DKT;

IXCOA(T,RG).. IMD('COAL',T,RG) =L= SUM(TCOA, PRO(TCOA,T,RG));
IXOIL(T,RG).. IMD('COIL',T,RG) =L= SUM(TOIL, PRO(TOIL,T,RG));
IXGAS(T,RG).. IMD('NGAS',T,RG) =L= SUM(TGAS, PRO(TGAS,T,RG));

MXCOA(T,RG).. IMF('COAL',T,RG) =L= SUM(TCOA, PRO(TCOA,T,RG));
MXOIL(T,RG).. IMF('COIL',T,RG) =L= SUM(TOIL, PRO(TOIL,T,RG));
MXGAS(T,RG).. IMF('NGAS',T,RG) =L= SUM(TGAS, PRO(TGAS,T,RG));

YY(T,RG)..  Y(T,RG) =E= A(RG)*AL(T) * (K(T,RG)**KPVS(RG) *
            L(T,RG)**(1-KPVS(RG)))**(1-ESUB(RG)) *
            (DMD('ELE-I',T,RG)**ELVS(RG) *
            SUM(NIND, PRO(NIND,T,RG))**(1-ELVS(RG)))**ESUB(RG);

TRNDMD(T,RG).. SUM(NTRA, PRO(NTRA,T,RG))+DMD('ELE-T',T,RG) =G=
               PFPF*A(RG)*AL(T)*Y(T,RG)**EATRN(RG)*L(T,RG)**(1-EATRN(RG));

PUBDMD(T,RG).. SUM(NOTH, PRO(NOTH,T,RG))+DMD('ELE-O',T,RG) =G=
               PFPF*A(RG)*AL(T)*Y(T,RG)**EAPUB(RG)*L(T,RG)**(1-EAPUB(RG));

CC(T,RG)..      Y(T,RG)  =E=  C(T,RG) + I(T,RG) + EC(T,RG);
KK(T+1,RG)..    K(T+1,RG) =E=  DKT*K(T,RG) + NYPER*I(T,RG);
TM(TLAST,RG)..  R(RG) * K(TLAST,RG) =L=  I(TLAST,RG);
```

```
UTIL..   UTILITY =E=  SUM((T,RG), NEGISHI(RG)*L(T,RG)*BETA(T)*
                      LOG(C(T,RG)/L(T,RG)))
                      ;

** Initialization of Variable **

K.LO(T,RG) = K0(RG);
C.LO(T,RG) = C0(RG);
I.LO(T,RG) = I0(RG);
Y.LO(T,RG) = Y0(RG);
Y.FX(TFIRST,RG) = Y.LO(TFIRST,RG);

PRO.LO(AT,T,RG) = PRO0(AT,RG);
PRO.FX(AT,TFIRST,RG) = PRO.LO(AT,TFIRST,RG);

DMD.LO(EDM,T,RG) = DMD0(EDM,RG);

IMD.LO(FOSS,T,RG) = IMD0(FOSS,RG);
IMD.FX(FOSS,TFIRST,RG) = IMD.LO(FOSS,TFIRST,RG);

EXD.LO(FOSS,T,RG) = EXD0(FOSS,RG);
EXD.FX(FOSS,TFIRST,RG) = EXD.LO(FOSS,TFIRST,RG);

IMF.LO(FOSS,T,RG) = IMF0(FOSS,RG);
IMF.FX(FOSS,TFIRST,RG) = IMF.LO(FOSS,TFIRST,RG);

OPTION ITERLIM  = 100000;
OPTION RESLIM   = 999999;
OPTION SOLPRINT = OFF;

MODEL ENERGY /ALL/;

SOLVE ENERGY MAXIMIZING UTILITY USING NLP;

** Result Report **

PUT /;
PUT " Aggregate " /;
PUT "-----------" /;
PUT "Total primary energy production (MTOE)" /;
PUT " Year      Coal      Gas      Oil   Hydro.  Geothm.  Biomass     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT SUM((TCOA,RG), PRO.L(TCOA,T,RG)):10:3;
  PUT SUM((TGAS,RG), PRO.L(TGAS,T,RG)):9:3;
  PUT SUM((TOIL,RG), PRO.L(TOIL,T,RG)):9:3;
  PUT SUM(RG, PRO.L('HYDRO',T,RG)):9:3;
  PUT SUM(RG, PRO.L('GEOTR',T,RG)):9:3;
  PUT SUM(RG, PRO.L('BIO-O',T,RG)):9:3;
  PUT SUM((AT,RG), PRO.L(AT,T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Economic indicator and CO2 emission" /;
PUT " Year    Income    Popul.  Ele_eff. Y_per_cap   CO2_Em." /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT SUM(RG, Y.L(T,RG)):10:3;
  PUT SUM(RG, L(T,RG)):10:3;
  PUT (SUM(RG, EFF(T,RG))/4):10:3;
  PUT (1000*SUM(RG, Y.L(T,RG))/SUM(RG, L(T,RG))):10:3;
  PUT SUM(RG, EE.L(T,RG)):10:3;
  PUT /;
);
```

```
PUT /;
PUT "Energy demand each sector & Elec-nonelec. energy (MTOE)" /;
PUT " Year   Indust.  Transp.    Other    Total      Elec.  Non-ele" /;
LOOP(T,
 PUT (ORD(T)*NYPER+1980):5:0;
 PUT (SUM(RG, SUM(NIND, PRO.L(NIND,T,RG))+DMD.L('ELE-I',T,RG)/EFF(T,RG))):10:3;
 PUT (SUM(RG, SUM(NTRA, PRO.L(NTRA,T,RG))+DMD.L('ELE-T',T,RG)/EFF(T,RG))):9:3;
 PUT (SUM(RG, SUM(NOTH, PRO.L(NOTH,T,RG))+DMD.L('ELE-O',T,RG)/EFF(T,RG))):9:3;
 PUT (SUM(RG, SUM(NIND, PRO.L(NIND,T,RG))+DMD.L('ELE-I',T,RG)/EFF(T,RG) +
              SUM(NTRA, PRO.L(NTRA,T,RG))+DMD.L('ELE-T',T,RG)/EFF(T,RG) +
              SUM(NOTH, PRO.L(NOTH,T,RG))+DMD.L('ELE-O',T,RG)/EFF(T,RG))):9:3;
 PUT SUM((ET,RG), PRO.L(ET,T,RG)):11:3;
 PUT SUM((NT,RG), PRO.L(NT,T,RG)):9:3;
 PUT /;
);

PUT /;
PUT " Regional " /;
PUT "----------" /;
PUT "Regional of primary energy production (MTOE)" /;
LOOP(RG,
  PUT "REGION =";
  PUT ORD(RG):2:0 /;
  PUT " Year     Coal      Gas      Oil   Hydro.     Geo.  Biomass    Total"/;
  LOOP(T,
    PUT (ORD(T)*NYPER+1980):5:0;
    PUT SUM(TCOA, PRO.L(TCOA,T,RG)):9:3;
    PUT SUM(TGAS, PRO.L(TGAS,T,RG)):9:3;
    PUT SUM(TOIL, PRO.L(TOIL,T,RG)):9:3;
    PUT PRO.L('HYDRO',T,RG):9:3;
    PUT PRO.L('GEOTR',T,RG):9:3;
    PUT PRO.L('BIO-O',T,RG):9:3;
    PUT (SUM(TCOA, PRO.L(TCOA,T,RG))+SUM(TGAS, PRO.L(TGAS,T,RG))+
         SUM(TOIL, PRO.L(TOIL,T,RG))+PRO.L('HYDRO',T,RG)+
         PRO.L('GEOTR',T,RG)+PRO.L('BIO-O',T,RG)):9:3;
    PUT /;
  );
);

PUT /;
PUT "Regional of economic indicator & exogenous variable" /;
PUT "Income (Billion 1990 US dollar)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT Y.L(T,'JAV'):10:3;
  PUT Y.L(T,'SMT'):10:3;
  PUT Y.L(T,'KAL'):10:3;
  PUT Y.L(T,'OTH'):10:3;
  PUT SUM(RG, Y.L(T,RG)):10:3;
  PUT /;
);
PUT "Income per capita (1990 US dollar)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT (1000*Y.L(T,'JAV')/L(T,'JAV')):10:3;
  PUT (1000*Y.L(T,'SMT')/L(T,'SMT')):10:3;
  PUT (1000*Y.L(T,'KAL')/L(T,'KAL')):10:3;
  PUT (1000*Y.L(T,'OTH')/L(T,'OTH')):10:3;
  PUT (1000*SUM(RG, Y.L(T,RG))/SUM(RG, L(T,RG))):10:3;
  PUT /;
);
PUT "Population (Million)" /;
```

```
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT L(T,'JAV'):10:3;
  PUT L(T,'SMT'):10:3;
  PUT L(T,'KAL'):10:3;
  PUT L(T,'OTH'):10:3;
  PUT SUM(RG, L(T,RG)):10:3;
  PUT /;
);
PUT "Electricity use efficiency (%)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland   Average" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT EFF(T,'JAV'):10:3;
  PUT EFF(T,'SMT'):10:3;
  PUT EFF(T,'KAL'):10:3;
  PUT EFF(T,'OTH'):10:3;
  PUT (SUM(RG, EFF(T,RG))/4):10:3;
  PUT /;
);

PUT /;
PUT "CO2 Emission (Billion TON)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT EE.L(T,'JAV'):10:3;
  PUT EE.L(T,'SMT'):10:3;
  PUT EE.L(T,'KAL'):10:3;
  PUT EE.L(T,'OTH'):10:3;
  PUT SUM(RG, EE.L(T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Domestic import of coal (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT IMD.L('COAL',T,'JAV'):10:3;
  PUT IMD.L('COAL',T,'SMT'):10:3;
  PUT IMD.L('COAL',T,'KAL'):10:3;
  PUT IMD.L('COAL',T,'OTH'):10:3;
  PUT SUM(RG, IMD.L('COAL',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Domestic import of oil (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT IMD.L('COIL',T,'JAV'):10:3;
  PUT IMD.L('COIL',T,'SMT'):10:3;
  PUT IMD.L('COIL',T,'KAL'):10:3;
  PUT IMD.L('COIL',T,'OTH'):10:3;
  PUT SUM(RG, IMD.L('COIL',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Domestic import of gas (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
```

```
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT IMD.L('NGAS',T,'JAV'):10:3;
  PUT IMD.L('NGAS',T,'SMT'):10:3;
  PUT IMD.L('NGAS',T,'KAL'):10:3;
  PUT IMD.L('NGAS',T,'OTH'):10:3;
  PUT SUM(RG, IMD.L('NGAS',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Domestic export of coal (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT EXD.L('COAL',T,'JAV'):10:3;
  PUT EXD.L('COAL',T,'SMT'):10:3;
  PUT EXD.L('COAL',T,'KAL'):10:3;
  PUT EXD.L('COAL',T,'OTH'):10:3;
  PUT SUM(RG, EXD.L('COAL',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Domestic export of oil (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT EXD.L('COIL',T,'JAV'):10:3;
  PUT EXD.L('COIL',T,'SMT'):10:3;
  PUT EXD.L('COIL',T,'KAL'):10:3;
  PUT EXD.L('COIL',T,'OTH'):10:3;
  PUT SUM(RG, EXD.L('COIL',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Domestic export of gas (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT EXD.L('NGAS',T,'JAV'):10:3;
  PUT EXD.L('NGAS',T,'SMT'):10:3;
  PUT EXD.L('NGAS',T,'KAL'):10:3;
  PUT EXD.L('NGAS',T,'OTH'):10:3;
  PUT SUM(RG, EXD.L('NGAS',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Foreign import of coal (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT IMF.L('COAL',T,'JAV'):10:3;
  PUT IMF.L('COAL',T,'SMT'):10:3;
  PUT IMF.L('COAL',T,'KAL'):10:3;
  PUT IMF.L('COAL',T,'OTH'):10:3;
  PUT SUM(RG, IMF.L('COAL',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Foreign import of oil (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
```

```
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT IMF.L('COIL',T,'JAV'):10:3;
  PUT IMF.L('COIL',T,'SMT'):10:3;
  PUT IMF.L('COIL',T,'KAL'):10:3;
  PUT IMF.L('COIL',T,'OTH'):10:3;
  PUT SUM(RG, IMF.L('COIL',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Foreign import of gas (MTOE)" /;
PUT " Year      Java  Sumatera  Kalimant OthIsland     Total" /;
LOOP(T,
  PUT (ORD(T)*NYPER+1980):5:0;
  PUT IMF.L('NGAS',T,'JAV'):10:3;
  PUT IMF.L('NGAS',T,'SMT'):10:3;
  PUT IMF.L('NGAS',T,'KAL'):10:3;
  PUT IMF.L('NGAS',T,'OTH'):10:3;
  PUT SUM(RG, IMF.L('NGAS',T,RG)):10:3;
  PUT /;
);

PUT /;
PUT "Demand sector (MTOE) " /;
LOOP(RG,
  PUT "REGION =";
  PUT ORD(RG):2:0 /;
  PUT " Year    Industry   Transport OtherSector" /;
  LOOP(T,
    PUT (ORD(T)*NYPER+1980):5:0;
    PUT (SUM(NIND, PRO.L(NIND,T,RG))+DMD.L('ELE-I',T,RG)/EFF(T,RG)):12:3;
    PUT (SUM(NTRA, PRO.L(NTRA,T,RG))+DMD.L('ELE-T',T,RG)/EFF(T,RG)):12:3;
    PUT (SUM(NOTH, PRO.L(NOTH,T,RG))+DMD.L('ELE-O',T,RG)/EFF(T,RG)):12:3;
    PUT /;
  );
);

PUT /;
PUT "Electricity & nonelectricity energy (MTOE)" /;
LOOP(RG,
  PUT "REGION =";
  PUT ORD(RG):2:0 /;
  PUT " Year       Industry       Transport          Other          Total"/;
  PUT "          ELE     NON     ELE     NON     ELE     NON     ELE     NON"/;
  LOOP(T,
    PUT (ORD(T)*NYPER+1980):5:0;
    PUT (DMD.L('ELE-I',T,RG)/EFF(T,RG)):8:3;
    PUT SUM(NIND, PRO.L(NIND,T,RG)):8:3;
    PUT (DMD.L('ELE-T',T,RG)/EFF(T,RG)):8:3;
    PUT SUM(NTRA, PRO.L(NTRA,T,RG)):8:3;
    PUT (DMD.L('ELE-O',T,RG)/EFF(T,RG)):8:3;
    PUT SUM(NOTH, PRO.L(NOTH,T,RG)):8:3;
    PUT SUM(ET, PRO.L(ET,T,RG)):8:3;
    PUT SUM(NT, PRO.L(NT,T,RG)):8:3;
    PUT /;
  );
);

PUT /;
PUT "Electricity energy production by fuel (MTOE)" /;
LOOP(RG,
  PUT "REGION =";
  PUT ORD(RG):2:0 /;
  PUT " Year    Coal     Gas     Oil   Hydr.  Geoth.    Total" /;
  LOOP(T,
```

```
    PUT (ORD(T)*NYPER+1980):5:0;
    PUT PRO.L('COA-P',T,RG):8:3;
    PUT PRO.L('GAS-P',T,RG):8:3;
    PUT PRO.L('OIL-P',T,RG):8:3;
    PUT PRO.L('HYDRO',T,RG):8:3;
    PUT PRO.L('GEOTR',T,RG):8:3;
    PUT SUM(ET, PRO.L(ET,T,RG)):9:3;
    PUT /;
  );
);

PUT /;
PUT "Production of all energy technology (MTOE)" /;
LOOP(RG,
  PUT /;
  PUT "REGION =";
  PUT ORD(RG):2:0 /;
  PUT " Year  COAL-IND  COAL-OTH   GAS-IND   GAS-TRA   GAS-OTH " /;
  LOOP(T,
    PUT (ORD(T)*NYPER+1980):5:0;
    PUT PRO.L('COA-I',T,RG):10:3;
    PUT PRO.L('COA-O',T,RG):10:3;
    PUT PRO.L('GAS-I',T,RG):10:3;
    PUT PRO.L('GAS-T',T,RG):10:3;
    PUT PRO.L('GAS-O',T,RG):10:3;
    PUT /;
  );
  PUT /;
  PUT " Year   OIL-IND   OIL-TRA   OIL-OTH   BIO-OTH " /;
  LOOP(T,
    PUT (ORD(T)*NYPER+1980):5:0;
    PUT PRO.L('OIL-I',T,RG):10:3;
    PUT PRO.L('OIL-T',T,RG):10:3;
    PUT PRO.L('OIL-O',T,RG):10:3;
    PUT PRO.L('BIO-O',T,RG):10:3;
    PUT /;
  );
  PUT /;
  PUT " Year    COAL-P     GAS-P     OIL-P     HYDRO     GEOTR" /;
  LOOP(T,
    PUT (ORD(T)*NYPER+1980):5:0;
    PUT PRO.L('COA-P',T,RG):10:3;
    PUT PRO.L('GAS-P',T,RG):10:3;
    PUT PRO.L('OIL-P',T,RG):10:3;
    PUT PRO.L('HYDRO',T,RG):10:3;
    PUT PRO.L('GEOTR',T,RG):10:3;
    PUT /;
  );
);
```

APPENDIX B

OUTPUT PROGRAM

* BASE CASE *

Aggregate

Total primary energy production (MTOE)

Year	Coal	Gas	Oil	Hydro.	Geothm.	Biomass	Total
1990	4.201	14.328	38.854	1.292	0.903	17.038	76.616
2000	49.997	33.152	38.854	2.829	5.430	17.038	147.301
2010	105.336	38.779	38.854	2.829	5.714	20.329	211.841
2020	202.000	58.025	38.854	3.275	5.918	24.266	332.339
2030	330.592	106.616	40.897	5.380	5.918	34.887	524.290

Economic indicator and CO2 emission

Year	Income	Popul.	Ele_eff.	Y_per_cap	CO2_Em.
1990	100.770	181.583	0.324	554.953	45.528
2000	175.846	216.110	0.333	813.688	102.739
2010	259.477	246.529	0.342	1052.524	161.845
2020	412.429	272.131	0.351	1515.554	270.585
2030	677.386	293.032	0.360	2311.644	430.793

Energy demand each sector & Elec-nonelec. energy (MTOE)

Year	Indust.	Transp.	Other	Total	Elec.	Non-ele
1990	27.154	15.536	33.926	76.616	7.877	68.739
2000	91.817	21.497	33.986	147.301	18.507	128.794
2010	141.487	33.014	37.340	211.841	25.576	186.265
2020	230.749	51.203	50.387	332.339	38.064	294.275
2030	372.424	78.268	73.598	524.290	59.553	464.737

Regional

Regional of primary energy production (MTOE)

REGION = 1

Year	Coal	Gas	Oil	Hydro.	Geo.	Biomass	Total
1990	3.186	9.568	24.212	0.678	0.868	7.130	45.642
2000	27.089	13.224	24.212	2.215	4.113	7.130	77.983
2010	53.295	20.216	24.212	2.215	4.113	9.730	113.781
2020	106.342	30.602	24.212	2.215	4.113	10.000	177.484
2030	176.327	45.306	24.212	2.215	4.113	10.000	262.173

REGION = 2

Year	Coal	Gas	Oil	Hydro.	Geo.	Biomass	Total
1990	0.755	2.773	8.585	0.335	0.012	6.342	18.802
2000	15.467	13.076	8.585	0.335	0.012	6.342	43.817
2010	33.626	12.152	8.585	0.335	0.012	6.342	61.051
2020	61.779	17.711	8.585	0.335	0.012	7.168	95.591
2030	92.821	46.280	8.585	0.335	0.012	13.297	161.330

REGION = 3

Year	Coal	Gas	Oil	Hydro.	Geo.	Biomass	Total
1990	0.124	0.955	2.690	0.137	0.001	1.642	5.549
2000	3.821	5.821	2.690	0.137	0.001	1.642	14.112
2010	13.718	4.955	2.690	0.137	0.001	2.333	23.834
2020	26.223	7.135	2.690	0.137	0.001	4.096	40.282
2030	46.072	12.396	2.690	0.137	0.001	6.613	67.910

REGION = 4

Year	Coal	Gas	Oil	Hydro.	Geo.	Biomass	Total
1990	0.136	1.032	3.367	0.142	0.022	1.924	6.623
2000	3.619	1.032	3.367	0.142	1.304	1.924	11.389
2010	4.697	1.457	3.367	0.142	1.588	1.924	13.174
2020	7.656	2.576	3.367	0.588	1.792	3.002	18.981
2030	15.371	2.635	5.410	2.693	1.792	4.976	32.877

Regional of economic indicator & exogenous variable

Income (Billion 1990 US dollar)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	56.530	27.210	9.880	7.150	100.770
2000	99.729	47.130	16.742	12.245	175.846

Year	Java	Sumatera	Kalimant	OthIsland	Total
2010	143.680	70.760	29.413	15.625	259.477
2020	221.971	118.619	50.165	21.674	412.429
2030	349.146	203.431	85.857	38.951	677.386

Income per capita (1990 US dollar)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	523.166	736.519	1020.201	265.789	554.953
2000	792.808	1022.680	1299.303	390.628	813.688
2010	1035.097	1273.049	1820.394	434.259	1052.524
2020	1504.611	1830.244	2621.780	533.068	1515.554
2030	2281.733	2778.939	3980.772	860.967	2311.644

Population (Million)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	108.054	36.944	9.684	26.901	181.583
2000	125.792	46.084	12.886	31.348	216.110
2010	138.808	55.583	16.157	35.980	246.529
2020	147.527	64.810	19.134	40.659	272.131
2030	153.018	73.205	21.568	45.242	293.032

Electricity use efficiency (%)

Year	Java	Sumatera	Kalimant	OthIsland	Average
1990	0.360	0.336	0.324	0.276	0.324
2000	0.370	0.345	0.333	0.283	0.333
2010	0.379	0.354	0.342	0.291	0.342
2020	0.390	0.364	0.351	0.299	0.351
2030	0.400	0.373	0.360	0.307	0.360

CO_2 Emission (Billion TON)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	29.317	9.609	2.991	3.612	45.528
2000	55.334	30.718	9.592	7.095	102.739
2010	85.581	48.677	19.168	8.418	161.845
2020	144.631	80.707	33.222	12.024	270.585
2030	223.115	129.561	56.658	21.458	430.793

Domestic import of coal (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	26.375	0.000	0.000	3.619	29.995
2010	53.295	0.000	0.000	4.697	57.992
2020	106.342	0.000	0.000	7.656	113.998
2030	176.327	0.000	0.000	8.707	185.034

Domestic import of oil (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	1.347	0.000	0.000	3.367	4.714
2010	24.212	0.000	0.000	3.367	27.579
2020	24.212	0.000	0.000	3.367	27.579
2030	8.442	0.000	0.000	5.410	13.853

Domestic import of gas (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	11.390	0.000	0.000	1.032	12.422
2010	20.216	0.000	0.000	1.457	21.673
2020	30.602	0.000	0.000	2.576	33.179
2030	26.107	0.000	0.000	1.467	27.573

Domestic export of coal (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	0.000	15.075	14.920	0.000	29.995
2010	0.000	5.256	52.736	0.000	57.992
2020	0.000	70.886	43.112	0.000	113.998
2030	0.000	170.002	15.032	0.000	185.034

Domestic export of oil (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	0.000	4.714	0.000	0.000	4.714
2010	0.000	27.579	0.000	0.000	27.579
2020	0.000	27.579	0.000	0.000	27.579
2030	0.000	13.303	0.550	0.000	13.853

Domestic export of gas (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	0.000	12.422	0.000	0.000	12.422
2010	0.000	21.168	0.505	0.000	21.673
2020	0.000	23.581	9.598	0.000	33.179
2030	0.000	8.839	18.735	0.000	27.573

Foreign import of coal (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000
2020	0.000	0.000	0.000	0.000	0.000
2030	0.000	0.000	0.000	0.000	0.000

Foreign import of oil (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.000	0.000	0.000	0.000
2010	11.692	0.000	0.000	1.542	13.234
2020	24.212	0.000	0.000	0.538	24.750
2030	8.442	0.000	0.000	0.187	8.630

Foreign import of gas (MTOE)

Year	Java	Sumatera	Kalimant	OthIsland	Total
1990	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000
2020	0.000	0.000	0.000	0.000	0.000
2030	0.000	0.000	0.000	0.000	0.000

Demand sector (MTOE)

REGION = 1

Year	Industry	Transport	OtherSector
1990	16.949	10.084	18.609
2000	45.570	13.762	18.651
2010	71.710	20.777	21.295
2020	115.642	31.186	30.656
2030	173.032	45.914	43.227

REGION = 2

Year	Industry	Transport	OtherSector
1990	5.746	2.587	10.469
2000	29.046	4.293	10.477
2010	43.505	7.060	10.486
2020	72.575	11.694	11.321
2030	124.990	18.881	17.459

REGION = 3

Year	Industry	Transport	OtherSector
1990	2.330	1.075	2.144
2000	10.314	1.652	2.145
2010	18.033	2.963	2.838
2020	30.693	4.988	4.601
2030	52.752	8.037	7.120

REGION = 4

Year	Industry	Transport	OtherSector
1990	2.129	1.790	2.704

2000	6.886	1.790	2.713
2010	8.239	2.214	2.721
2020	11.838	3.334	3.809
2030	21.649	5.436	5.792

Electricity & nonelectricity energy (MTOE)

REGION = 1

Year	Industry		Transport		Other		Total	
	ELE	NON	ELE	NON	ELE	NON	ELE	NON
1990	2.200	14.749	0.972	9.112	1.867	16.742	5.039	40.603
2000	9.320	36.250	0.994	12.768	1.909	16.742	12.223	65.759
2010	13.958	57.752	1.017	19.760	1.953	19.342	16.927	96.854
2020	21.874	93.769	1.040	30.146	1.997	28.658	24.911	152.573
2030	33.717	139.316	1.064	44.850	2.043	41.184	36.824	225.349

REGION = 2

Year	Industry		Transport		Other		Total	
	ELE	NON	ELE	NON	ELE	NON	ELE	NON
1990	1.040	4.706	0.000	2.587	0.372	10.097	1.412	17.390
2000	2.822	26.224	0.000	4.293	0.380	10.097	3.202	40.614
2010	4.169	39.336	0.000	7.060	0.389	10.097	4.558	56.493
2020	6.845	65.730	0.000	11.694	0.398	10.923	7.243	88.347
2030	12.096	112.894	0.000	18.881	0.407	17.052	12.503	148.827

REGION = 3

Year	Industry		Transport		Other		Total	
	ELE	NON	ELE	NON	ELE	NON	ELE	NON
1990	0.631	1.699	0.000	1.075	0.046	2.098	0.677	4.872
2000	1.002	9.312	0.000	1.652	0.047	2.098	1.049	13.063
2010	1.728	16.305	0.000	2.963	0.048	2.789	1.776	22.057
2020	2.895	27.798	0.000	4.988	0.050	4.552	2.944	37.338
2030	5.105	47.647	0.000	8.037	0.051	7.069	5.156	62.754

REGION = 4

Year	Industry		Transport		Other		Total	
	ELE	NON	ELE	NON	ELE	NON	ELE	NON
1990	0.373	1.756	0.003	1.787	0.373	2.331	0.749	5.874
2000	1.647	5.239	0.003	1.787	0.382	2.331	2.031	9.357
2010	1.921	6.317	0.003	2.212	0.390	2.331	2.315	10.860
2020	2.563	9.276	0.003	3.331	0.399	3.409	2.965	16.016
2030	4.659	16.991	0.003	5.433	0.408	5.383	5.070	27.807

Electricity energy production by fuel (MTOE)

REGION = 1

Year	Coal	Gas	Oil	Hydr.	Geoth.	Total
1990	0.612	0.173	2.708	0.678	0.868	5.039
2000	3.014	0.173	2.708	2.215	4.113	12.223
2010	7.718	0.173	2.708	2.215	4.113	16.927
2020	15.702	0.173	2.708	2.215	4.113	24.911
2030	27.615	0.173	2.708	2.215	4.113	36.824

REGION = 2

Year	Coal	Gas	Oil	Hydr.	Geoth.	Total
1990	0.322	0.031	0.712	0.335	0.012	1.412
2000	0.322	0.031	2.502	0.335	0.012	3.202
2010	0.322	0.031	3.858	0.335	0.012	4.558
2020	0.322	0.031	6.543	0.335	0.012	7.243
2030	0.322	0.031	11.803	0.335	0.012	12.503

REGION = 3

Year	Coal	Gas	Oil	Hydr.	Geoth.	Total
1990	0.107	0.023	0.409	0.137	0.001	0.677
2000	0.107	0.023	0.781	0.137	0.001	1.049
2010	0.107	0.023	1.508	0.137	0.001	1.776
2020	0.107	0.023	2.676	0.137	0.001	2.944
2030	0.107	0.023	4.888	0.137	0.001	5.156

REGION = 4

Year	Coal	Gas	Oil	Hydr.	Geoth.	Total
1990	0.112	0.031	0.442	0.142	0.022	0.749
2000	0.112	0.031	0.442	0.142	1.304	2.031

2010	0.112	0.031	0.442	0.142	1.588	2.315
2020	0.112	0.031	0.442	0.588	1.792	2.965
2030	0.112	0.031	0.442	2.693	1.792	5.070

Production of all energy technology (MTOE)

REGION = 1

Year	COAL-IND	COAL-OTH	GAS-IND	GAS-TRA	GAS-OTH
1990	2.442	0.132	3.852	0.404	2.604
2000	23.943	0.132	3.852	4.060	2.604
2010	45.445	0.132	3.852	11.052	2.604
2020	81.462	9.178	3.852	21.438	2.604
2030	127.009	21.704	3.852	36.142	2.604

Year	OIL-IND	OIL-TRA	OIL-OTH	BIO-OTH
1990	8.455	8.708	6.876	7.130
2000	8.455	8.708	6.876	7.130
2010	8.455	8.708	6.876	9.730
2020	8.455	8.708	6.876	10.000
2030	8.455	8.708	6.876	10.000

Year	COAL-P	GAS-P	OIL-P	HYDRO	GEOTR
1990	0.612	0.173	2.708	0.678	0.868
2000	3.014	0.173	2.708	2.215	4.113
2010	7.718	0.173	2.708	2.215	4.113
2020	15.702	0.173	2.708	2.215	4.113
2030	27.615	0.173	2.708	2.215	4.113

REGION = 2

Year	COAL-IND	COAL-OTH	GAS-IND	GAS-TRA	GAS-OTH
1990	0.422	0.011	0.942	0.017	1.102
2000	15.134	0.011	7.748	1.723	1.102
2010	33.293	0.011	2.702	4.490	1.102
2020	61.446	0.011	0.942	9.124	1.102
2030	92.488	0.011	17.064	16.311	1.102

Year	OIL-IND	OIL-TRA	OIL-OTH	BIO-OTH
1990	3.342	2.570	2.642	6.342
2000	3.342	2.570	2.642	6.342
2010	3.342	2.570	2.642	6.342
2020	3.342	2.570	2.642	7.168
2030	3.342	2.570	2.642	13.297

Year	COAL-P	GAS-P	OIL-P	HYDRO	GEOTR
1990	0.322	0.031	0.712	0.335	0.012
2000	0.322	0.031	2.502	0.335	0.012
2010	0.322	0.031	3.858	0.335	0.012
2020	0.322	0.031	6.543	0.335	0.012
2030	0.322	0.031	11.803	0.335	0.012

REGION = 3

Year	COAL-IND	COAL-OTH	GAS-IND	GAS-TRA	GAS-OTH
1990	0.015	0.002	0.542	0.002	0.002
2000	3.712	0.002	4.458	0.579	0.002
2010	13.609	0.002	1.554	1.890	0.002
2020	26.114	0.002	0.542	3.915	0.002
2030	45.963	0.002	0.542	6.964	0.002

Year	OIL-IND	OIL-TRA	OIL-OTH	BIO-OTH
1990	1.142	1.073	0.452	1.642
2000	1.142	1.073	0.452	1.642
2010	1.142	1.073	0.452	2.333
2020	1.142	1.073	0.452	4.096
2030	1.142	1.073	0.452	6.613

Year	COAL-P	GAS-P	OIL-P	HYDRO	GEOTR
1990	0.107	0.023	0.409	0.137	0.001
2000	0.107	0.023	0.781	0.137	0.001
2010	0.107	0.023	1.508	0.137	0.001
2020	0.107	0.023	2.676	0.137	0.001
2030	0.107	0.023	4.888	0.137	0.001

REGION = 4

Year	COAL-IND	COAL-OTH	GAS-IND	GAS-TRA	GAS-OTH
1990	0.022	0.002	0.582	0.005	0.003
2000	3.505	0.002	0.582	0.005	0.003
2010	4.583	0.002	0.582	0.430	0.003
2020	7.542	0.002	0.582	1.549	0.003
2030	15.257	0.002	0.582	1.608	0.003

Year	OIL-IND	OIL-TRA	OIL-OTH	BIO-OTH
1990	1.152	1.782	0.402	1.924
2000	1.152	1.782	0.402	1.924
2010	1.152	1.782	0.402	1.924
2020	1.152	1.782	0.402	3.002
2030	1.152	3.825	0.402	4.976

Year	COAL-P	GAS-P	OIL-P	HYDRO	GEOTR
1990	0.112	0.031	0.442	0.142	0.022
2000	0.112	0.031	0.442	0.142	1.304
2010	0.112	0.031	0.442	0.142	1.588
2020	0.112	0.031	0.442	0.588	1.792
2030	0.112	0.031	0.442	2.693	1.792