THE ROLE OF NUCLEAR POWER AND OTHER ENERGY OPTIONS IN COMPETITIVE ELECTRICITY MARKET STUDY USING MESSAGE MODEL

Scorpio Sri Herdinie, Edi Sartono*)

ABSTRACT

THE ROLE OF NUCLEAR POWER AND OTHER ENERGY OPTIONS IN COMPETITIVE ELECTRICITY MARKET STUDY USING MESSAGE MODEL. The electricity demand in Indonesia is very high due to the National Economic Development based on industrialization and supported by a strong agriculture base. It can be noted that in the last five years, the annual electricity growth rate has been reaching around 15% per annum. Though during the economic crisis the electricity demand have time to reduction. Start early 2000s the economic growth in Indonesia will gradually increase. As a consequence, the electricity growth rate also increase in the next coming decades. MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts) is a model designed for the optimization of energy system (i.e. energy supplies and utilization). The goal of this study is to support the national planning and decision making process in the energy and electricity sector in Indonesia with regard to the economic, health, environmental and safety aspects. The objective of this study is to analyse the role of Nuclear Power Plant in the whole energy systems by introducing the new electricity regulation and structure in the market. Seen that Nuclear Power Plant will be enter the Java Bali system in the period between 2015-2020. and will dominate the addition of capacities by the end period of study (year 2020-2025). Nuclear energy has very important long term roles in the energy scenario and it is possible to do the market competitiive when the Multi buyer Multi Seller (MBMS) will be done in the system electricity in Indonesia (the government has changed the target of MBMS realization into 2007).

ABSTRAK

STUDI PERAN PEMBANGKIT TENAGA NUKLIR DAN ENERGI LAIN DI DALAM KOMPETISI PASAR LISTRIK DENGAN MENGGUNAKAN PROGRAM MESSAGE. Tuntutan akan kebutuhan listrik Indonesia sangat tinggi dalam kaitan dengan Pengembangan Ekonomi Nasional berdasar pada Industrialisasi yang didukung oleh pertanian kuat. Hal ini dapat dilihat bahwa pada lima tahun terakhir, laju pertumbuhan listrik telah mencapai sekitar 15% tiap tahun. Meskipun selama krisis ekonomi, permintaan listrik sempat mengalami suatu pengurangan. Mulai awal 2000-an pertumbuhan ekonomi Indonesia secara berangsur-angsur meningkat. Sebagai konsekwensi, laju pertumbuhan listrik akan juga meningkat pada dekade yang akan datang. MESSAGE (*Model for Energy Supply Strategy Alternatives and their General Environmental Impacts*) adalah suatu model optimalisasi sistem energi (yaitu, penyediaan energi dan pemanfaatan). Tujuan dari studi ini adalah untuk mendukung proses pengambilan keputusan dan perencanaan energi nasional dan sektor listrik di Indonesia yang mempertimbangkan nilai ekonomi, kesehatan, lingkungan dan aspek keselamatan. Sasaran studi ini adalah untuk meneliti peran Pembangkit Energi Nuklir pada keseluruhan sistem energi dalam kaitannya dengan peraturan sistem pasar listrik yang baru. Hasil dari studi ini dapat disimpulkan bahwa pembangkit Listrik tenaga Nuklir akan masuk ke dalam Sistem Jawa-Bali pada periode tahun 2015–2020, dan akan mendominasi penambahan kapasitas pada periode akhir studi (tahun 2020-2025). Peran energi nuklir jangka panjang sangat penting di dalam skenario penyediaan energi khususnya listrik dan memungkinkan untuk berkompetitif dengan energi yang lain dalam menghadapi sistem pasar yang Multi Buyer Multi Seller (MBMS), jika sistem tersebut diberlakukan di Indonesia (pemerintah telah mentargetkan perwujudan sistem pasar MBMS pada tahun 2007).

---

*) *Staf Bidang Sistem Energi – P2EN*

I. INTRODUCTION

We all have come to realize that the increasing demand and supply of energy is a reality and a necessity to support social-economic development. Developing countries, like Indonesia and other South East Asian countries, have low standards of living and low consumption of energy. In their endeavors to reach a high quality of life, they need a lot of energy and electricity to fuel their social-economic development. The electricity demand in Indonesia is very high due to the National Economic Development based on industrialization and supported by a strong agriculture base. It can be noted that in the last five years, the annual electricity growth rate has been assumed at around 15% per annum. However, due to the economic crisis the electricity demand has experienced a reduction. Nevertheless, it is forecasted that eventually in the early 2000s the economic growth in Indonesia will gradually increase. As a consequence, the electricity growth rate will also increase in the next coming decades.

The sustainable economic growth has emerged as an important issue on a global level. There has been a strong argumentation that decision making for energy planning could be misleading without addressing the impacts in energy production and the use in health, environment, and safety. In this regard, a wise and strategic assessment to support decision making regarding energy and the electric sector as well as nuclear power issues is needed, i.e. a comparative assessment that considers a range of factors related to the entire fuel chain of energy sources, including their technical and economic performance as well as their impact to health and environment. While costs remain a key factor, they must be measured in many comparative ways.

The Agency (IAEA) has developed computer tools to assist such comparative assessment above. Besides, the Agency certainly has the accumulation of experiences from the member countries that have gone through such assessment before. Therefore the Agency can play a great role in assisting the Government of the Republic of Indonesia in conducting the comparative assessment of different energy sources for electricity generations. That can be provided by the Agency through TC Project for Indonesia and RCA Project in the Region.

I.1. Model Overview

MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts) is a model designed for the optimization of energy system (i.e. energy supplies and utilization). The model was originally developed at International Institute for Applied Systems Analysis (IIASA). The IAEA acquired the latest version of the model and several enhancements have been made in it, most importantly addition of a user-interface to facilitate its application.

The underlying principle of the MESSAGE model is optimization of an objective function under a set of constraints that define the feasible region containing all possible solutions of the problem. The value of the objective function helps to choose the solution considered best according to the criteria specified.

MESSAGE is designed to formulate and evaluate alternative energy supply strategies consonant with the user-defined constraints such as limits on new investment, fuel availability and trade, environmental regulations and market penetration rates for new technologies. Environmental aspects can be analyzed by accounting, and if necessary limiting, the amounts of pollutants emitted by various technologies at various steps in energy supplies. This helps to evaluate the impact of environmental regulations on energy system development.

II. CASE STUDY DEVELOPMENT

The study will be developed with stressing on optimal expansion of electricity generation with introducing of new regulation on electricity market in Indonesia and changing on structure of power producer and Transmission/Distribution

a. Objective

   To analyse the role of Nuclear Power Plant in the whole energy systems with introducing the new regulation and structure electricity on the marked.

b. Base year

   A time horizon of 25 years was chosen for this study, starting from year 2000 to 2025. It is broken down into five periods of five years each.

c. Energy Network

   In first approximation MESSAGE could be labelled a physical flow model. Given a vector of demands for specified energy goods or services, it assures sufficient supply, utilizing the technologies and resources considered. MESSAGE allows modelling of all steps in the energy flows from supply to demand, which is generally referred to as energy chain and steps are called levels (e.g. useful, final and primary).

   The whole Indonesia energy network is very complex. To represented the Indonesia energy flows, will be divided with 3 (three) Region energy Flows, named MAIN REGION, JAVA REGION and OUTSIDE JAVA REGION. Main region means all energy level that are presenting the national energy as resources, production and/or export. Java region means the level of energy distribution and consumed by the demand in region of Java Island. Outside Java means all the energy level of energy produced distribution and consumed by the demand in Outside Java Island.

MAIN REGION

The level of resources in the main region consist of oil and coal; primary level consist of domestic and Import oil, extract coal; secondary consist of all product of refinery, energy level of export are crude oil, coal and gas. Refinery products are transported and distributed to consumer in Java and Outside Java region.

Indonesia have 10 units refinery plant with total installed capacity of 1,057 thousand barrel per day with the average total fuel production 276.7 million barrel in a year. The refinery specified into two (2) types which area refinery for domestic and import oil with six types of product i.e. avture, gasoline, diesel, heavy oil, kerosene, and liquid petroleum gas (LPG).These products are transported to demand by pipeline, ship, truck and other transportation mode. Geothermal and hydro as resources in electricity supply. Fig II.1.a,b,c shows the schematic representation of the simple Indonesia energy flows.

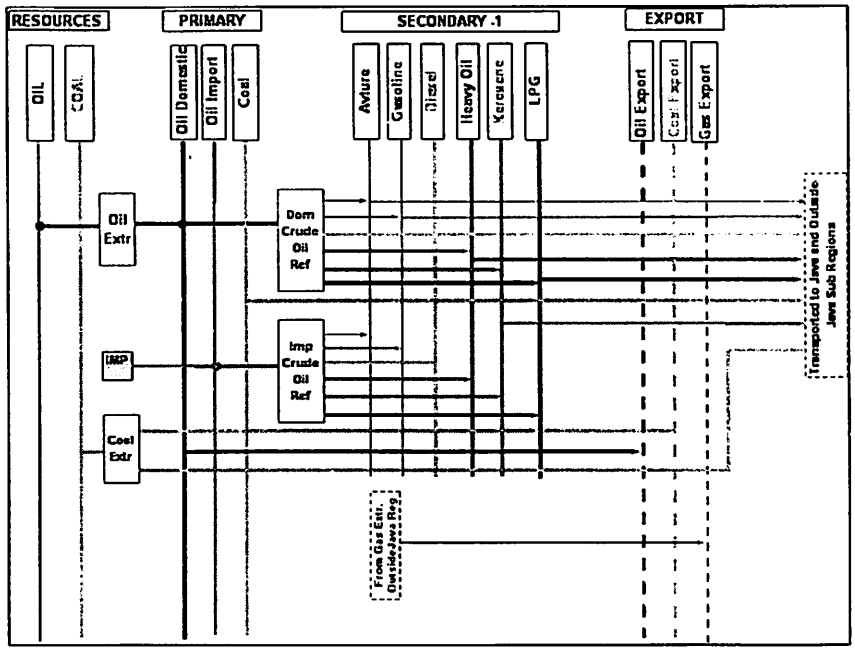

Fig. II.1.a. Main Region Energy System

JAVA REGION

In Java region it is assumed that there are no energy resources. The energy level are secondary and final energy. The secondary level consists of electricity, diesel oil, heavy oil, gas, coal. The final demand consists of services, manufacture, transportation, household, agriculture-construction-mining sector. Electricity grid already exists in Java Island with installed capacity of about 15.5 GWe consist of, oil power plant (diesel, gas turbine, steam oil fired, combine cycle), gas power plant (gas

turbine, steam gas fired, combine cycle), coal power plant, hydro (small and large) and geothermal.

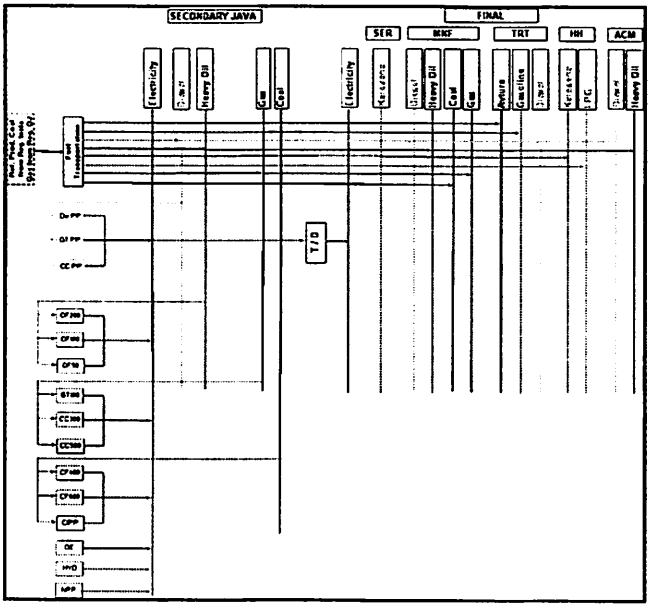

Fig. II.1.b. Sub. Region Java Energy System

OUTSIDE JAVA REGION

Most of the gas resources exist in Outside Java region are transported and distributed to other region by pipeline as primary energy. The Outside Java comprises of four big islands, electricity grid will be assumed as one grid system with installed capacity of about 5.3 GWe compresses of oil power plant (diesel, gas turbine, steam oil fired, combine cycle) gas power plant (gas turbine, steam gas fired, combine cycle), gas power plant (gas turbine, steam gas fired, combine cycle), coal power plant, hydro (small and large) and geothermal.

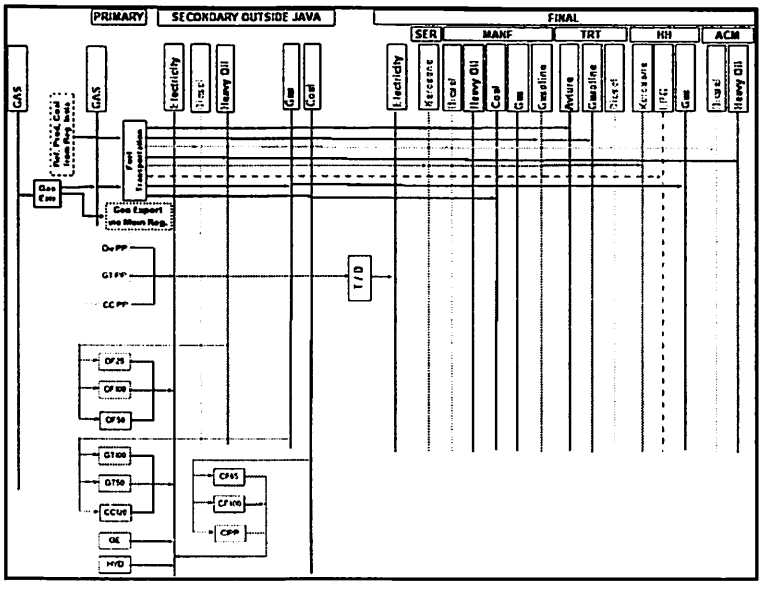

Fig. II.1.c. Sub. Region outside Java Energy system

d. Candidate of Power plants for Future

The power plans for Future development Java – Bali grid system consist

1. Nuclear power plant (1000 MWe)
2. Coal Power plant (600 MWe)
3. Coal Power plant (400 MWe)
4. Gas Combined Cycle Power Plant (500 MWe)

In this case the geothermal and hydro not competing in the grid, the plant will be fixed in the system as committed power plant.

Table II.1. The economic and technical parameter of power plant

	Unit	Coal PP	Gas CC	NPP
Capital cost	$/kWe	1,100.00	650	1,800
Construction time	Year	5	3	6
Ec. Life time	Year	30	30	40
Fixed O&M cost	$/kWyr	10	8	46
Variable O&M cost	$/kWyr	17.5	17.5	71.8
Efficiency	fraction	0.33	0.4	1
Capacity factor	fraction	0.65	0.8	0.8

III. ENERGY SOURCE

Indonesia's oil reserves are not large – as of year 2000 they equaled 9,61 million barrels. Of these, proven reserves are 5,12 million barrels, and potential reserves are 4,490 million barrels. Compared to the world's oil reserves at 916.6 billion barrels, Indonesia's reserves are small, at just 1 percent.

The pattern of development of natural gas reserves shows that they are decreased from 1978 to 1984, but then increased from 1985 to 1996. As of year 2000 Indonesia's proven and potential gas reserves were respectively 94.75 trillion standard cubic feet (tscf) and 75.56 tscf for a total of 170.31 tscf. Compared to the world's reserves, Indonesia's natural gas reserves are small – only about 2 percent.

Total known coal resources reached 38,874.86 billion tones in 2000, but the amount of economically exploitable coal, either through open-pit or underground mining, is still limited. Thus proven reserves are only 4.9 billion tones; the rest is still inferred, indicated and hypothetical reserves. Indonesia's coal reserves are only 3 percent of the world's reserves.

Results of investigations have shown that in this area there are 70 prospective locations for geothermal energy development, with a total potential of 19.7 GWe, consisting of 5.5 GWe in Java Island, 8.3 GWe in Sumatra Island and the rest in Sulawesi Island and other islands. Of this total potential, only a small portion is being utilized, about 0.59 GWe.

The potential of wind energy is in general small on account of the generally low average wind speed of between 3 and 5 m/second. But in certain areas, particularly in the eastern part of Indonesia, the wind speed is higher than 5 m/sec. The total potential of wind energy is estimated to be 0.45 GWe. The current installed capacity of wind generators is still small, estimated at about 220 kWe for rural electricity.

Table III.1. Energy Sources

Energy Source	Unit	Total
Crude Oil	Billion Barrel	9.61
Natural Gas	Trillion Cubic Feet	170.31
Coal	10^6Tons	38,874.86
Geothermal Power	Mwe	19,658
Hydro Power	MWe	75,674

IV. ELECTRICITY SECTOR

IV.1. Electricity System

The electricity supply in Indonesia, especially for the Java-Bali interconnected system, represents 80% of the whole Indonesian electricity consumption. Nearly 65.5% of the average electricity produced (PLN and private industry/captive power) was generated in Java. The reasons were the more intensive economic development in Java and the availability of an interconnection grid. The fuels for electricity generation are coal, gas, middle distillate, fuel oil, hydropower and geothermal power generation. Coal is Indonesia's cheapest primary energy resources up to certain level of use, where ash disposal or air pollution problem becomes the limitation. However, more efficient technology and clean technology can mitigate the problem. One of the options is that nuclear power generation for future electricity supply strategy for efficient and clean technology.

The Java-Bali system consists of various types of fuel, type of plant and capacity of the power generation. The 600 MWe coal power plants is the largest capacity and there are some diesel power plants for local peaking. The electricity sending to transportation,

mining-agriculture-construction, household, services and manufacture sectors. The largest consumers are household, manufacture and services sector.

Outside Java, load dependency of electricity generation is neglected; no use of concepts such as base load, peak load, peak time, off-peak time is made. Rather, small units of coal, oil, gas-fired steam plants, and hydro power plants as drawn up in the installation schedules or in potential studies, and diesel generator sets are the options. As in reality, power plants outside Java are operated at comparably low capacity factors that slightly grow over the time horizon.

The electricity system in Sumatra, Kalimantan, Sulawesi, and others, assumed as one system, called the outside Java-Bali system. The system consists of various types of fuel, type of plant and small capacity of the power generation. There are a lot of small diesel power plants, less than 1 MWe which supply the system for peaking. The four (4) units of 65 MWe coal power plants are the largest capacity located in Sumatra, as a mine-mouth power plant. Most of the electricity is consumed by household and services sectors.

IV.2. Composition of Power Supply System

Most electricity used in Indonesia was supplied by State Electricity Company (PLN), while the rest were produced by private company. Since PLN could not serve the entire regions in Indonesia, Non PLN companies emerged to produce electricity on their own capacity, for example those managed by cooperatives, local government, and other private companies. Installed capacity of PLN electricity tended to increase during the last five years, with 10.62 % increase per year. The PLN total installed capacity up to 2001 is 21,058.83 MW with more than 29 million consumers or increase 1.43% that compared 20,761 MW in 2000. In Java the install capacity in year 2001 was 15,494 MW or 74% of the total installed capacity. The peak load for Indonesia which is 16,314 MW in 2001, or increase 6.5% from the past (year 2000).

Table IV.1. National Installed Capacity of Power Plants (MW)

POWER PLANT	1999			2000			2001		
	PLN	IPP	Captive	PLN	IPP	Captive	PLN	IPP	Captive
PLTA/*Hydro PowerPlant*	3,012.10			3,015.25	7.59	1,176.44	3,105.86	6.75	
PLTP/*Geothermal*	360.00			360.00	165		380.00		
P L TU-B/*Steam Coal*	4,615.00			4,790.00	819	322.47	4,920.00	511.61	
PLTU-G/*Steam Natural Gas*	1,030.00			855.00	50	2,288.43	855.00	387.12	
PLTG-G/*Natural Gas Turbine*	324.46			343.66	395.82		343.66	702.05	
PLTGU-G/Combine Cycle	4,125.24			3,616.66			3,616.66	6.00	
PLTU-M/*Steam Oil*	1,125.00			1,125.00		421.66	1,125.00	135.00	
PLTD/Diesel	2,651.87			2,549.85	166.01	8,507.47	2,585.02	431.03	
PLTG-M/*Gas Turbine Oil*	911.65			859.71		2,205.62	881.06	40.00	
PLTGU-M/Combine Cycle	2,436.46			3,246.56			3,246.56		
PLTU-LK/*Dendro Thermal*					5.38	298.04		147.38	
TOTAL	20,591.78	3,400.00	13,519.79	20,761.69	1,608.80	15,220.13	21,058.82	2,366.94	12,691.84
National	37,511.57			37,590.62			36,117.60		

Source data: DJLPE, PLN Statistics2001, Indonesia University "Energy Outlook 2000".

V. ENERGY DEMAND

The energy demand projection based on results of study of Comprehensive Assessment of Different Energy Sources for Electricity Generation in Indonesia year 2002 using MAED model.

Table V.1 Indonesia Final Energy Demand Projection (PJ)

	2000	2005	2010	2015	2020	2025
Gasoline	62.007	71.493	84.149	98.193	114.402	133.056
Diesel	108.081	123.734	146.783	174.269	210.141	252.222
Heavy Oil	134.143	158.363	199.261	246.2	308.386	382.272
Coal	7.443	10.373	15.868	22.862	32.666	46.323
GAS	4.588	6.669	10.922	16.737	24.651	36.034
Non-Comm.	293.328	304.593	321.54	335.983	344.654	363.715
Electricity	66.572	86.017	117.965	157.27	210.403	283.676
Coke	0.232	0.256	0.309	0.385	0.502	0.673
Feed stock						
a. Oil product	0.7	1.576	2.276	2.976	4.202	5.252
b. Gas	2.801	6.303	9.104	11.905	16.807	21.009
TOTAL	679.895	769.377	908.177	1066.78	1266.814	1524.232

VI. ENERGY PRODUCTION, EXPORT – IMPORT

Up to 1986 the growth of Indonesian export was still dominated by oil and gas. Since 1987, it changed due to some new deregulation and policies issued by the Indonesian government. Export volume of oil and its products in 2000 was 38,012.5 thousand mton or decreased around 13.7 % compared to 1999. In 2000, the total value of export of oil and its products was US$ 7,958.4 million; it was higher than the value of export 1999 around 35.77%. Although Indonesia go into the producer of Oil and Gas, as an OPEC Organization, Indonesia still import oil and gas from other country for fill the national demand. Value of the Indonesia import oil and gas in year 2000 is US $ 6,019.5 million or 17.96% from the total value.

Table VI.1. Energy Production, Export and Import

	Unit	1998	1999	2000
Type Of Production				
Crude Oil and Condensate	*Thousand Barrel*	568,782.26	545,579.1	517,488.7
Gas	*MMSCF*	2,978,851.90	3,022,053.1	2,901,301.7
LNG	*Million Tons*	27,179,907.27	29,812,374.2	27,321,019.9
LPG	*Million Tons*	2,343,944.17	2,263,518.1	2,087,669.1
Coal	*Million Tons*	60,320,952	70,702,680.0	61,094,410.0
Type Of Export				
Crude Oil	*Million USD*	34,449.0	4,949.5	6,282.5
Refinery Products	*Million USD*	695.4	912.2	1,675.9
LNG	*Million USD*	3,389.8	4,489.1	6,802.1
LPG	*Million USD*	257.1	339.2	393.7
IMPORT				
Total Import of Crude Oil	*Barrel*	72,475,974.0	84,692,005.0	79,978,099.0
	103 USD	985,736.0	1,501,245.6	2,303,513.3
Total Import of Fuel Oil	*Barrel*	54,053,825.0	79,901,993.0	87,001,611.0
	103 USD	803,446.3	1,656,375.9	2,889,988.0
TOTAL Import	*Barrel*	126,529,799.0	164,593,998.0	166,979,710.0
	103 USD	1,789,182.3	3,157,621.5	5,193,501.3

VII. RESULTS AND ANALYSIS

VII.1. Electricity

a. Java Bali System

Figure VII.1.1 show the Composition of energy generation (GWyr) and capacity addition of various power plants in Java-Bali system, the total largest generation produced by coal fired power plant (CFPP) with capacity 400 MW with total amount 1,967 TWyr entire the study period and the second is CFPP with capacity 600 MW about 945.6 TWyr. This program only chose the coal generating, because coal generating cheapest price if compared to the price of other generating. This matter differ from calculation optimasion at ENPEP program. In ENPEP program will relied on requirement supply-demand and price energy.

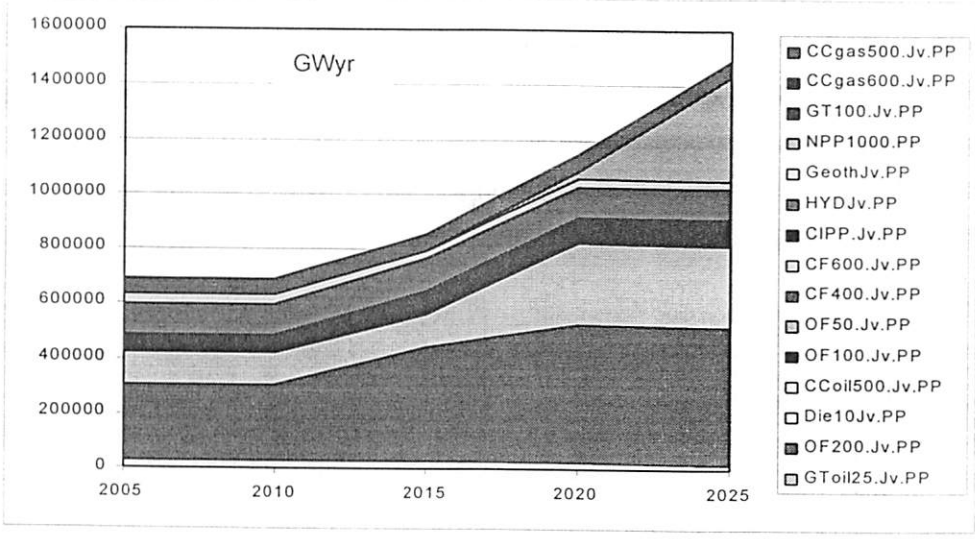

Figure VII.1.1 The Composition of energy generation (GWyr) by various power plants in Java-Bali system

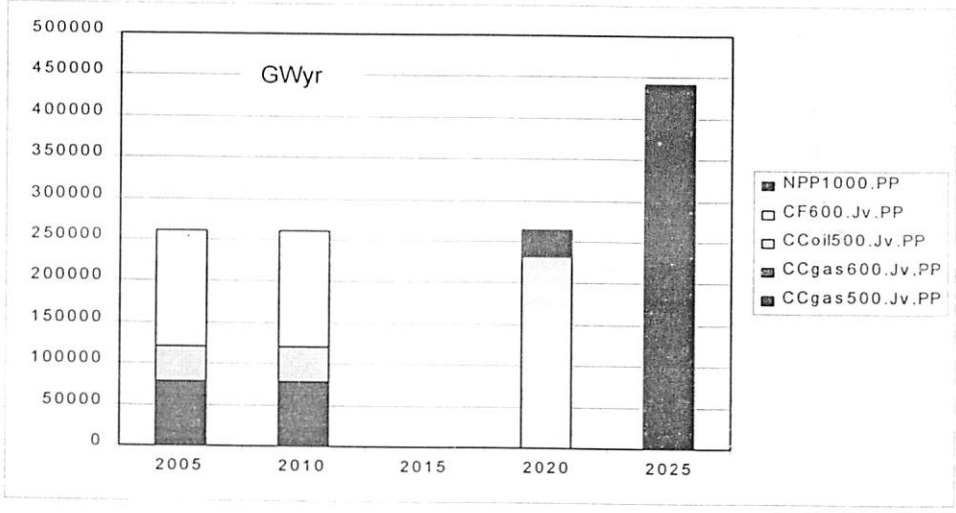

Figure VII.1.2.Capacity addition of various power plants in Java Bali system

Seen at the first and second period of study (2000-2005 and 2005-2010), power plant which in competition at this study emerging only Coal fired and Combine gas cycle power plant compete market with oil cycle combine power plant, while at the third period of study (2010-2015) no addition of new generating. At fourth period (2015-2020), Coal fired generating still predominate market, competing with nuclear generating (about 87.5%). Nuclear Power Plant will be entering in the Java Bali system at year period between 2015 and 2020. And will predominating addition of capacities by the end period of study (year 2020-2025).

b. Outside Java-Bali

Figure VII.1.3. Composition of energy generation (GWyr) and capacity addition of various power plants in Outside Java-Bali, the total largest generation produced by hydro power plant (HPP) 7.5 TWyr entire the study period and the second is oil fired power plant with unit capacity 25 MW about 6.6 TWyr.

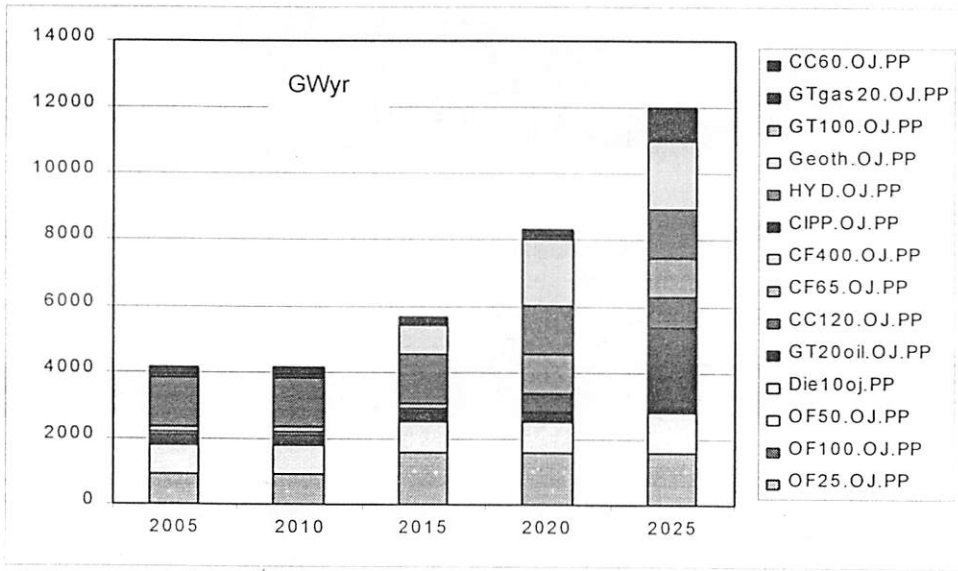

Figure VII.1.3. Composition of energy generation (GWyr) by various power plants in Outside Java-Bali

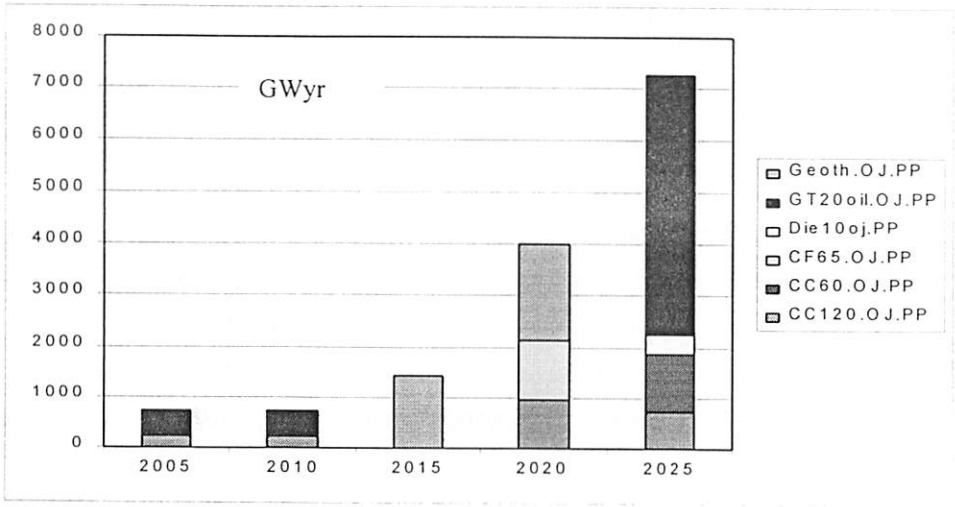

Figure VII.1.4.Capacity addition of various power plants in Outside Java Bali

VII.2. Energy Supply

The largest primary energy will be supplied by coal with the total 12,199 TWyr, about 86.38% share. Second share is about 5.63% or 795.7 TWyr supplied by gas, other primary are hydro 556.5 TWyr (4.01%), oil 398.4 TWyr (2.82%) and geothermal 162.4 TWyr (1.15%). Most of coal supply for generating power plants, it is about 99,87% to total domestic use. This matter is caused in this study include coal generating as generating candidate which competition.

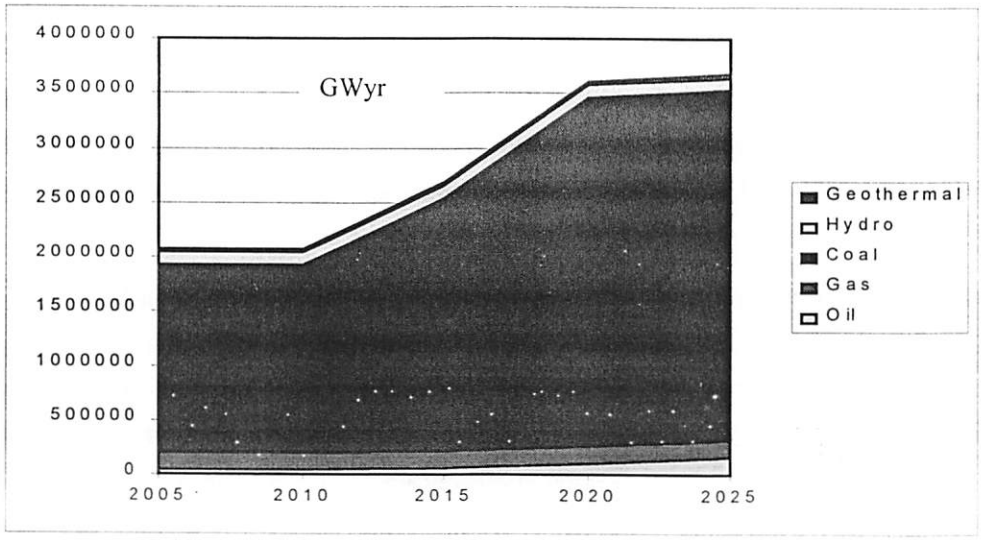

Figure.VII.2.1. Indigenous Energy Supply

As well as coal power plant, the largest gas supply for generating power plant in Java-Bali system, it is about 587.4 TWyr (97.83%), about 6.8 TWyr (1.14%) for outside Java-Bali region and the remain less then 1% each for other purpose (household, manufacturing in Java and outside Java).

VIII. CONCLUSION

1. MESSAGE is one of models that recommended by IAEA with useful tool for energy and electricity planning. Especially for energy system in Indonesia that has complex energy system, many type of energy resources, regionalized area, and spreading of demand.

2. The result for Balance Estimation based only seeing cheap price. This matter seen at pigure VII.2.1, that program only chose the coal generating, because coal generating cheapest price if compared to the price of other generating. This matter differ from calculation optimasion at ENPEP program. In ENPEP program will relied on requirement supply-demand and price energy. In this study, seen that Nuclear Power Plant will be entering in the Java Bali system at year period between 2015 and 2020. And will dominate addition of capacities by the end period of study (year 2020-2025). Domination of coal supply for domestic use, specially for power generation, shows that the coal power plant cheaper than other power plant.

3. At present, Indonesia does not have any NPP. The introduction of NPP in Indonesia is not only to reach an optimum energy mix considering costs and environment, but also to relieve the pressure arising from increasing domestic demand for oil and gas (so that oil and gas could be used for export and feedstock to support the take-off era towards the Long Term Development Program - LTDP). This concept is exactly congruent to the national energy policy which stresses diversification, conservation and environmental awareness in energy supply development.

4. Nuclear energy has very important long term roles in the energy scenario and it is possible to do the market competitive when the Multi buyer Multi Seller will be done in the system electricity sell in Indonesia (the government has changed the target of MBMS realization into 2007).

IX. REFERENCES

1. Comprehensive Assessment of Different Energy Sources for Electricity Generation in Indonesia, "*Energy Demand and Supply Analysis (Phase I)*"; "*Energy Supply Analysis Including Environmental Assessment (Phase II)*", Indonesia-IAEA, 2002-2003.
2. PT. PLN Statistic year 1999-2001.
3. University of Indonesia "*Indonesia Energy Outlook & Statistics*", Jakarta, 2002.
4. Directorate General of Electricity and Energy Utilization, "*Electricity and Energy Statistic year 2001*", Jakarta, November 2002.
5. *"Perekonomian Indonesia tahun 2004: Prospek Dan Kebijakan"*, Kantor Menteri Negara Perencanaan Pembangunan Nasional/Badan Perencanaan Pembangunan Nasional (BAPPENAS), Desember 2003.