Electricity Planning in Indonesia using DECADES Tools[1]

Agus Sugiyono
La Ode M.A. Wahid
Irawan Rahardjo
Agency for the Assessment and Application of Technology (BPPT)

Farid S. Kresna
National Atomic Energy Agency (BATAN)

1. Introduction

BPPT, Indonesia and IAEA, Austria have been conducting a cooperation study on electricity optimization planning for Indonesia. 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 (1997-1998), 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 - 2020) as an optimum result of the integration between national economic growth, common energy technology, and environmental aspects. Scopes of the study are:

- to improve current database in CSDB
- to build strategic scenarios that can maintain sustainable energy mix for electricity generation.
- to optimize the electricity supply by using DECPAC Model.
- to analyze the result and the environmental impact.

2. Background on Indonesia

In DECADES Tools one of the main input data is electricity demand projection. Some background on geographical, social and economic condition in Indonesia need to consider before make a projection. Indonesia is the largest archipelago in the world. It consists of five major islands and about 30 smaller groups. The geography of Indonesia is quite magnificent, supported by tropical climate and weather. The climate changes every six months. The dry season (June to September) is influenced by the Australian continental air masses; while the rainy season (December to March) is the result of the Asian and Pacific Ocean air masses. The air contains vapor, which precipitates and produces rain in the country. Tropical areas have rains almost the whole year through.

Indonesia is the world's fourth most populated country with a population of 200 millions. The population growth is controlled through efforts to lower the birth and mortality rate, especially that of infants and children. These efforts in particular have been implemented through family planning programs which also have the purpose of improving the welfare of mother and child and at the same time create a small, happy, and prosperous family. Family planning program in Indonesia is success, in which it is able to reduce the population growth rate from 2.10 % per year in 1967-1970 to 1.66 % per year in 1990-1995. Based on BAPPENAS estimation, the average population growth rate during 1995-1999 period is 1.6 %

[1] Presented at IAEA Regional Training Course on Comparative Assessment of Nuclear Power & Other Energy Sources in Support of Sustainable Energy Developments, 8 June – 3 July 1998, Taejon, Korea

per year. Furthermore, it is expected that the population growth rate will become 1.4 % per year in 2000-2004 period.

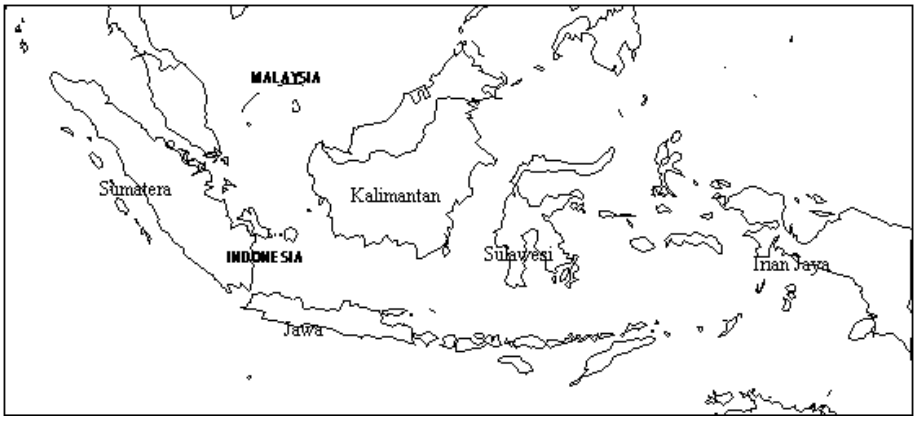

Figure 1. Map of Indonesia

Indonesia enjoys strong and consistent economic growth of around 6-7 % per year in the past (1990-1995). Stipulated by government deregulatory, market oriented policies, manufacturing and modern service sectors are making up an ever-greater proportion of GDP. Growth and structural change in the economy are being driven by private sector investment, both domestic and foreign. In this economic activity, mining and quarrying sector is divided into oil and gas, non-oil and quarrying. Manufacturing industry sector is also divided into oil and gas, and non-oil and gas. Service sectors are divided into public, private, and defense. Manufacturing industry's (not including oil) contribution on the national GDP in 1990 was 10 %, and in 1995 reached 14.7 %. Share of agricultural in the GDP was about 20.2 % in 1990; while, the combined contribution from agricultural, forestry and fishery was only 16.7 % in the 1995. Despite the fact that the share of agriculture in national GDP is expected to continue declining, its role in the economy is still vital since it provides the mayor source of employment.

Table 1. Historical Data for Population and Economic Growth

Year	Total Population (thousand)	Urban (thousand)	Rural (thousand)	GDP Growth (% constant price)
1990	179,250	55,434	123,816	-
1991	182,223	55,615	126,608	6.95
1992	185,259	55,792	129,467	6.43
1993	188,359	55,962	132,397	6.60
1994	191,524	56,127	135,397	7.54
1995	194,755	56,277	138,478	8.22

Source: BPS, Statistical Year Book of Indonesia

Based on the economic growth projection done by National Development Planning Board (BAPPENAS), there is a decrease of GDP growth from 7.1 % per year in period of 1995-1999 to 7.0 % per year in 2000-2004. While, the non-oil and gas economic growth remains in the same growths of 7.0 % per year. During 1995-1999, GDP growth of Indonesia (including oil and gas) is higher than economic growth of non-oil and gas. However, in 2000-2004, the GDP has the same growth as economic development of non-oil and gas. Therefore the projection should be update through the financial crash that has hit ASEAN economies, including Indonesia, continuing from June 1997. It has prompted to revise the investment on

infrastructure project. The Indonesia economics slump following extra ordinary of the decreasing Rupiah's exchange rate to foreign currencies from 2,475 Rupiah per US Dollar (early 1997) to average of 8000 Rupiah per US Dollar (early 1998) and drop again to 14000 Rupiah (in June 1998). In this condition, make Indonesia may not be able to maintain the economic growth predicted. In May 1998 the inflation rate counted 5.24 percent. The Center Bureau of Statistics (BPS) has assessed that inflation would reach 80 percent in 1998 when based on a monthly rate of around 5 percent in the seven months ahead.

Table 2. Macro Economic and Population Growth Projection

	Growth Rate (%/year)	
	(1995-1999)	(2000-2004)
Economic Growth	7.1	7.0
Non-Oil and Gas Economic Growth	7.0	7.0
Population Growth	1.6	1.4

3. Energy Resources

Indonesia has a lot of energy resources such as oil, natural gas, coal, hydropower, geothermal, solar, wind, and biomass. Total oil resources in Indonesia estimated by PERTAMINA is about 72 billion barrels in 1994, in which about 10.15 billion barrels are proven and probable reserves. In the same year, total gas resources were estimated about 266 TSCF, in which 90.03 TSCF was classified as proven and probable reserves. More than 60 % of gas reserves are located in off-shores. Total coal reserves are located mainly in Kalimantan and Sumatra that estimated about 36.34 billions tonnes in 1994, in which 24 billion tonnes are measured and indicated reserves. Indonesian coal types are ranged from lignite to anthracite, but only sub-bituminous and bituminous coal, almost 35 % of the total coal reserves are used for coal power plant and industrial sectors. Indonesia has a large hydropower potential of 75.50 GW, however only 2.91 % of the total hydropower potential or 2.20 GW has been utilized. Hydropower potential is distributed into 1,210 locations with a total electricity estimated production around 401,644 GWh. The total geothermal potential in Indonesia has been estimated about 16.1 that consisted of about 44 % reserve and 56 % resource of the total potential. Most or almost 56 % of the total reserves are located in Jawa-Bali, while geothermal resources in Jawa-Bali are only about 13 % of the total geothermal reserves in Indonesia.

Table 3. Primary Energy Resources in Indonesia

Reserve	Oil	Gas		Coal		Hydro		Geothermal	
	10^9 BOE	TSCF	10^9 BOE	10^9 Ton	10^9 BOE	GW	10^9 BOE	GW	10^9 BOE
Jawa	1.98	8.89	1.56	0.06	0.20	4.50	0.01	7.80	0.03
Sumatera	6.00	19.84	3.48	24.68	93.20	15.80	0.05	4.90	0.02
Kalimantan	1.39	22.81	4.00	11.50	43.40	21.60	0.07	-	-
Others	0.78	38.49	6.75	0.10	0.40	33.60	0.11	3.40	0.01
Total Indonesia	10.15	90.03	15.79	36.34	137.20	75.50	0.24	16.10	0.05

The primary energy supply for domestic market grows in line with economic expansion. Oil, which at present (1996) dominates with 37 % of the domestic market, will and reach a level nearly 2.8 times higher in the year 2020 as compare with 1996. Gas consumption grows by 4.1 % from 1996 until 2020, annually leading to a decline share to total primary energy. In the future time, coal will take over a dominant role.

Table 4. Primary Energy Supply Projection

Type of Energy	Primary Energy Supply (PJ/year)						
	1990	1995	2000	2005	2010	2015	2020
Biomass	1,002.15	1,113.11	1,209.59	1,301.69	1,425.77	1,540.76	1,688.83
Hydro/Geothermal	141.75	188.78	275.81	475.96	544.17	538.04	520.65
Coal	194.37	341.27	466.91	1,006.84	2,023.90	3,695.11	5,875.98
Gas	669.28	1,131.54	1,653.99	1,969.51	2,320.29	2,659.58	3,126.78
Oil	1,377.22	1,668.23	2,028.76	2,342.87	2,697.39	3,447.97	4,764.33
TOTAL	3,384.78	4,442.96	5,635.09	7,096.85	9,011.52	11,881.46	15,976.58

4. Electricity Sector

The electricity generation in Indonesia is supplied by PLN (interconnected system and decentralize) and auto-generation (captive power). The PLN's installed capacity in Indonesia increase from 4,080 MW in 1984 to 14,895 MW in 1995, or increase in average of 12.36 % per year. While, the auto-generation installed capacity increases from 3,206.19 MW in 1984 to 6,538.81 MW in 1995 or increase in average of 6.6 % per year. The electricity production of PLN increases about 14.08 % per year during that time, the production increases from 13.75 TWh to 59.40 TWh. The installed capacity of PLN in 1995 is mainly contributed by steam power plant, it is about 32.35 % of the total installed capacity. Gas combined cycle power plant is the second largest electric generation plant that contributes about 29.64 % of the total installed capacity. The rests of the installed capacity are contributed by hydropower plant (14.63 %), diesel power (14.61 %), gas turbine (about 6.73 %), and geothermal plant (2.04 %).

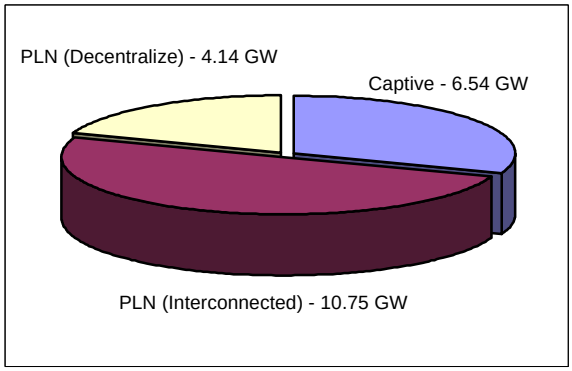

Figure 2. Share of PLN and Captive Power

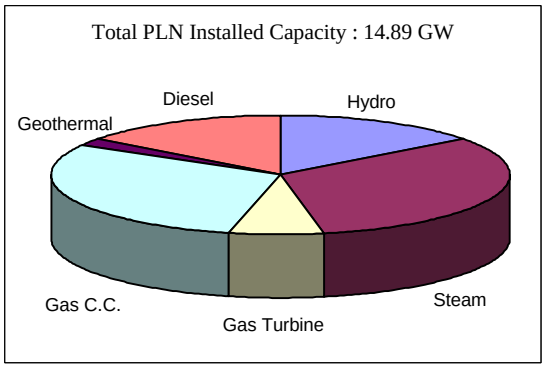

Figure 3. PLN Installed Capacity

Government policy on electric generation in principle is based on KUBE (General Policy of Energy Sector). It is consisted of energy policies on energy intensification, energy diversification, and energy conservation. In the utilization of oil as a depletable energy source, the Government encourages to use non-oil energy sources for electric power generation. The energy supply strategy for generation plant will be more emphasized on the utilization of clean energy sources that environmental friendly such as hydropower and geothermal. Next priority in the energy supply strategy is to use the energy sources that have abundant reserve such as coal and gas. Meanwhile, nuclear power is the last option of the energy source for generation plant.

5. System Modelling

The DECADES tools are used to make comparative assessment in this study. The methodology provides for:

- establishment of country specific database (CSDB) including technical, economic and environmental characteristic.
- analyze energy chain for each fuel type.
- optimize power system expansion under chosen set of resources.

In this study, 1995 is used as based year. The projection period of the study is 25 years; from 1996 to 2020; each year period have 2 period. Discount that used in the study is 10 %. Minimum reserve margin range from 15 % to 20 % and maximum reserve margin range from 25 to 30 %.

The power plant is divided into two groups, i.e. fixed system and variable system. The fixed system power plant is the power plants from existing, under construction, and under planning power plants. While, the variable system power plant is only the chosen power plants that have possibility to be developed in the future. Variable system is divided into thermal power plant and hydropower. The thermal power plant types is coal-fired power plant, oil steam power plant, gas turbine power plant, gas combine cycle, geothermal power plant, and nuclear power plant. The other plants for expansion is hydropower that divided into two types: DAM type hydropower with installed capacity 400 MW and run of river type hydropower with installed capacity 0.4 MW.

In the study two scenarios propose to taken into account are business as usual (BAU) without nuclear power plant and consider nuclear power plant (NUC) scenario. The sensitivity analysis using abatement technology and reducing discount rate from 10 % to 8 % should be taken into account. Therefore due to limitation of time and execution time is very slow (in case of Indonesia, one execution of Congen Sub-module need 5 hours) then in this study only run BAU scenario.

6. Electricity Comparison and Expansion

Comparison of the different thermal power plant for candidate power plant was carried out. The technology considered are:

- E4J : Coal Power Plant with install capacity 400 MW
- SXW : Coal Power Plant with install capacity 600 MW
- EOB : Oil Steam Power Plant with install capacity 65 MW
- EUB : Gas Turbine Power Plant with install capacity 65 MW
- EYB : Gas Combined Cycle Power Plant with install capacity 250 MW
- SPS : Geothermal Power Plant with install capacity 55 MW
- ENA1 : Nuclear Power Plant.

Except ENA1, all these technology are proven and are either in use in Indonesia. The comparison was made using technical, economic and environmental data collected for the CSDB. Figure 4 shows the annual production cost of each technology. For simplicity, it was assume that all plant operated at 3800 GWh/y. Among the thermal plant, the gas combine cycle has economic advantages. The gas turbine power plant only has advantage is operated at low capacity factor and the cost is increasing with high capacity factor. The geothermal power plant relatively has middle cost comparing with others power plant. Nuclear power plant has high investment cost but for capacity factor more than 0.8 will be competitive comparing with oil steam power plant.

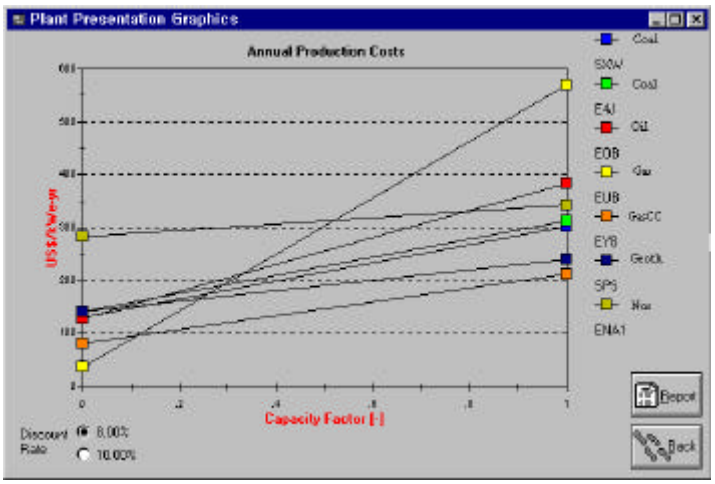

Figure 4. Annual Production Cost Comparison

In the study two scenarios propose to taken into account:

- Business as usual (BAU) : without nuclear power plant, and
- Consider nuclear power plant (NUC).

The sensitivity analysis using abatement technology and reducing discount rate from 10 % to 8 % should be taken into account. Therefore due to limitation of time and execution time is very slow (in case of Indonesia, one execution of Congen Sub-module need 5 hours) then in this study only run BAU scenario.

Some of result from the optimization using DECPAC module has described in this section. Figure 5 shows thermal electricity generating capacity and Table 6 shows electricity system cost. Capacity added and particulate emission is shown in Figure 7 and Figure 8.

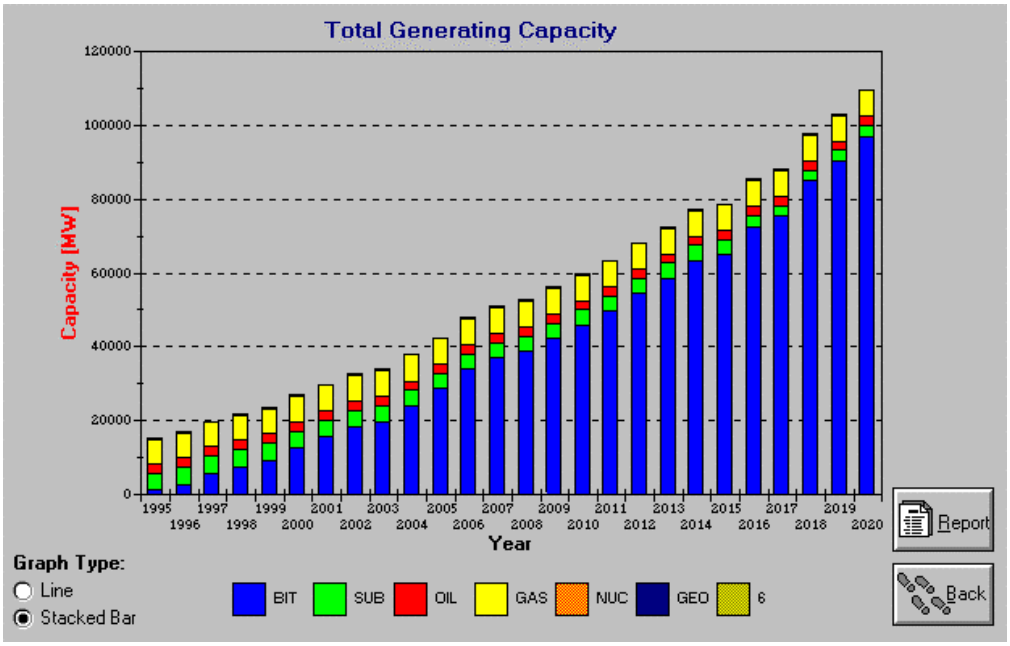

Figure 5. Thermal Electricity Generating Capacity

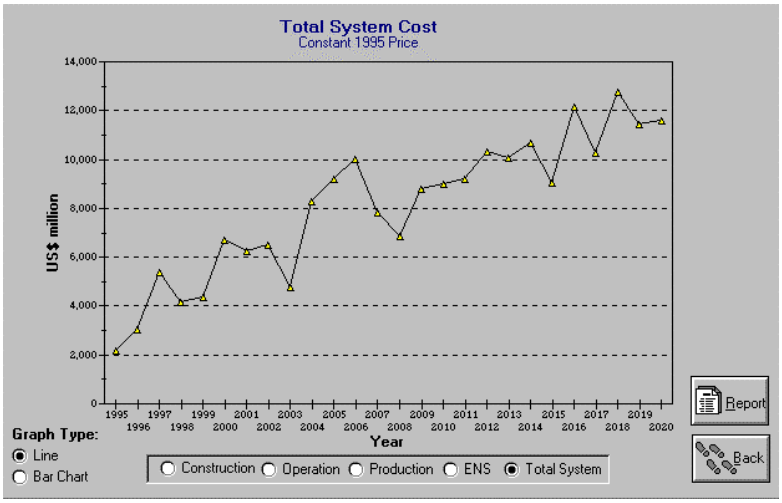

Table 6. Electricity System Cost.

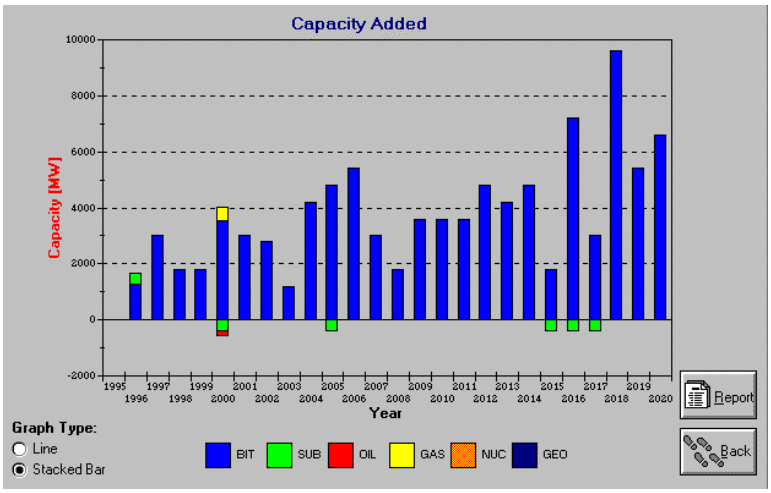

Figure 7. Capacity Added

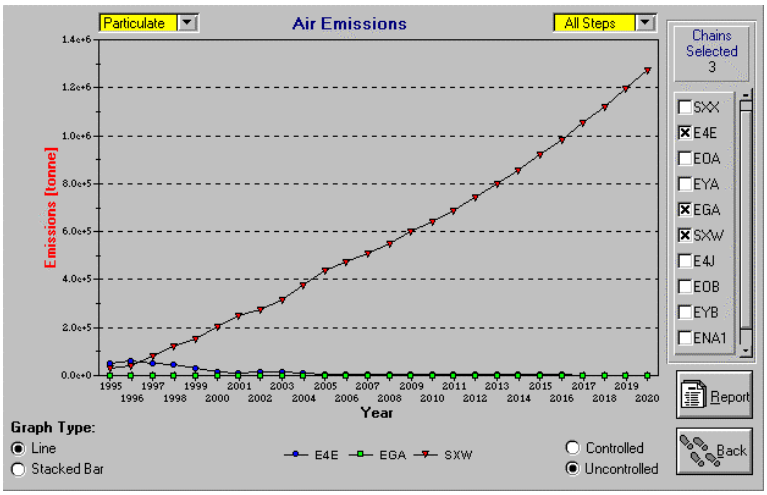

Figure 8. Particulate Emission

7. Conclusion and Recommendation

After running model using DECADES Tools at KAERI, some concluding remark and recommendation as follows:

- In view of the various indigenous energy resources in Indonesia, all available proven technological option will have to be used for the planned expansion of the country's power system in the coming decades.
- The role of coal for electricity generation will plays dominant in the future, followed by natural gas, hydropower, geothermal and nuclear. Nevertheless the used of oil still exist which decreasing share.
- Whatever the mix of different energy sources chosen for the future electricity generation, the environmental emission from the electricity sector will increase by an order of magnitude over the next 25 years.
- Which the increasing energy activities in the future it is necessary to manage and control the above possible impact by way of:
  - The use of clean energy resources
  - The use of clean energy technology
- Indonesia's CO_2 emission will increase which an average growth rate of 7 % per annum for the next 25 years which the minimum cost scheme a considerable reduction of CO_2 emission could be achieve mainly by replacing some number coal power plant by nuclear power plant.

As CSDB in BPPT, Indonesia has been constructed, the CSDB needs to be developed further. Database validation needs to be implemented by experts in order to make those data useful. Therefore, BPPT has proposed a project proposal under the IAEA Technical Co-operation Programme for 1998 to 2000 in 1997. The title of the proposal is the *Assessment of Sustainable Energy Supply Strategies for Electric Generation in Indonesia*. If the project proposal is accepted, DECADES software will be more useful as a tool for electric generation planning in Indonesia.

DECADES software is one of the tools that can be used for electricity generation planning in Indonesia. This tool can estimate an environmental impact from the electricity generation technology. In the globalization era, the environmental impacts of the electricity generation technology will become an important issue that can influence the economy of the country.

Reference

1. A. Symon, *Energy in Indonesia*, Financial Times Energy Publishing Asia Pacific, Singapore, 1997.
2. BPS, *Statistical Year Book of Indonesia*, in Indonesia, Jakarta, 1996.
3. IAEA, *DECADES Tools: User's Manual for Version 1.0*, Vienna, 1997.
4. PT PLN (Persero), *PLN Statistics 1995*, Jakarta, October 1996.
5. Zuhal, *Indonesia Electricity*, in Indonesian, Jakarta, 1996.