

Comparative Assessment of Electricity Supply Strategies in Indonesia¹

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Abstract

The objective of the study is design an optimal strategies for the national electricity supply in Indonesia for the long term (1996-2021). The situation of the fossil energy reserves is characterized by limited oil reserves, sufficient gas reserves and abundant coal reserves. The GDP grows on average by 6 % per annum. The electricity demand grows by 8.2 % per annum from about 52 TWh in 1991 to 556 TWh in the year 2021. About 70 % is consumed in the industrial sector, which has an average growth rate in electricity consumption of 8.5 % annually. Abundant coal reserves make coal attractive as the major fuel for power plant in Indonesia under the BAU scenario. The ERC scenario carried out in this study showed that clean coal power plants, equipped with desulphurization, denox, and dust filter units, generate electricity at lower costs than LWR nuclear power plants. Coal is by far the most economic supply option even under the conditions of the ERC scenario. For the CRC scenario nuclear power plant would be necessary in 2006 with installed capacity 1.34 GW and grow to 6.72 GW by the year 2021.

1. Introduction

This study is part of the inter-agency joint project on data bases and methodologies for comparative assessment of different energy sources for electricity generation (DECADES). In case of Indonesia, known as *Comparative Assessment of Electricity Supply Strategies in Indonesia*, are being carried out within the Research Contract between IAEA and Agency for the Assessment and Application of Technology (BPPT), Indonesia.

The objective of the study is design an optimal strategies for the national electricity supply in Indonesia for the long term (1996-2021). Taking into account economic and environmental aspect, and to analyze the impacts of alternative strategies. In this study three scenario has been introduced to make strategies for electricity supply, i.e. :

- Business as Usual Case (BAU)

The BAU is a worst case scenario for estimating the environmental consequences if pollution control will not be implemented.

- Emission Reduction Case (ERC)

The emission reduction technologies for Suspended Particulate Matter (SPM), NO_x and SO₂ considered in the ERC scenario.

- CO₂ Reduction Case (CRC)

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In the CRC scenario, CO₂ reduction target was applied for the year 2006 by 12.5 % and the year 2021 by 25.0 % base on the ERC.

2. Economic and Energy 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. About 37 % of the population is in the under 15 age group. The creation of job opportunities is a tremendous challenge for the government.

In the 1970, the country experienced relatively high Gross Domestic Product (GDP) 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.

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 $101.8 \cdot 10^{12}$ scf. Unfortunately, the most of the reserves have a 70 % CO₂ content that need large investments to develop the field, to process the gas, and to dispose CO₂ into the reservoir.

Table 2-1. Energy reserves compared to utilization in 1990

	Oil 10 ⁹ Barrel	Natural Gas 10 ¹² SCF	Coal 10 ⁹ Ton	Hydropower GW	Geothermal GW
Jawa	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

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.

3. Electricity Generation Plan

The electricity demand in Indonesia is supplied by State Electricity Company (PLN) and captive power plants. The electricity generation increase from 19.3 TWh in 1980 to 47.7 TWh in 1989, or by 9.5 % per annual on average. The generation of captive power plants was higher than PLN's generation up to 1986. This is mainly due to PLN's lack of generation, transmission and distribution capacity. Another often cited reason, low domestic prices of diesel, is a consequence of this shortcoming. Faced with the dilemma that industries need electricity and that PLN cannot meet the industrial demand, the government of Indonesia set the diesel price at low level in order to enable industries to generate electricity at a competitive price.

The population forecast is shown in Table 3-1. A continue decline in the population growth rate is expected because family planning policy is attempting to further reduce this rate. The population growth rate decline to 0.87 % per annum by the end of Pelita XI.

Table 3-1. Population Forecast

Period	Pelita	Pelita Center year	Population	Growth Rate (%/a)
1989 - 1993	V	1991	183.85	1.80
1994 - 1998	VI	1996	200.34	1.73
1999 - 20003	VII	2001	216.49	1.56
2004 - 2008	VIII	2006	231.97	1.39
2009 - 2013	IX	2011	246.45	1.22
2014 - 2018	X	2016	259.61	1.05
2019 - 2023	XI	2021	271.12	0.87

Pelita = National Development Plan

Table 3-2 shows the GDP growth rates until the end of the national development plan (Pelita) XI. The GDP grows on average by 6 % per annum. Because of the still increasing population the GDP per capita grows at a rate of 4.6 % per annum. It will increase from U.S.\$ 630 per capita in the year 1991 up to about U.S \$ 2,430 per capita in the year 2021 (in 1991 prices).

The electricity demand grows by 8.2 % per annum from about 52 TWh in 1991 to 556 TWh in the year 2021 (see Figure 3-1). About 70 % is consumed in the industrial sector, which has an average growth rate in electricity consumption of 8.5 % annually.

Regarding households, the growth potential is highest in rural areas. While 75 % of urban households were electrified at the end of the year 1989, this applied to only 25 % of

rural households. Electricity consumption by electrified households is much lower in rural areas.

Table 3-2. Economic Growth

Pelita	Real GDP (%/a)	GDP/Capita (%/a)	Real GDP (Billion Rupiah 1985)
V	6.4	4.5	140.033,10
VI	5.7	3.9	184.823,70
VII	6.3	4.7	248.503,60
VIII	5.1	3.7	332.006,80
IX	6.0	4.7	428.336,70
X	6.1	5.0	574.134,30
XI	6.2	5.4	777.568,90
Average	6.0	4.6	

In 1989, rural households consumed only 350 kWh as compared to 750 kWh by urban households. Thus, there is an enormous growth potential in rural areas and the existence of local operators clearly demonstrates that rural households want to have access to electricity. It has been assumed for the projections of this study that the connection rate of rural households reaches 80 % in Pelita XI (center year 2021) with an annual electricity consumption in the order of 1,000 kWh per electrified household. The corresponding figures for urban households are 100 % and 1,200 kWh, which will already be reached earlier.

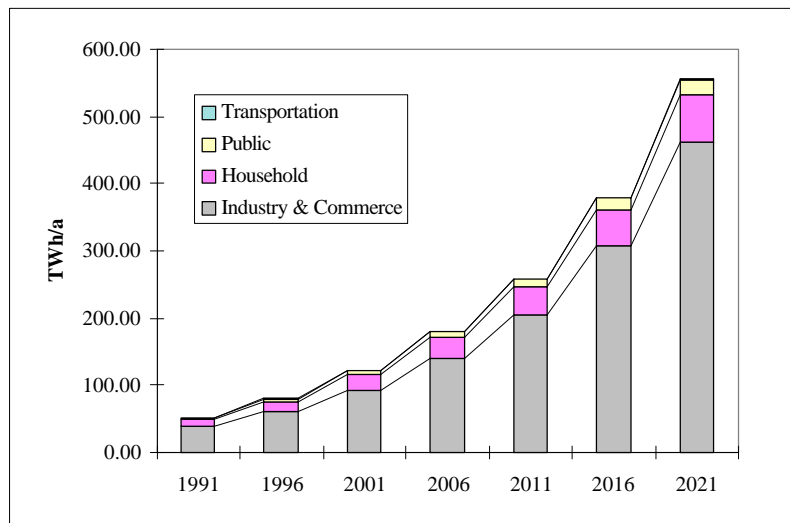


Figure 3-1. Electricity Demand by Sector (the BAU & ERC scenario)

In the CRC scenario the electricity demand is projected growing slightly than in the BAU and ERC scenario. This is based on the following assumption :

- Consumer will have stronger incentive to buy electricity appliance with high efficiency, i.e. : using compact fluorescent lamps, variable speed electric motor, and high efficiency refrigerators.

- The electricity use in boiler will be substituted with direct heat because of using Combined Heat and Power (CHP) technology.

4. Electricity Supply Strategies

4.1. Business as Usual Case (BAU)

There is a remarkable expansion of coal-fired steam power plants from 1.7 GW in the year 1991 (mid five year development plan, Pelita V) to 80 GW in the year: 2021 (mid year Pelita XI). The average growth rate is 14 % per annum, which means a doubling of the generation capacity every 5 year. In line with this base load and intermediate load capacity development is the growth of the peak load gas turbines, which will reach 20 GW in the year 2021. The growth rate of gas turbine including the field gas turbine in the outside Jawa will reach almost 10% p.a. With the data chosen in this study the electric high voltage line from Sumatera to Jawa is not economically competitive.

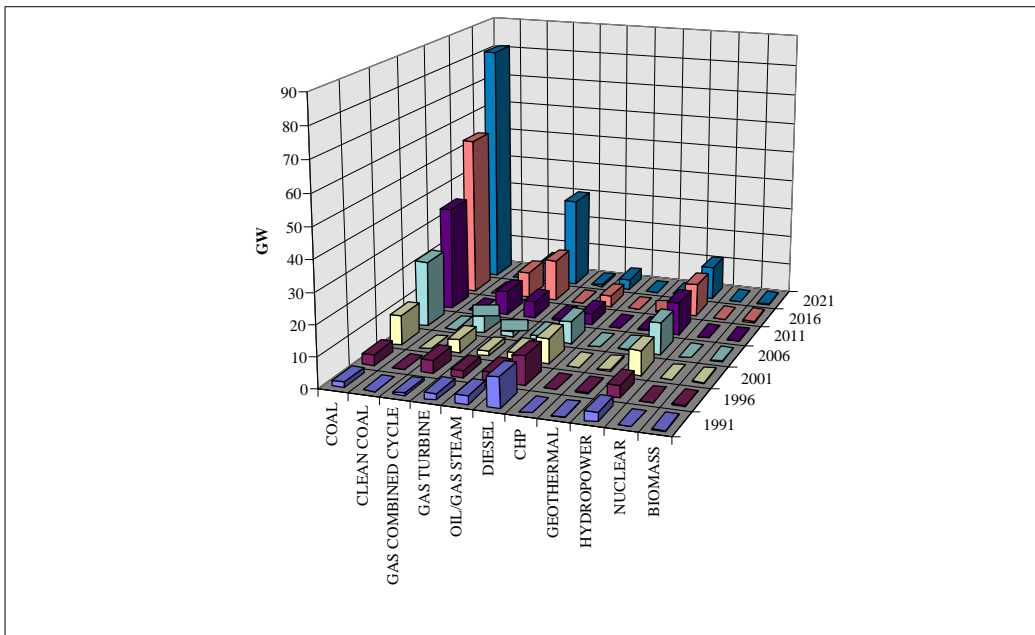


Figure 4-1 Development of Power Plant Capacities (the BAU case)

4.2 Emission Reduction Case (ERC)

By utilization of clean technology the power plant capacity mix in 2021 will still be dominated by coal power plant with share increase to 61% of total national capacity. Coal fired steam power plan in this scenario for the year 2021 80% of that already using denitrification and desulfurization units and the remaining 20% is the residual capacity of conventional and that located in outside Jawa. That capacity accompanied by optimization model is gas-turbine, hydropower, and gas combined cycle with share 22%, 8%, and 4% respectively. Another power plan chosen by diesel, oil firing, biomass steam, and geothermal with total share 5%. The capacity utilization factor will be increase from 35% in 1991 to 53% in 2021 same as BAU scenario.

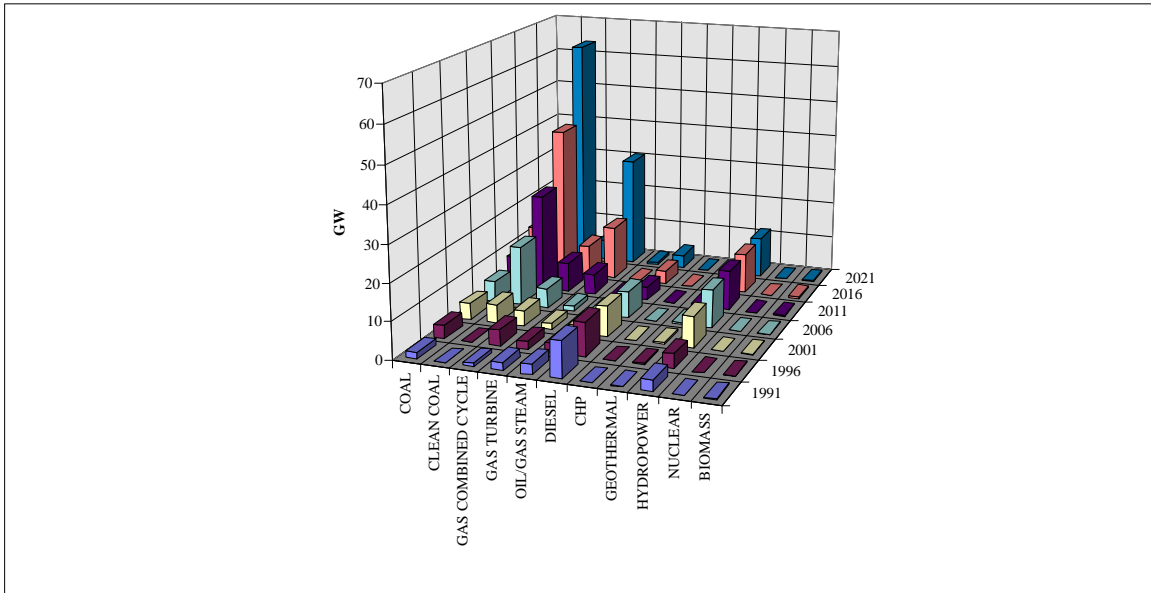


Figure 4.2 Development of Power Plant Capacities (the ERC case)

4.3 CO₂ Reduction Case (CRC)

The major greenhouse gases are CO₂ (carbon dioxide), methane, and nitrous oxide. Only CO₂ emission is taken into account in this study. Although the CO₂ emission in Indonesia is still low comparing with the total CO₂ emission in the world, Indonesia is aware of this issue. As one of the 150 signatory states of the Rio Convention, Government of Indonesia agreed to report on the status and tendency of CO₂ emission in its territory.

With that constraints the power plant capacity mix after year 2011 have very different figure. In 2021 the capacity will still be dominated by coal power plant but accompanied by gas turbine with similar share 23% of total national capacity respectively. Most coal fired steam power plan in this scenario for the year 2021 is already using denitrification and desulfurization units. As the optimization result, that capacity followed by gas combined cycle, geothermal, hydropower, and oil-gas fired with share 15%, 10%, 9% and 8% respectively. Nuclear power plant chosen with 5% share of the total capacity. Another power plan chosen are combined heat power(CHP), diesel, and biomass steam with total share 7%. The capacity utilization factor without combined heat-power (CHP) will be increase from 35% in 1991 to 50% in 2021.

The electricity generation by nuclear power grows from 8.2 Twh/a in the year 2006 to 41.2 Twh/a in 2021 corresponding to a capacity 1.34 GW by the year 2006 and 6.72 GW by the year 2021. On the other hand, the occurrence of nuclear power as part of the electricity mix must not be misinterpreted as a recommendation to build the nuclear power plant. To conclude, it is not the intention of this study to comment on the pros and cons of nuclear power.

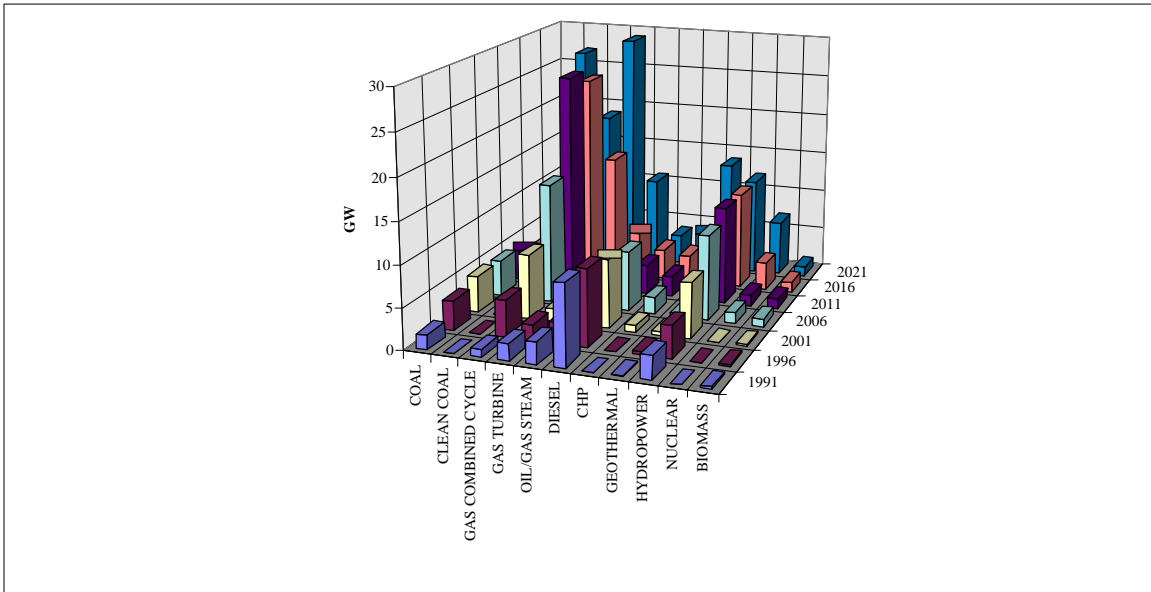


Figure 4-3 Development of Power Plant Capacities (the CRC case)

4.4 Environmental Indicator

Even if the expansion of capacity from electric power is accomplished with technologies which meet the relevant standards, pollution will still be released into the atmosphere because the so-called clean technology are not 100 % effective in removing air pollutants.

Table 4-1 Total Pollutant Emission

Kilo Tons/a		1991	1996	2001	2006	2011	2016	2021
SO2	BAU	81.067	131.00	296.74	623.76	971.39	1507.80	2316.20
	ERC	81.067	130.06	181.10	290.09	426.19	662.80	1023.90
	CRC	81.046	128.49	151.50	136.66	146.82	220.14	324.06
NO2	BAU	232.19	316.76	451.09	741.78	1103.60	1699.10	2593.40
	ERC	232.21	316.29	292.82	316.14	412.53	627.79	955.32
	CRC	232.26	312.53	372.49	387.44	451.94	550.34	656.25
SPM	BAU	22.68	30.02	54.47	103.92	156.47	242.71	363.91
	ERC	22.68	29.89	34.63	47.23	63.93	99.04	144.36
	CRC	22.76	29.76	32.82	55.20	62.96	68.79	76.61
VHC	BAU	10.74	13.70	12.24	11.20	14.06	21.83	34.53
	ERC	10.75	13.72	11.15	10.99	13.90	21.82	34.35
	CRC	10.68	13.42	16.15	17.87	23.90	31.51	41.61

Table 4-2 Total CO₂ Emission

million Tons/a	1991	1996	2001	2006	2011	2016	2021
BAU	154	218	292	406	559	794	1139
ERC	154	218	289	404	555	787	1126
CRC	154	218	280	336	444	612	840

5. Conclusion

Abundant coal reserves make coal attractive as the major fuel for power plant in Indonesia under the BAU scenario. The ERC scenario carried out in this study showed that clean coal power plants, equipped with desulphurization, denox, and dust filter units, generate electricity at lower costs than LWR nuclear power plants. Coal is by far the most economic supply option even under the conditions of the ERC scenario.

According to this study for the CRC scenario nuclear power plant would be necessary in 2006 with installed capacity 1.34 GW and grow to 6.72 GW by the year 2021. On the other hand, fuel swithces and changes of the technology mix cause significant rise of the total electricity supply cost.

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