INTRODUCTION OF NUCLEAR POWER PLANT FOR MITIGATING THE IMPACT OF GLOBAL WARMING

Ida Nuryatin Finahari
Center of Nuclear Energy Development-BATAN
Jl. Kuningan Barat Mampang Prapatan Jakarta 12710
Phone/Faximile : 021-5204243, email : finahari@batan.go.id

ABSTRACT

INTRODUCTION OF NUCLEAR POWER PLANT FOR MITIGATING THE IMPACT OF GLOBAL WARMING. *Energy utilization for power plants in Indonesia is still highly depending on the burning of fossil fuel like coal, oil, and gas. From the combustion of fossil fuel, greenhouse gases such as CO_2 and N_2O are produced. An increase of CO_2 gas emission to the atmosphere can block the heat loss from the earth surface and will increase the greenhouse effect that results in the temperature increase of the earth surface (global warming). Global warming can cause a very extreme climate change on earth. One of the solutions to reduce CO_2 gas emission produced by fossil fuel power plants is to utilize the plants with flue gas treatment facility. At such facility, CO_2 gas is reacted with certain mineral based substances thus can be used as base material in food-, pharmaceutical-, construction-, and cosmetic industry. Another alternative to reduce CO_2 gas emission is by replacing fossil fuel power plants with nuclear power plants. Considering the environmental and economic aspects, the nuclear power plant does not emit CO_2 gas, so that the use of nuclear power plant can mitigate the impact of global warming. Based on the operational experience of nuclear power plants in advanced countries, the cost of generating electricity from nuclear power plants is more competitive than that of fossil fuel power plant.*

Keywords: CO_2 gas emission, global warming, climate change, fossil fuel power plant, nuclear power plant

ABSTRAK

INTRODUKSI PLTN UNTUK MENGURANGI DAMPAK PEMANASAN GLOBAL. *Pemakaian energi di Indonesia untuk pembangkit listrik masih sangat bergantung pada pembakaran bahan bakar fosil seperti batubara, minyak bumi dan bahan bakar gas. Dari pembakaran bahan bakar fosil dihasilkan gas rumah kaca CO_2 dan N_2O. Adanya kenaikan laju emisi gas CO_2 di udara dapat menghambat hilangnya panas dari permukaan bumi dan akan meningkatkan efek rumah kaca yang dapat menyebabkan naiknya suhu permukaan bumi (pemanasan global). Pemanasan global dapat mempengaruhi perubahan iklim yang sangat ekstrim di bumi. Salah satu upaya untuk mengendalikan laju emisi gas CO_2 yang ditimbulkan dari pembangkit listrik berbahan bakar fosil adalah dengan melengkapi instalasi pengolahan gas buang pada unit pembangkit. Pada instalasi ini gas CO_2 direaksikan dengan bahan mineral tertentu, yang dapat dimanfaatkan sebagai bahan baku pada industri makanan, farmasi, konstruksi dan industri kosmetik. Alternatif lain untuk mengurangi laju emisi gas CO_2 adalah pemanfaatan energi nuklir (PLTN) untuk menggantikan pembangkit listrik berbahan bakar fosil. Ditinjau dari aspek lingkungan dan ekonomi, PLTN tidak mengeluarkan emisi gas CO_2 sehingga dengan memanfaatkan PLTN dapat mengurangi dampak pemanasan global. Pengalaman pengoperasian PLTN di negara-negara maju menunjukkan bahwa biaya pembangkitan listrik PLTN cukup kompetitif dibanding pembangkit listrik berbahan bakar fosil.*

Kata kunci : emisi gas CO_2, pemanasan global, perubahan iklim, pembangkit listrik berbahan bakar fosil, pembangkit listrik tenaga nuklir

1. INTRODUCTION

Power plants in Indonesia are still highly depending on the burning of fossil fuel such as coal, oil, and gas. From the use of fossil fuel as energy sources, greenhouse gases such as CO_2 and N_2O are produced. An increasing concentration of these gases in the earth atmosphere can block the heat loss from the earth surface and this will cause the increase of the greenhouse effect that results in an increase in temperature of the earth surface. This greenhouse effect is well known as the main cause of the occurrence of global warming. This occurrence can cause a very extreme climate change on earth, such as the increase of air and sea water temperature, extended dry season—that shifts the plant season pattern for farmers, and also an increase of flood frequency.

It is shown that fossil fuel power plants have contributed to CO_2 gas emission for about 27% of total emission of the energy sector in Indonesia. This level will increase continuously if no effort to reduce the use of fossil energy as energy sources is taken[1].

In fact, Indonesia is facing an energy crisis in recent years. To meet the shortage of energy in the electricity sector, the Indonesian government has launched a program for the increase of electricity project. This program is to build coal fired power plant with the capacity of 10,000 MW[2]. It seems that Indonesia still depends highly on coal as main fuel for power plant for several years. This is indicated by the government regulation Nr. 5/2006. The regulation arranges the national energy mix with target to increase the utilization of coal from 14.1% in year 2003 to 32.7% in year 2025 and gas from 26.5% in year 2003 to 30.6% in year 2025. On the other hand, the utilization of oil will be decreased from 54.4% in year 2003 to 26.2% in year 2025[3].

The occurrence of global warming and climate change will be continued, that's why it requires the efforts seriously to reduce the CO_2 gas emission released from fossil fuel power plants. One of the solutions to reduce the emission is by capturing CO_2 in flue gas released. It is possible to capture CO_2 released in power plant by reacting it with certain mineral substances, such as calcium hydroxide to produce calcium carbonate. This product can be used as base material in food-, pharmaceutical-, and construction industry. Another treatment method is reacting CO_2 gas with olivine and serpentine, producing magnesium carbonate. This product can also be used as base material in food-, pharmaceutical-, and cosmetic industry.

Another alternative to reduce CO_2 gas emission is by replacing fossil fuel power plants with nuclear power plants. Principally, the operation of a nuclear power plant does not release CO_2 gas. In conventional thermal power plants, it requires combustion of a fossil fuel such as coal, oil or gas to provide heat and then generate electricity. On the other hand, for a nuclear power plant, this heat is provided by nuclear fission inside the nuclear reactor. When a relatively large fissile atomic nucleus (usually uranium-235) is struck by a neutron it forms two or more smaller nuclei as fission products, releasing energy and neutrons in a process called nuclear fission. The neutrons then trigger further fission, and so on. When this nuclear chain reaction is controlled, the energy released can be used to heat water, produce steam and drive a turbine that generates electricity. Therefore, this study is aimed to introduce the nuclear power plant as one of an alternative solution to solve the problem of global warming especially in Indonesia due to the greenhouse gas emissions.

2. GREENHOUSE EFFECT AND GLOBAL WARMING IMPACTS

Solar energy, in the form of visible light, is absorbed by the earth's surface and reemitted as infrared radiation. Certain gases in the atmosphere have the ability to absorb

infrared radiation which is translated to heat. The result is a higher atmospheric equilibrium temperature than would occur in the absence of these gases. This temperature enhancement is called the greenhouse effect, and gases that have the ability to absorb infrared radiation and produce this effect are called greenhouse gases [see Figure 1][4].

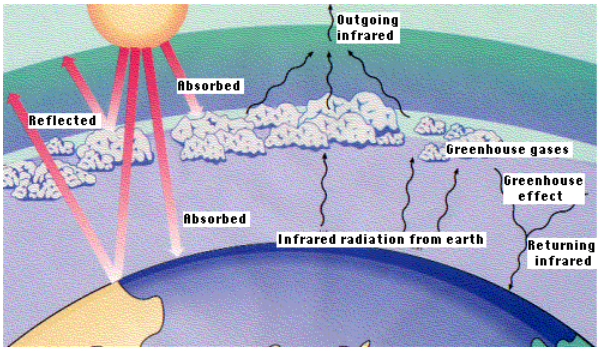

Figure 1. Mechanism of the greenhouse effect [4]

The greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, ozone and a variety of chlorofluorocarbons. While water vapor has the largest effect, its concentrations are not directly affected, on a global scale, by human activities. Carbon dioxide was from fossil fuel combustion, forest fire, respiration. Methane was from rice paddies, fermentation of animal waste, biomass burning. Nitrous oxide was from fertilized soils, fossil fuel combustion. Ozone was from photochemical reactions in the troposphere. CFC-11 was from antropogenic sources, manufacturing of foam, aerosol propellant; CFC-12 was from refrigerant, aerosol propellant.

Table 1. Greenhouse gases concentration in the atmosphere (ppm) [4]

Gas	*Preindustrial revolution*	*In year 1990*	*Global Warming Potential*
CO_2	280 ppm	353 ppm	1
CH_4	0.8 ppm	1.72 ppm	11
N_2O	0.288 ppm	0.310 ppm	270
CFC	0	0.000280 ppm	3,400

In Table 1 is shown a list of the greenhouse gases, their concentrations in preindustrial revolution and in 1990, and the value of global warming potential (estimates of relative greenhouse efficiencies). CO_2 gas has the smallest value of global warming potential, about 1, so the other greenhouse gases are much more efficient absorbers of infrared radiation than carbon dioxide gas. But CO_2 gas has the most concentration in the atmosphere. Atmospheric concentration of carbon dioxide in year 1990 of 353 ppm compared to the preindustrial revolution (in year 1850) value of 280 ppm and about 375 ppm in year 2005. The atmospheric concentration of carbon dioxide is increasing at the rate of about 0.3% per year, so CO_2 gas emission has obtained the primary attention in recent years.

The contributions from the various greenhouse gases to global warming are shown in Figure 2. The CO_2 gas contributes to about 50% of total greenhouse gas emissions. CO_2 gas emissions from fossil fuel energy use remain the largest contributor to total worldwide emissions, but CH_4, CFCs and N_2O also are important. CO_2 production from increased industrial activity (fossil fuel burning) and other human activities such as cement production and tropical deforestation has increased the CO_2 concentrations in the atmosphere. The

principal sources of CO_2 gas emission in energy sector especially from power plant sector and industrial sector in the world with emissions of more than 0.1 million tons of CO_2 per year are summarized in Table 2.

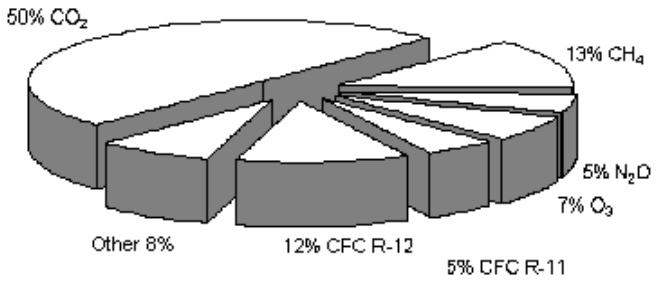

Figure 2. Estimates of greenhouse gas contributions to global warming [5]

Table 2. Profile by process or industrial activity of worldwide large CO_2 sources with emissions of more than 0.1 million tons of CO_2 ($MtCO_2$) per year [6]

Sources	*Emissions (Mt CO_2/year)*	*Percentage (%)*
Fossil Fuel		
1. Power Plant	10,539	78.0
2. Cement Industry	932	7.0
3. Refineries	798	6.0
4. Iron and steel industry	646	5.0
5. Petrochemical Industry	379	2.8
6. Oil and gas processing	50	0.4
7. Other sources	33	0.2
Biomass		
1. Bioetanol and Bioenergy	91	0.6
T o t a l	13,466	100.0

Global warming impact shows that the earth surface temperature in the world increased about $(0.6 \pm 0.2)^oC$. The increasing concentration of CO_2 and other greenhouse gases due to human activities will enhance the greenhouse effect and cause global warming. The global warming can result in extreme climate change on the earth surface [7].

The impacts of climate change are rising sea levels, increasing global temperature and sea water temperature, and damage to natural ecosystems. The global warming can cause melting of glaciers resulting in sea level rise too. The total surface area of glaciers has decreased by 50% since the end of the 19th century[7].

Increasing sea water temperature about 1-1,25^oC will affect algae that grow on its underside of sea. And warming could reduce the ocean's ability to absorb CO_2 so affecting coral bleaching. In Palau, an island nation in the Pacific Ocean, some 500 miles (800 km) east of the Philippines and 2000 miles (3200 km) south of Tokyo, coral bleaching has occurred until a depth of 90 meter. And the coral species population has decreased until 99% with economic loss about US$ 91 billion [8]. In Indonesia, coral bleaching has occurred to about 30% and in Seribu Island archipelago to about 90-95% until a depth of 25 meter[9].

3. POWER PLANTS IN INDONESIA

At the end of December 2005, the total installed capacity of power plants in Indonesia is 22,515.09 MW. The total power plant capacity broken down by type of power plant was as follows: Steam Turbine 6,900 MW (33%), Combined Cycle 6,281 MW (28%), Diesel 2,982 MW (13%), Hydro 3,221 MW (14%), Gas Turbine 2,724 MW (12%) and Geothermal 395 MW (2%).

Table 3. Installed capacity of fossil fuel power plants (MWe) from 2002 to 2005[10]

Year	*Steam Turbine*	*Gas Turbine*	*Combined Cycle*	*Diesel*
2002	6,900	1,224.72	6,863.22	2,589.12
2003	6,900	1,224.72	6,863.22	2,670.42
2004	6,900	1,481.57	6,560.97	2,933.43
2005	6,900	2,723.63	6,280.97	2,994.54

Table 4. Total consumption of fossil fuel for power plants from 2002 to 2005

Year	*Natural Gas (ton)*	*Oil (ton)*	*Coal (ton)*
2002	3,899,613	6,024,198	14,054,377
2003	3,725,317	6,583,377	15,260,305
2004	3,566,282	7,355,499	15,412,738
2005	2,891,455	8,571,388	16,900,972

From total installed capacity 22,515.09 MW at mentioned above, 84% is dominated by fossil fuel power plant or about 18,887 MWe [see Table 3]. And the total consumption of fossil fuel for power plants from 2002 to 2005 is shown in Table 4 [10]. The amount of CO_2 gas emissions from total consumption of fossil fuel for power plants (Table 4) can be calculated theoretically and the reaction equations can be written as follows:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (gas as fuel)

$C_{Oil} + O_2 \rightarrow CO_2$ (oil as fuel)

$C_{Coal} + O_2 \rightarrow CO_2$ (coal as fuel)

Basis of calculation is 1 ton of fossil fuel		*amount of CO_2 formed*	
	Mole	*Mole*	*Ton*
Gas (natural gas)	0.0625	0.0625	2.75
Oil (diesel oil, Carbon content 87 wt%)	0.0720	0.0720	3.16
Coal (sub-bituminous, Carbon content 76 wt%)	0.0633	0.0633	2.80

The total amount of CO_2 gas emissions obtained is summarized in Table 5.

Table 5. The amount of CO_2 gas emissions from fossil fuel power plants in Indonesia from 2002 to 2005

Year	Natural gas (ton CO_2)	Oil (ton CO_2)	Coal (ton CO_2)	T o t a l (ton CO_2)
2002	10,723,935	19,036,465	39,352,255	69,112,655
2003	10,244,621	20,803,471	42,728,854	73,776,946
2004	9,807,275	23,243,376	43,155,666	76,206,317
2005	7,951,501	27,085,586	47,322,721	82,359,808

4. DISCUSSION

Table 5 shows the result of calculations for the amount of CO_2 gas emission from fossil fuel power plant in Indonesia from 2002 to 2005. The result in this table show that total CO_2 gas emission increases continuously, i.e., about 6% per year. The emission of CO_2 gas from

power plant will continuously increase considering the increase in the electric power demand in the future. PLN estimated that the use of coal as fuel for power plants increased to be 71.9 million ton per year in year 2010[12]. This is four times higher compared to the coal consumption in year 2005. This data also indicates that the CO_2 gas emission in year 2010 will increase four times compared to that in year 2005.

The occurrence of global warming and climate change will continue, that's why it requires serious efforts to reduce the CO_2 gas emission released from fossil fuel power plants. One of the efforts to reduce the emission is by capturing CO_2 in flue gas released. It is possible to capture CO_2 released in power plant by reacting it with certain mineral substances, such as calcium hydroxide to produce calcium carbonate. This product can be used as base material in the food-, pharmaceutical-, and construction industry. Another treatment method is reacting CO_2 gas with olivine and serpentine, producing magnesium carbonate. This product can also be used as base material in the food-, pharmaceutical-, and cosmetic industry [13,14].

1. $Ca(OH)_2 + CO_2 \rightarrow CaCO_{3(p)} + H_2O$
2. $1/2(Mg)_2SiO_4 + CO_2 \rightarrow MgCO_3 + 1/2SiO_2$
3. $Mg_3[Si_2O_5(OH_4)] + 3CO_2 \rightarrow 3MgCO_3 + 2SiO_2 + 2H_2O$

These carbon dioxide capture and storage systems (CCS) can reduce CO_2 gas emissions per kWh by approximately 80-90%, but CO_2 capture increase the cost of electricity production by 35-70% for an NGCC (natural gas combined cycle) plant, 40-85% for PC (pulverized coal) plant and 20-55% for an IGCC (integrated coal gasification combined cycle) plant. However, CO_2 capture systems require significant amounts of energy for their operation. Power plants require more fuel to generate each kilowatt-hour of electricity produced. Based on a review of the literature, the increase in fuel consumption per kWh for plants capturing 90% CO_2 using best current technologies ranges from 24-40% for PC plants, 11-22% for NGCC plants and 14-25% for coal based IGCC systems compared to similar plants without CCS. And this case will increase in cost of electricity average about 43% [see Table 6 [6].

Table 6. CO_2 capture costs for power plants based on current technology[6]

	Type of Power Plants		
	PC	**NGCC**	**IGCC**
Percent increase in electricity production cost	40-85%	35-70%	20-55%
Percent increase in fuel consumption per kwh	24-40%	11-22%	14-25%

CO_2 gas can be used as feedstock in chemical industry to produce methanol and urea.

4. $CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$
5. $CO_2 + 2NH_3 \rightarrow CO(NH_2)_2 + H_2O$

Greenhouse gas emission reductions from the energy sector also can be obtained by changing fuel and energy supplies, particularly for electric power generation. The prospect of reducing power plant CO_2 emissions by up to 90% by eliminating all power plant emissions by use of nuclear and renewable energy sources was considered. For example, nuclear power plants with the capacity of 1,000 MW need about 27 ton per year nuclear fuel. This is equivalent to coal fuel of 2,600,000 ton per year. The comparison of type and amount of waste produced from coal fired power plants and nuclear power plants is shown in Table 7.

Table 7. Comparison of waste production from coal fired power plant and nuclear power plant 1,000 MWe [15]

Waste	Coal fuel power plant (ton)	Nuclear power plant (ton)
HLW	-	27
ILW	-	310
LLW	-	460
CO_2	6,000,000	-
SOx	244,000	-
NOx	222,000	-
Ash	320,000	-

In Table 7 is shown that although nuclear power plant is produced nuclear waste i.e. low level waste (LLW), intermediate level waste (ILW) and high level waste (HLW), but it is not producing CO_2 gas emissions. As a comparison, a 1,000 MWe nuclear power plant as a substitute for coal fuel power plant at the same capacity will reduce 6,000,000 tons of CO_2 gas emission per year[15].

Considering environmental aspect, the nuclear power plant is not emitting greenhouse gases and considering economic aspect, based on operation experiences of nuclear power plant in advance countries, it shows that cost of generating electricity of nuclear power plant is more competitive than fossil fuel power plant [see Table 8].

The basic policy of radioactive waste management in Indonesia is as follows: [16]

- Radioactive waste generation from the use of nuclear energy should be as minimum as possible.
- Any discharge of liquid and gas effluent to the environment should be as low as possible.
- Handling, treatment and disposal of radioactive wastes should be carried out by taking into account the environment protection consideration.
- Conditioning wastes should be emplaced at nuclear site and specially constructed for this purpose.
- Research and development in radioactive waste management should be carried out to support the safety aspect of present and future nuclear energy program.

Table 8. Comparison of cost of generating electricity [17]

(Discount rate 5%, 40 year lifetime, 85% load factor)

	Cost of generating electricity (cent/kWh)		
	Nuclear	Coal	Gas
Franch	2.54	3.33	3.92
Germany	2.86	3.52	4.90
Slovakia	3.13	4.78	5.59
Japan	4.80	4.95	5.21
Korea	2.34	2.16	4.65
USA	3.01	2.71	4.67
Canada	2.60	3.11	4.00

Based on the energy planning study on CADES, Indonesia will introduce nuclear power plant 0f 2,000 MWe in 2016[18]. It means that the introduction of nuclear power plant can reduce 12,000,000 tons of CO_2 gas emission per year. This is equal to a reduction of 14.5% CO_2 gas emission from fossil-fuel power plant in 2005.

5. CONCLUSION

1. An increase of CO_2 gas emission to the earth atmosphere may block the heat loss from the earth surface and will increase greenhouse effect that results in temperature increase on the earth surface. This greenhouse effect may cause global warming. Global warming may cause a very extreme climate change on earth.
2. One of the efforts to reduce CO_2 gas emission produced by fossil power plants is to utilize the fossil fuel-based plant with flue gas treatment facility. At this facility, CO_2 gas is reacted with certain mineral substances, such as calcium hydroxide, olivine and serpentine, to produce calcium carbonate and magnesium carbonate that can be used as base material in the food-, pharmaceutical-, construction- and cosmetic industry.
3. Another alternative to reduce CO_2 gas emission is by replacing fossil fuel power plants with nuclear power plants. Considering aspects of environmental and economic, the operation of nuclear power plant is not emitting CO_2 gas, so that the use of nuclear power plant can mitigate the impact of global warming. As a comparison, a 1,000 MWe nuclear power plant as a substitute for coal fired power plant at the same capacity, will reduce 6,000,000 tons of CO_2 gas emission per year. Based on operational experience of nuclear power plants in advanced countries, it is shown that cost of generating electricity of nuclear power plants is more competitive than fossil fuel power plant.

REFERENCE

[1] NASRU ALAM AZIZ, 2005, *Ketika Fosil Membakar Bumi*, Harian Kompas, Sabtu, 8 Oktober 2005.

[2] ANONIM, 2006, *Pembangunan Pembangkit, Pemerintah Hati-hati Jamin Proyek Percepatan Kelistrikan*, Harian Kompas, Selasa, 26 September 2006.

[3] ANONIM, 2006, *Training Pemodelan Ekonomi Energi Markal*, Pusat Data dan Informasi, Departemen ESDM, 3-7 April 2006 Hotel Peninsula, Jakarta.

[4] BISIO ATTILIO, BOOTS SHARON, 1995, *Encyclopedia of Energy Technology and the Environment*, Vol.1, John Wiley & Sons, New York.

[5] ANONIM, Atmosfer dan Pemanasan Global, http : //www.vochtech.org.bn/virtual_lib/ swisscontact/Atmosfer/atmosfer.htm

[6] METS BERT, OGUNLADE DAVIDSON, HELEN DE CONINK, MNUELA LOOS, LEO MEYER, 2003, *Carbon Dioxide Capture and Storage*, IPCC (Intergovernmental Panel on Climate Change) Special Report 2003.

[7] HABIBA GITAY, AVELINO SUAREZ, ROBERT T. WATSON, 2002, *Climate Change and Biodiversity*, Intergovernmental Panel on Climate Change (IPCC) Technical paper V, April 2002.

[8] ALEX RETRAUBUN, 2007, Pulau Kecil di Tengah Pemanasan Global, Harian Kompas, Sabtu, 2 Juni 2007.

[9] MUDIYARSO, DANIEL, 2003, Sepuluh Tahun Perjalanan Negoisasi Konvensi perubahan Iklim, Harian Kompas.

[10] PT. PLN (Persero), 2006, *Statistik PLN 2005*, Juli 2006.

[11] EL-WAKIL, M.M., 1984, *Power Plant Technology*, McGraw-Hill International Editions.

[12] PLTU Suralaya, 2006, *Pasokan Batu Bara Kurang*, Harian Kompas, Jumat, 4 Agustus 2006.

[13] ANONIM, *The Greenhouse Gases, Calcium Carbonate,* http://www.globalwarming.orgGlobalWarmingorg.

[14] HERZOG HOWARD, 2002, *Carbon Sequestration via Mineral Carbonation : Overview Assessment,* MIT Laboratory for Energy and the Environment.

[15] IAEA, 2000, *Quarterly Journal of the International Atomic Energy Agency*, IAEA Bulletin Vol.42 No.3 (2000) Vienna, Austria.
[16] ANONIM, *Radioactive Waste Management in Indonesia*, Updated as of March 2007 FNCA Consolidated Report (Indonesia).
[17] OECD/IEA NEA, 2005, *Projected Costs of Generating Electricity*, http : //www.nea.fr/html/publ
[18] CADES, Comprehensive Assessment of Difference Energy Source for Electricity Generation in Indonesia, Energy Demand and Supply Analysis, May 2002.