Case Studies on Comparing Sustainable Enery Mixes for Electricity Generation in Indonesia[*)]

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1. Introduction

Agency for the Assessment and Application of Technology (BPPT), Indonesia and International Atomic Energy Agency (IAEA), Austria has been conducting a cooperation study since 1995. In the phase I study (1995-1997) that carried out within the Research Contract with titled *Comparative Assessment of Electricity Supply Strategies in Indonesia*, BPPT is still using MARKAL model. In the phase II study (1997-1999), a software package (DECADES) developed by IAEA is used for the study. The title of the study is *Case Studies on Comparing Sustainable Energy Mixes for Electricity Generation in Indonesia*.

The objective of the phase II study is to design sustainable energy mix for electricity generation in Indonesia for a long period (1995 - 2025) as an optimum result of the integration among national economic growth, common energy technology, and environmental aspects. For the first year term (1997-1998), BPPT completed Country Specific Database (CSDB) as an input for DECADES Tools. In the second year term (1998-1999), the study has main tasks as follows:

- To build strategic planning for electricity generation that can maintain sustainable energy mix. Taken into consideration of the economic crisis that hit Indonesia since 1997.
- To establish and assess indicators for sustainable energy development.

The paper will discuss final report of the second year term and proposed project for the year 1999-2000.

2. Electricity in Indonesia

Electricity in Indonesia is operated by PLN (State Electricity Company), IPP (Independent Power Producer), and auto-generation (captive power). In 1997, PLN installed capacity reached 18.9 GW while that of IPP and captive power reached consecutively 0.8 GW and 12.4 GW. Meanwhile, the total electricity generation was 116.5 TWh that consisted of 74.0 TWh of PLN, 3.4 TWh of IPP, and 39.1 TWh of captive power. In other words, PLN was the biggest player for electricity generation in Indonesia with share of 63.5% of the total generation.

During seven years period from 1990 to 1997, total electric generation production had grown rapidly from about 57000 GWh to 113000 GWh or had increased with the average growth rate of 10 percent per year. The electricity production is used to fulfill the rapid increase of electricity demand in industrial, residential, and commercial sectors. However most of the electricity demand is used to meet the energy demand in industrial sector.

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The electricity generation capacity is mostly generated by oil basis, while, the remaining is generated by coal, natural gas, hydropower, and geothermal. Even though all of those energy for electric generation are obtained from Indonesian's energy resources, environmental and economical aspects as a result of the increase of the energy demand for electricity have to be considered. Fossil fuels are not only used to meet domestic energy demand but also used for export. Fossil fuels are also considered as depletable energy sources. Pollutant emissions from using fossil fuels also have to be considered. Meanwhile, hydropower and geothermal that are considered as non-exported energy sources are available in big potential in Indonesia. However, their potential are mostly far from demand sites that would affect to high investment costs to develop. In addition, development of hydropower needs large area for plant site.

PLN has been hit hard by the economic crisis by the depreciation of the rupiah (Rp) since July 1997, with the result that PLN's annual deficit is now projected to reach USD 1 billion. PLN's financial situation has been exacerbated by expenses (fuel purchases and debt payments) in dollars, while revenues (subsidized tariffs) are earned in rupiah.

Currently, PLN operates in 27 provinces divided into 16 operation areas that consist of 4 PLN Distributions, 11 PLN Regions and 1 PLN special Region of Batam. While, PLN's revenue is mostly or 80% from Java Bali interconnection system. In addition, PLN has several separate systems in Outside of Java and Bali. Sumatra is the second biggest (10%) revenue for PLN. In planning, Sumatra will be interconnected to Java-Bali interconnection system in the year 2000

3. Modeling Aspect

3.1. System Representation

Table 1 shows the installed capacity, electricity generation and capacity range for the PLN in 1997. The installed capacity mainly is generated by steam power plant. While the rests of the installed capacity are generated by gas combined cycle power plant and diesel power plant respectively. The biggest share of electricity generation is also generated by steam power plant. The main fuel for steam power plant is coal.

Table 1. PLN Power Plant: Unit Number, Installed Capacity, Electricity Generation, and Capacity Range in 1997

Power Plant Type	Unit Number	Install Capacity (MW)	Electricity Generation (TWh)	Capacity Range (MW)		
				Minimum	Medium	Maximum
Hydropower	154	2.44	5.1	4	63	175
Steam	38	6.77	31.5	12.8	65	400
Gas Turbine	50	1.29	1.7	12.8	30	84
Gas C. Cycle	40	5.59	27.3	30	135	400
Geothermal	6	0.36	2.6	10	30	55
Diesel	3683	2.49	5.8	0.1	6.3	12.4
Total PLN	3971	18.95	74.0			

Taken into account the current situation, in the model a fixed system for power plant as shown in Table 2. Table 3 shows technology that considered for the candidate for power plant. Except ENA (nuclear), all these technologies are proven and are already committed to install

in Indonesia. In line with government policy, oil power plant will be phased-out in the future. Therefore, oil power plant doesn't be included in the candidate for power plant.

Table 2. Fixed System

No.	Power Plant	Symbol	Unit (MW)
1	Coal Steam	E4E	400
2	Oil Steam	EOA	65
3	Diesel	EDD	1
4	Gas Turbine	ETA	20
5	Gas Combined Cycle	EYA	250
6	Geothermal	EGA	55
7	DAM hydroelectric	EWA	400

Table 3. Candidate System

No.	Power Plant	Symbol	Unit (MW)
1	Coal Steam	SXW	600
2	Diesel	EDC	1
3	Gas Turbine	EUB	65
4	Gas Combined Cycle	EYB	250
5	Geothermal	SPS	55
6	DAM hydroelectric	EWB	600
7	Nuclear	ENA	600

3.2. Building Scenario

Two scenario cases are created in the study to make strategy for sustainable electricity development (Table 4). For each of two scenarios of electricity demand (BAU and NEC) is added with two scenario cases as follows:

- penalty on depletion of fossil fuel (coal, oil, and gas)
- add constraint for gas availability.

Table 4. Scenario and Case

Scenario	Comment	Case
BAU	Business As Usual (Taken into account the Economic crisis)	1. Penalty on depletion of coal
		2. Penalty on depletion of oil
		3. Penalty on depletion of gas
		4. Constraint for gas availability
NEC	No Economic Crisis	1. Penalty on depletion of coal
		2. Penalty on depletion of oil
		3. Penalty on depletion of gas
		4. Constraint for gas availability

4. Result

4.1. Output of the Model

As the electricity demand continues to increase, while, the energy sources to generate the electricity are limited that would lead to some negative consequences both economically and environmentally in the future. In order to solve the problem, energy strategies by comparing sustainable energy mixes for electricity generation needs to be explored and

extended. DECADES Model can be used as a tool for justifying the strategies. However, we had technical problem to run the DECPAC Model. Therefore, the results of the model for comparing sustainable energy mixes for electric generation can not be presented now.

4.1.1. Energy Production Cost

The comparison of each technology was made using technology, economic and environment data collected for the CSDB. If there is no adequate data for CSDB then RTDB from DECADES or generic data from EM Model (Ver. 1.4 developed by OKO-Institut and GTZ) is used. Figure 1 shows the annual production cost of each technology. For simplicity, it was assumed that all plant operated at 6500 GWh/y. Among the thermal plants, the gas combine cycle has economic advantages if power plant is operated with capacity factor lower than 0.20. The oil fired power plant only has advantage than gas combined if operated with capacity factor lower than 0.35. The coal power plant relatively has a lowest cost comparing with others power plant if operated with capacity factor more than 0.30. Nuclear power plant has high investment cost and only competitive comparing with gas combined cycle power plant for capacity factor more than 0.5.

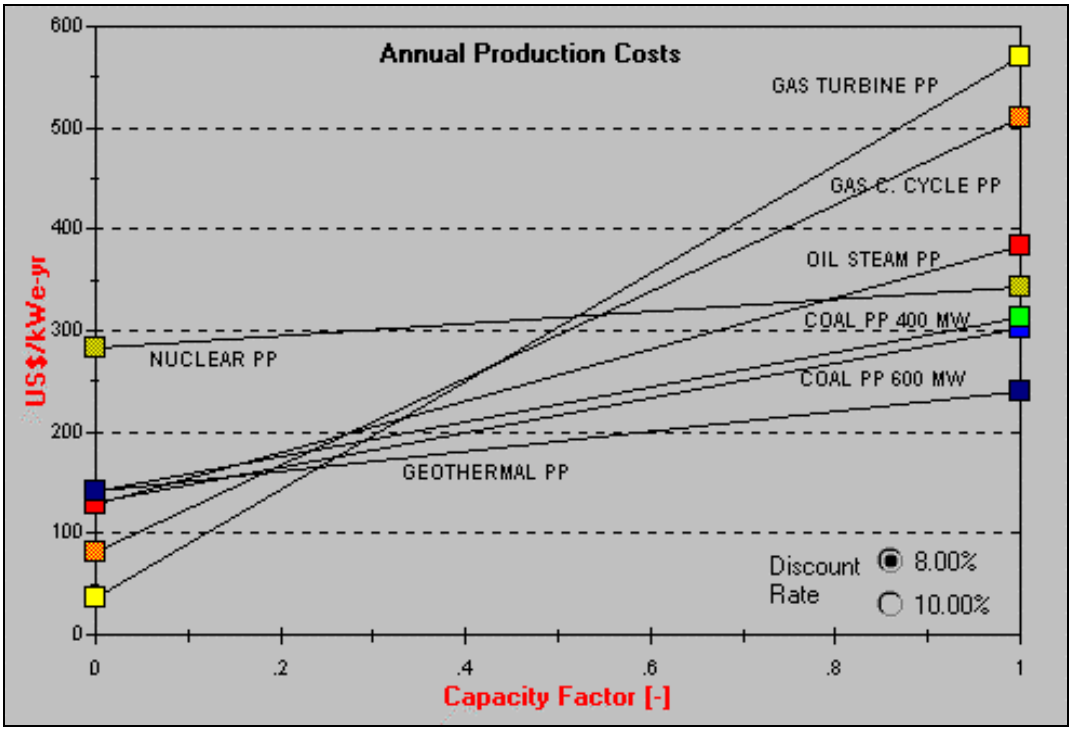

Figure 1. Energy Production Cost

4.1.2. Electricity Sales by PLN

In the crisis electricity sales by PLN is still increasing as show in Figure 2. In the period 1991 until 1997 electricity sale grows about 11 % to 16 % per year, but during the economic crisis condition (1997-1998) it only grows about 1 % per year. While electricity sales of PLN for industry decreases about 9 % per year.

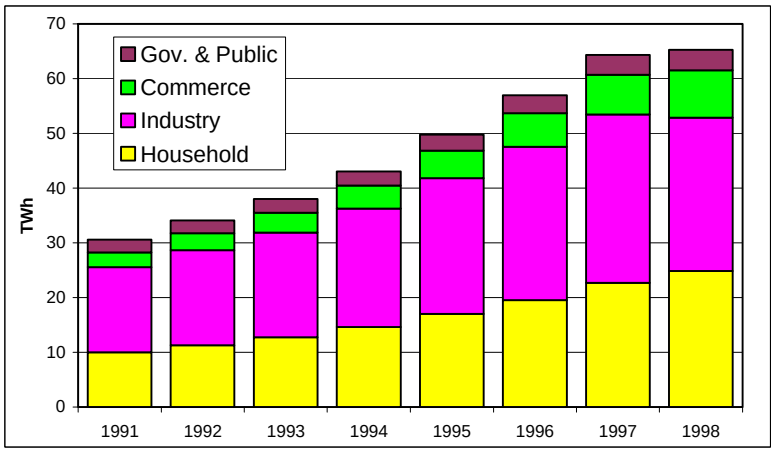

Figure 2. Electricity Sale by Sectors (PLN)

4.1.3. Load Curve

There is no significant change in PLN load curve since 1983. In 1999 the peak load time is 18 - 22 h and off peak time is 23 - 17 h. Maximum peak load in the economic crisis is still increase if compare with the condition before economic crisis (1996).

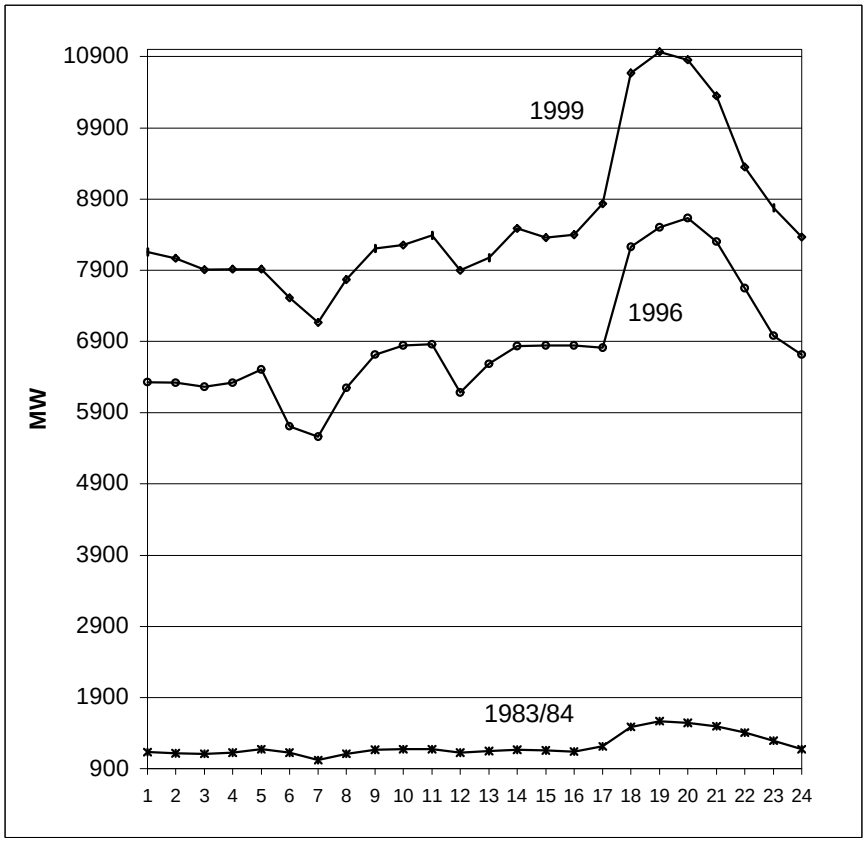

Figure 3. PLN Load Curve in 1983/84, 1996, and 1999

4.2. PLN Effort

PLN makes effort to struggle in the economic crisis situation. Some efforts that currently are considered are as follows.

4.2.1. Tariff Agreement

To compensate for the depreciation of the rupiah, PLN announced in January 1998 that it would pay its energy supply bills at the reduced rupiah rate of Rp 2,450/USD. The government of Indonesia later agreed to cover PLN payments for January-March 1998 and stated that PLN had overstepped its authority by not fulfilling its contract terms. Despite the statement, PLN continues to pay at reduced rupiah rates and has requested additional funds from the Ministry of Finance to cover its bills. PLN has stated publicly its intention to renegotiate contracts with independent power producers (IPP's), but has been slow to examine inefficiencies at its own plants. PLN has stepped back from implementing electricity tariff increases decreed in May 1998 for low-income consumers. The anticipated replacement of PLN's CEO, reducing demand for electricity and recent power outages have also focused attention on this beleaguered company.

4.2.2. Restructuring Policy

PLN has potential success in the restructuring of PLN into a private company and opening up of private sector opportunity. PLN is responding to this change in the climate by doing to the following:

- Establishing new Branches, Sector, and Regions
- Regrouping the Power Stations, Transmission Lines and Distribution Network outside of Java.
- Establishing Joint Ventures
- Establishing Supporting Units Subsidiaries
- Regrouping the Principal Projects in Java

As the policy mentioned, the future Java Bali Transmission Company will bear the responsibility as the key role to the electricity market development towards the Multi-Buyer Multi-Seller market around the year 2003. This means that new policy for Market Operator will be added to its existing duties as System Operator and Transmission Owner.

4.2.3. Marketing

In order to improve service to all customers and to increase sales of electricity, PLN has 3 special products as follows:

- **Gong 2000**
  PLN offers discount with the range 5 % to 50 % for connection charge of new electric power connection and expanding electric power connection.
- **Listrik Kencono**
  PLN offers discount for energy charge if any consumers with big energy consumption. The rate of the discount depends on the type of consumers and the voltage range (low voltage, medium voltage, and high voltage).
- **Listrik Prima**
  PLN offer new services for consumer that need high quality service with addition cost. There are 3 possibilities to have the facility, i.e.: for specific conditions can be supplied by double incoming resource electric power, installed by double incoming cubicle with ATS, and installed using under ground cable, if needed.

5. Sustainable Development Indicators

Chapter 40 of Agenda 21 calls for the development of indicators for sustainable development. A core set of indicators is proposed for monitoring progress at national level towards sustainable development through the implementation of Agenda 21. The indicators in the core set are presented in a Driving Force - State - Response framework. Driving force indicators indicate human activities, processes and patterns that impact on sustainable development, state indicators indicate the state of sustainable development and response indicators indicate policy options and other responses to the change in the state development.

Some indicators of sustainable development for electricity sector in Indonesia will be presented in Table 5.

Table 5. Indicator of Sustainable Development for Electricity Sector in Indonesia

Category	Chapters of Agenda 21	Indicators		
		Driving Force	State	Response
Social	Chapter 3: Combating Poverty	• Electricity Price (Rp./kWh)	• Electricity price per GDP (Rp/Rp) • Share of population with access to electricity (%)	• Rural Electrification Ratio (%)
Economic	Chapter 2: International Cooperation	• Local content of electric power plant (%)	• GDP from manufacturing sector (Rp.)	• Share of Industry Sector over GDP (%)
	Chapter 4: Changing Consumption Pattern	• Annual electricity consumption per capita (kWh/cap.) • Annual electricity consumption per GDP (kWh/Rp.) • Depletion of energy resource (J)	• Share of fossil fuel in electricity generation (%) • Reserve per production (R/P) of oil (year) • Reserve per production (R/P) of gas (year) • Reserve per production (R/P) of coal (year)	• Ratio of renewable resource consumption over non-renewable resource consumption (%)
Atmosphere	Chapter 9: Protection of the Atmosphere	• Emission of CO2 from electricity generation (t) • Emission of SOx from electricity generation (t) • Emission of NOx from electricity generation (t)	• Emission of SOx per unit of electricity generation (t/kWh) • Emission of NOx per unit of electricity generation (t/kWh)	• Expediture on air pollution abatement (US$) • Ambient concentration of SOx (ppm) • Ambient concentration of NOx (ppm)
Waste	Chapter 20: Solid Waste and Sewage Related Issues	• Liquid waste from electricity generation (t) • Solid waste from electricity generation (t)	• Liquid waste per unit of electricity generation (t/kWh) • Solid waste per unit of electricity generation (t/kWh)	• Waste recycling rate (%)

6. Proposed Project

In the period January 2000 until December 2000, BPPT has submitted renewal of research contract with detail of work as follows:

- analysis and evaluation impacts of restructuring policy in electricity sector and successful factor for solving a contract problem between IPP (Independent Power Producer) as a seller and PLN (State Electricity Company) as a buyer of electricity.
- making inventory of study result that related to energy and electricity planning in Indonesia, i.e.:
  - Environmental impacts of energy strategies for Indonesia
  - Technology assessment for energy related CO_2 reduction strategies for Indonesia
  - Long term energy supply strategies using optimization
- identifying for alternatives and criteria from above studies as a decision problem.
- intensive study and test-run of DAM (Decision Aiding Module) software as a tool to solve multiple criteria decision analysis problems
- performing 'what-if' analysis and 'trade-off' analysis using DAM software
- evaluation and analysis of DAM output
- reporting and submitting conclusion and recommendation of multiple criteria decision analysis.

7. Concluding Remark

Electricity demand continues to increase, while, the energy sources to generate the electricity are going to limited that would lead to some negative consequences both economically and environmentally in the future. In order to solve the problem, energy strategies by comparing sustainable energy mixes for electricity generation needs to be explored and extended. DECADES Model can be used as a tool for justifying those strategies. However, we had technical problem to run the Model in Indonesia.

Reference

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