Impacts of Coal Price on Indonesian Electricity Planning: The Oil Price Perspective and CO_2 Emissions

Muhammad Ery Wijaya
The Joint Graduate School of Energy and Environment
King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand

Bundit Limmeechokchai
Sirindhorn International Institute of Technology, Thammasat University
P.O. Box 22 Thammasat Rangsit Post Office, Pathum Thani 12121, Thailand
Corresponding author: bundit@siit.tu.ac.th

Abstract

Indonesia has an abundance of coal resources. The total resources are estimated to be about 90.5×10^9 tons. In 2006, Indonesia as the second largest coal exporter in the world launched its own coal price list. It is called the Indonesian Coal Index (ICI), which is ready to be used by the domestic market as well as abroad. The ICI consists of four coal grades based on their calorific values namely: ICI-1 (6,500 kcal/kg), ICI-2 (5,800 kcal/kg), ICI-3 (5,000 kcal/kg), and ICI-4 (4,200 kcal/kg). Currently, Indonesian government policy aims at promotion of coal utilization for power generation. This effort is to reduce oil utilization as well as to accelerate energy diversification. This paper analyzes effects of coal price changes on electricity price in Indonesian long term power planning. We investigated the impact of oil prices on Indonesian coal price, which is then applied to forecast Indonesian coal prices in the future. Results are presented as specific recommendations on electricity expansion planning with suitable ICI. Fuels for electricity generation are considered on the basis of economic values of coals as well as the CO_2 emissions.

Keywords: oil price, coal price, electricity cost, LEAP model, electricity expansion.

1. Introduction

Indonesia was formerly an oil exporting country and is a member of OPEC (The Organization of the Petroleum Exporting Countries). The Indonesian oil production from 2000 to 2006 decreased 41% from 517,489 barrel to 367,049 barrel and the proven reserve was 3.99×10^9 barrel in 2007, which declined 22.07% from 2000 [1]. To meet the domestic demand, Indonesia has imported oil, and since 2004, the country has been changing into a net oil importer.

Nearly at the same time, the world geopolitics and economic situation have hit the oil market. Its price has been sharply increasing. Coal becomes promising for oil substitution in the next decade. It is the most widely used energy source in electricity generation, as well as in the industrial sector.

Indonesia as one of the net oil importers has tried to accelerate energy diversification. Indonesia has abundant coal resources and uses coal as one of the promising energy resources for the near future. Currently, Indonesian government policy is to promote coal utilization in the power sector. This effort is to reduce oil utilization.

Total Indonesian coal resources are estimated to be about 90.5×10^{9} tons and are located in 12 coal seams over 15 provinces, while total reserves are only 18×10^{9} tons. Major coal deposits of Indonesia are in South Sumatra (54%), East Kalimantan (28%), South Kalimantan (10%), Riau (2%) and Central Kalimantan (1.4%) [1].

Indonesia was recorded as the seventh largest coal producer in 2007. The total coal production was 231 Mt [2]. Most of it was exported to other countries, and only around 15% of the total production was consumed in the domestic market. Total exported coal was 202 Mt, which consists of 171 Mt of steam coal and 31 Mt of cooking coal. This has made Indonesia the second largest coal exporter after Australia.

According to Electricity Law No. 15/1985, electricity generation in Indonesia is under state authority and conducted by the State Electricity Company (PLN/*Perusahaan Listrik Negara*). Total installed capacity was 30 GW in 2006. Nearly 70% of it was located in Java-Madura-Bali (Jamali) islands. The Jamali capacity mix consists of 43% coal, 39% natural gas, 13% hydro, 4% geothermal and the rest is oil [3]. The Jamali areas consumed almost 79% of total electricity production since past demand was concentrated on this location, and it is the most developed and the densest island in the country.

This paper analyzes the effects of coal price changes on electricity price in Indonesian long term electricity planning, particularly in the Jamali system. The price is analyzed by investigating the impact of changes in oil price on Indonesian coal prices, which is then used to forecast Indonesian coal price in the future. Finally, this paper investigates the environmental emissions of different Indonesian coal grades in the power sector.

2. Indonesian Coal Index

In 2006, Indonesia launched its own coal price list. It is called the Indonesian Coal Index (ICI). In the past, Indonesia used the Barlow Jonker[1] price index method as a reference of Indonesia's coal export price. This method has a more complicated calculation since it used Australian coal as a standard which has lower moisture content than Indonesian coal. The ICI was introduced by Argus[2] and Coalindo Energy[3] with the brand "Argus/Coalindo ICI" which is ready to be used by the domestic market as well as abroad. The ICI consists of four coal grades based on their calorific value namely: ICI-1, ICI-2, ICI-3 and ICI-4. Table 1 shows characteristics of each coal grade.

Table 1 Coal characteristics in ICI.

Grade	CV (kCal/kg)	TM (%)	Ash (%)	Sulfur (%)
ICI-1	6,500	> 12	> 12	> 1
ICI-2	5,800	> 18	> 10	> 0.8
ICI-3	5,000	> 30	> 8	> 0.6
ICI-4	4,200	> 40	> 6	> 0.4

Note: CV stands for calorific value.
TM stands for total moisture.

[1] Barlow Jonker is an international coal consulting and research: company coal market information, supply & demand including basin, reserves, mine, mining, & prices.

[2] Argus is a leading provider of price assessments, business intelligence and market data for the global coal, electricity, oil, gas, emissions and transportation industries.

[3] Coalindo Energy is the provider of Indonesia's coal price reference

The Argus and Coalindo Energy assessments decide the ICI methodology.The Argus assessment is based on daily market surveys, balance between buyers and sellers, transactional data, bids and offers, weighting average, and independent assessments. The Coalindo Energy assessment is based on panel methodology, buyers, sellers, and intermediaries are represented on the Coalindo Energy ICI panel. Ten percent of top and bottom prices were eliminated to ensure accuracy and independent assessment as well.

2.1 Effect of Fluctuation in Oil Price on the ICI

Coal is a substitute fuel for oil. An increase of oil price will affect coal price since the demand of coal will also increase as a consequence of demand shifting from oil to coal. The coal price consists of the following elements: coal pool price, transport costs, and tax [4]. We simplified this by assuming that all indexation factors in the coal pricing formula are fixed. We assumed that oil price varies from 30 to 160 US$/Barrel. The upper price range reflects a high oil price situation. This method is adopted from Nakawiro and Bhattacharyya [5].

Figure 1 presents the effect of oil price on the ICI. At 45 US$/Barrel oil price, ICI-1 is 36.2 US$/ton, ICI-2 is 30.4 US$/ton, ICI-3 is 22.5 US$/ton and ICI-4 is 19.5 US$/ton. The ICIs increase by over three times if the oil price increases to 160 US$/Barrel.

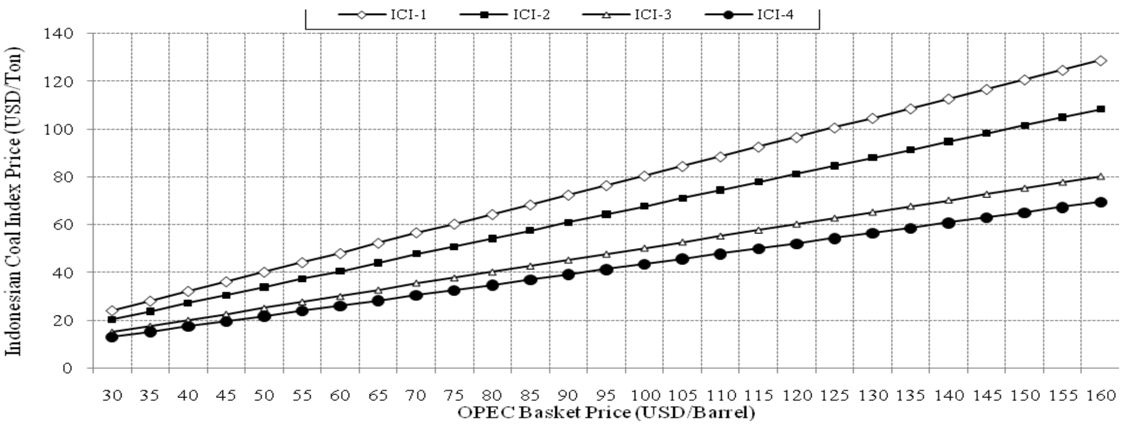

Figure 1. Effect of oil price on the ICI.

2.2 Coal Price Projection

The Energy Information Administration (EIA) of the United States has published an Annual Energy Outlook (AEO) [6] which includes oil price forecasting. In this paper, we use the EIA oil price forecasted to analyze long term ICI from 2006 to 2025. Two scenarios are considered in the EIA oil price forecasting: a low economic growth scenario and a high economic growth scenario. As mentioned before, the oil price affects the ICI directly. Different ICI grades are analyzed as a direct impact of oil price in Figures 2 and 3.

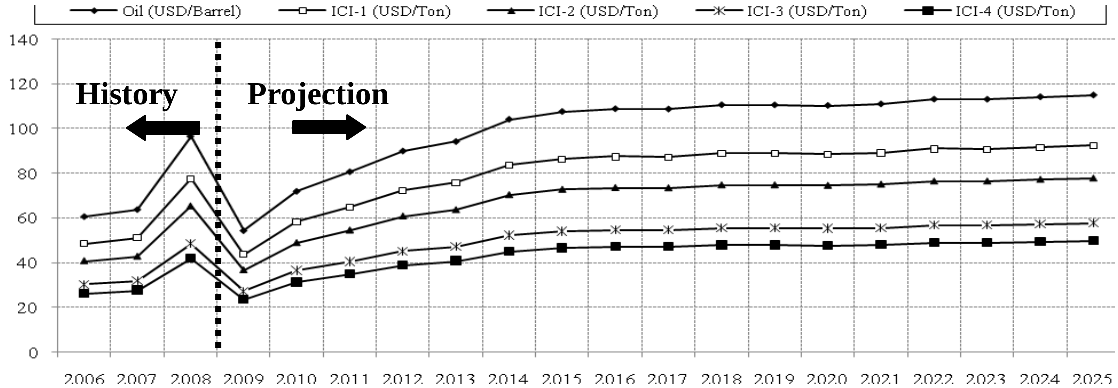

Figure 2 Indonesian coal price forecasting due to oil price in the low economic growth scenario.

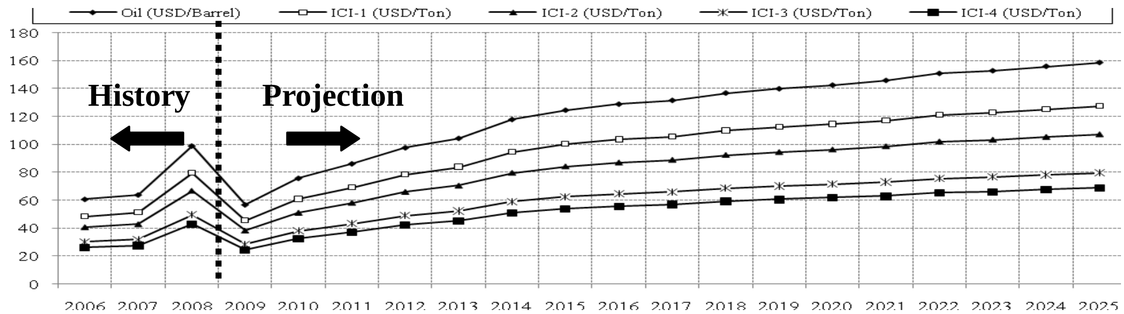

Figure 3 Indonesian coal price forecasting due to oil price in the high economic growth scenario.

In the low economic growth scenario, the highest oil price happens at the end of the period, about 115 US$/Barrel. It affects the ICIs by over two times that of the base year. The lowest prices both of oil and ICIs happen during 2008 to 2009. Similarly, in the high economic growth scenario, the lowest prices, both of oil and ICIs also happen from 2008 to 2009. After 2009, the oil price is increases sharply to nearly three times that of the base year. At the end of period, the oil price is projected to be 158.6 US$/barrel, while the price of ICIs increases to nearly three times that of 2006.

3. Methodology

3.1 Modeling Tool

The Long-range Energy Alternatives Planning (LEAP) model used in this study is a scenario-based energy-environment modeling tool developed by Stockholm Environment Institute (SEI). Its scenarios are based on comprehensive accounting of how energy is consumed, converted, and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on.

With its flexible data structures, LEAP allows for analysis as rich in technological specification and end-use details as the user chooses [7]

3.2 Cost of Electricity Generation

The basic goal of electricity supply economics is to estimate the production costs of electric power, based on the least-cost mix of available generating options [8]. The cost of electricity generation from power plants can be divided into fixed and variable costs. Fixed costs are mainly capital costs and fixed operation and maintenance costs. Variable costs include fuel and variable operation and maintenance costs. The estimation of fixed costs per unit of electricity generation requires estimation of factors such as the lifetime of power plants, load factor, and the discount rates. That of variable costs requires estimation of fuel cost, heat rate, and heat content, and the discount rate [9].

4. Development of Business as Usual (BAU) Scenario

In this study, the BAU scenario starts from 2006 as the base year. The data on existing, committed, and candidate power plants and electricity demand profile used in this study are based on national electricity planning 2006-2026 [10] and handbook of Indonesia's energy economic statistics [1]. The population growth rate is assumed to be 1% per year and the electrification ratio is expected to be 93% in 2026. The demand sector was divided into four categories: household, commercial, public and industrial sectors. The expected growth rates of electricity demand are given in Table 2.

The efficiency of transformation and distribution branches was calculated by using losses. In 2006 the losses were 15% and assumed to be reduced by 1% per five year period. The committed power plants in the Jamali system from 2006 to 2011 are gas turbine, geothermal, and coal steam with 790 MW, 470 MW, and 9,810MW respectively. The supply planning was based on required reserve margin. For Jamali, the projected reserve margin is 35% until 2019, and then from 2020 onwards the reserve margin is reduced to 30%. Typically the discount rate of power sector projects in Indonesia is 10% [11].

The committed power plants after 2011 are only nuclear power plants. It is expected that nuclear power plants will feed into the Jamali system in 2016, 2017, 2023 and 2024 with each additional capacity of 1,000 MW. Since there is no more data for committed power plants, the additional power plants would be calculated as an input in endogenous capacity variable and follow the government's intention in order to promote using coal resources optimally.

Table 2. Electricity growth in the Jamali system

Sector	Growth rate/year (%)			
	2006-2010	2011-2015	2016-2020	2021-2025
Household	8.9	8.2	7.1	6.2
Commercial	9.6	8.5	7.8	7.2
Public	10.7	11.1	10.7	10.7
Industry	4.0	3.5	3.6	3.8

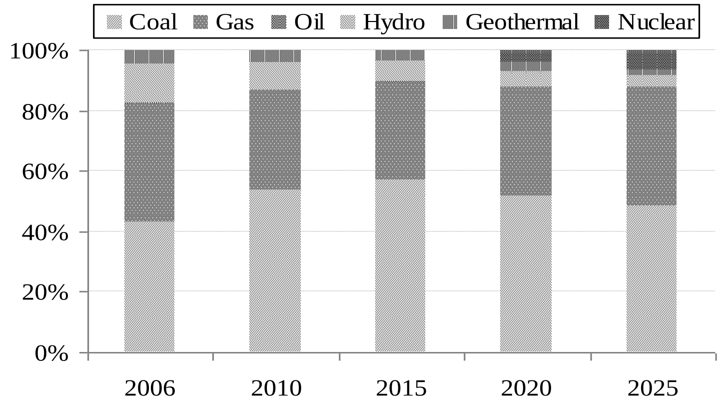

Figure 4 Capacity mix in the BAU scenario

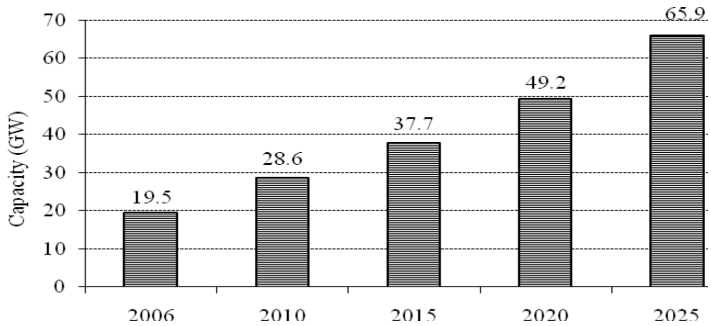

Figure 5 Electricity installed capacity in the BAU scenario

5. Results and Discussion

5.1 Business as Usual (BAU) scenario

Figure 4 shows the electricity generation capacity in the BAU scenario, where at the end of period, the capacity increases to over three times that of 2006 as the base year. In 2025, total electricity generation in the BAU scenario is nearly 66 GW, increasing from 2006 by 19.5 GW. The rapid electricity capacity growth is influenced by high growth rates in demand.

Coal utilization is rapidly grows from the base year until mid period with nearly 60% of total capacity generation. However, at the end of period, coal utilization goes down but is still the largest. The capacity in the BAU scenario is illustrated in Figure 5. In 2025, natural gas utilization is about 26 GW or 40% share in total capacity, taking the second place after coal. Nuclear power plants take the third place with 6% share, while geothermal power plants are last with only 1.3 GW or 2 % share in total capacity.

5.2 Coal in Electricity Generation

The fluctuation of oil price has influenced the fuel cost of steam power plants (see Figure 6 and 7). Typically, the efficiency of coal steam power plants in Indonesia is 32%. The low efficiency also affects the price. The fuel cost increases to almost double at the end of the period for all coal grades and all scenarios. In the low economic growth scenario, by using ICI-1 in the base year, the fuel cost is 20 US$/MWh and at the end of the period increases to about 38 US$/MWh. Moreover, the lowest fuel cost of ICI-1 is in 2009 with 18 US$/MWh. In the high economic growth scenario, in 2025, the fuel cost of using ICI-

1 is 52.71 US$/MWh. The lowest fuel cost of ICI-1 is also in 2009, which is 18.85 US$/MWh.

ICI-2, ICI-3, and ICI-4 follow the ICI-1 trend. However, we found that by using ICI-4, fuel cost is slightly higher than with using ICI-3. The reason is that the calorific value of the ICI-4 is lower than ICI-3 and the total moisture content of ICI-4 is higher than ICI-3. Those affect the energy transformation during coal burning in steam production, which means that the low calorific and high moisture content coal require more coal as compared with the higher calorific and lower moisture content coal. Furthermore, the ICI-4 price is not much different, if compared with ICI-3.

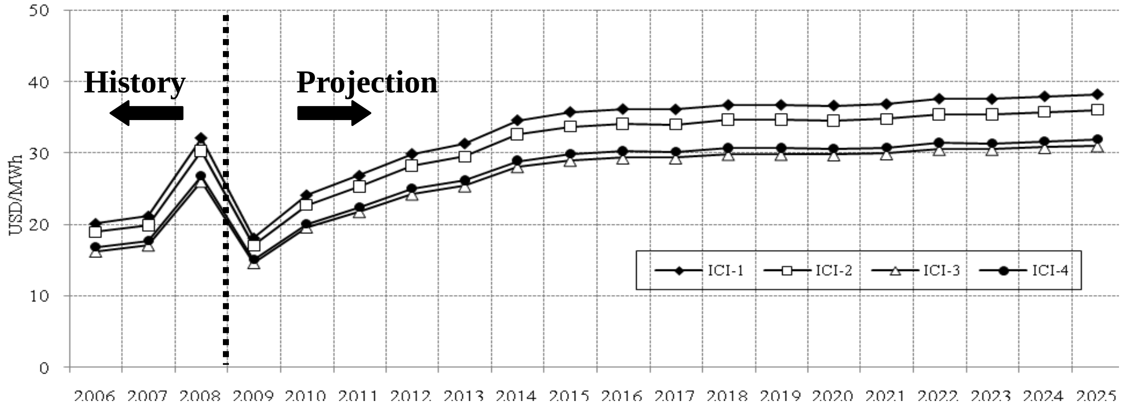

Figure 6 Fuel cost in the low economic growth scenario

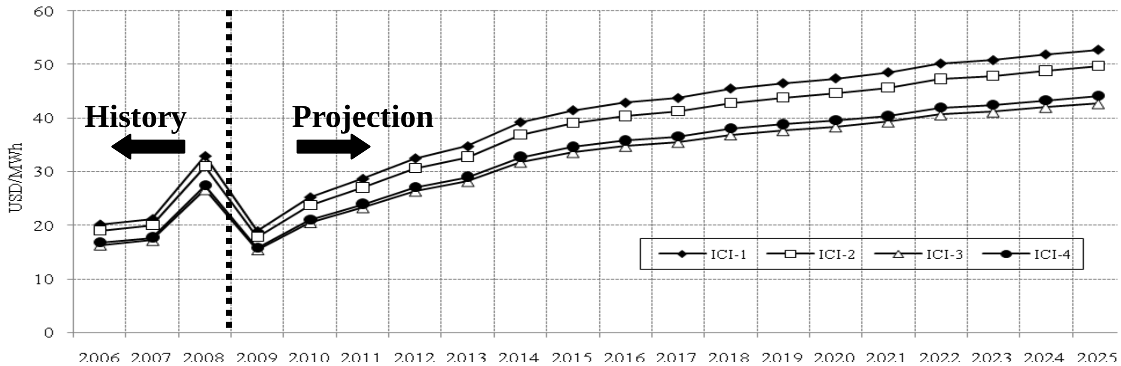

Figure 7 Fuel cost in the high economic growth scenario

Table 3. Component costs in electricity generation

Type	Capital cost (USD/kW)	Fuel cost (USD/kWh)	Variable O&M cost (USD/kWh)	Fixed O&M cost [f] (USD/kW)
Coal Steam	1,226[a]	*	0.002[b]	21.7
Gas Turbine	550[b]	0.086[b]	0.012[b]	12.4
Combined Cycle	600[c]	0.052[b]	0.005[b]	11.4
Geothermal	1,800[d]	0.048[b]	0.003[b]	95.3
Nuclear	1,728[e]	0.004[e]	0.008[e]	34.3

*Note: * fuel cost of coal steam varies depending on coal grade*
Source:

a) BATAN, 2002 [12]
b) PLN, 2005 [13]
c) IEA, 2005 [4]
d) Sanyal, 2005 [14]
e) BATAN, 2006 [15]
f) IAEA, 2002 in Chatzimouratidi and Pilavachi, 2008 [16]

5.3 Cost of Electricity Generation

In power development, when trying to make a decision for the best power plant that will be developed, costs are one of the sensitive parameters that should be considered. The lower the costs, the better is the performance of the power plants (Chatzimouratidi and Pilavachi, 2008). For power plant investors, costs also are important considerations due to benefits that they will earn from investment.

All calculated production costs are presented in Table 3. In 2025, in the low economic growth scenario, the lowest electricity production cost is for ICI-3 as fuel with 3.65 Cents/kWh. It is lower than using ICI-4 and ICI-2 with 3.75 Cents/kWh and 3.75 Cents/kWh, respectively. However, ICI-1 has the highest electricity production cost since it uses high calorific and low moisture content coal, which is 4.38 Cents/kWh (see details in Figure 8).

Similarly, in the high economic growth scenario, using ICI-3 as fuel results in the lowest electricity production cost. It is about 4.82 Cents/kWh. In second and third are the ICI-4 and ICI-2, which are 4.97 Cents/kWh, and 5.53 Cents/kWh, respectively. The highest electricity production cost comes from utilizing ICI-1, which is around 5.83 Cents/kWh (see details in Figure 9).

Compared with other power plant types such as gas turbine, combined cycle, geothermal, and nuclear, coal steam production cost by using different coal grades in Indonesia is not the lowest one. However, the lowest production cost goes to nuclear power plants (see Figure 10). Gas turbine power plants have the highest electricity production cost, though the capital cost is lower than the others. This is due to high fuel price and low efficiency of gas turbine power plants.

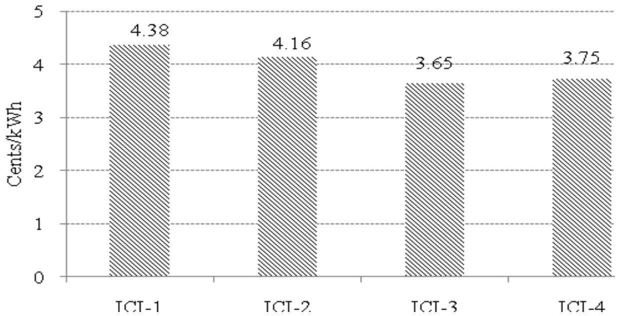

Figure 8 Electricity production cost in the low economic growth scenario in 2025

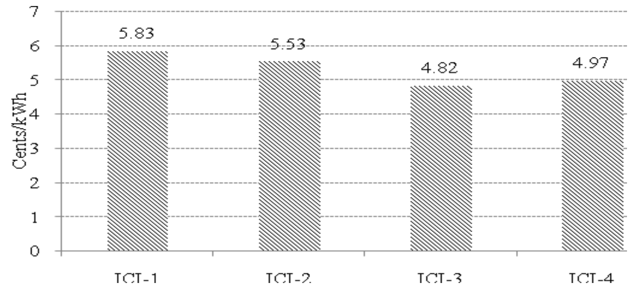

Figure 9 Electricity production cost in the high economic growth scenario in 2025.

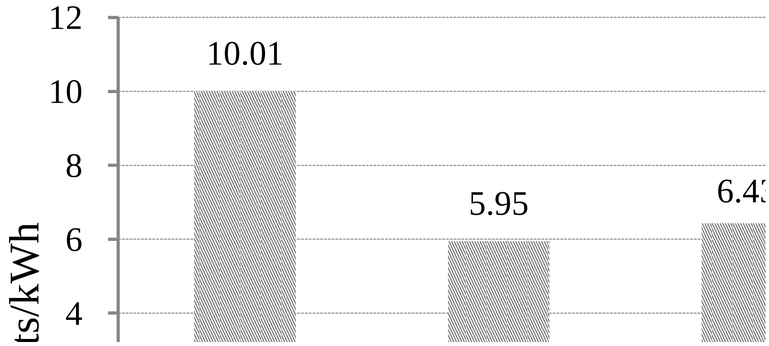

Figure 10 Electricity production cost from selected plant types in 2025.

5.4 Environmental Perspective

According to the IPCC (Intergovernmental Panel on Climate Change) assessment, the emissions from the power sector are the main focus since it is the main contributor of global warming. The largest growth in Greenhouse Gas (GHG) emissions between 1970 and 2004 has come from energy supply, transport, and industry, respectively, while residential and commercial buildings, forestry (including deforestation) and agriculture sectors have been growing at a lower rate [17]. The LEAP model uses the most up-to-date Global Warming Potential (GWP) factors recommended by the IPCC. Furthermore, GWPs are always expressed relatively to level of CO_2 [4]. The major global warming potentials that come from the power sector are carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrous oxide (N_2O).

In all periods, the lowest emissions come from utilization of ICI-1 as fuel since it uses high calorific coal and low moisture content. Meanwhile, the utilization of ICI-4 gives the highest emissions among the other ICIs. At the end of period, ICI-1, ICI-2, ICI-3 and ICI-4 emit 200, 230, 239, and 249 million tonnes of CO_2 equivalent, respectively. Total emissions of coal steam power plants using different coal grades are presented in Figure 11.

[4] CO_2-equivalent emission is the amount of CO_2 emission that would cause the same time-integrated radiative forcing, over a given time horizon, as an emitted amount of a long-lived greenhouse gas (GHG) or a mixture of GHGs. The equivalent CO_2 emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon. For a mix of GHGs it is obtained by summing the equivalent CO_2 emissions of each gas. CO_2-equivalent emission is a standard and useful metric for comparing emissions of different GHGs but does not imply the same climate change responses (IPCC, 2007).

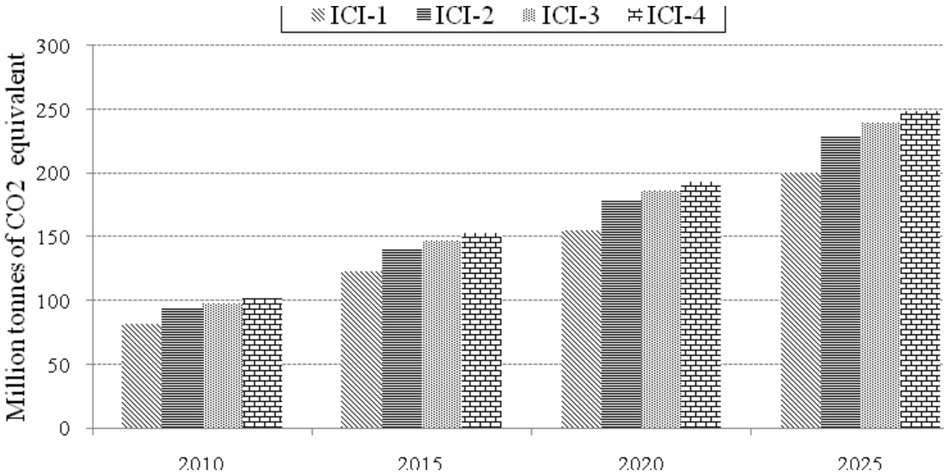

Figure 11 Total emissions from coal steam power plant using different coal grades.

6. Conclusion

The evaluation of the impact of changes in oil price on Indonesian coal price and the environmental impact of different coal grade utilization in the power sector reveals that in the future, oil prices will increase significantly. Furthermore, we assume that the increase of oil price will affect Indonesian coal prices since the global demand on oil will shift to coal. In addition, Indonesia as a country of abundant coal resources also will optimally use more coal in power generation. Another reason is to reduce. The cost of producing electricity, due to financial limitations of the government. Nevertheless, the government faces environmental issues since coal utilization in combustion processes produces greenhouse gases, more than other fuels.

By ignoring all external costs, various Indonesian coal grade utilization in power generation has been analyzed in order to obtain what kind of ICI type would be the most suitable for an electricity generation fuel, which is considered on economic value as well as CO_2 emissions. It is found that ICI-1 with 6500 kCal/kg is the most environmental friendly among the other coal grades, but the cost to produce electricity from ICI-1 is more expensive compared to the others. The lowest cost to produce electricity is by using ICI-3, though it is not the lowest emission producer among the other ICI types.

Furthermore, Indonesia needs to develop its clean coal technology to answer those cost challenges. The steps to decrease environmental impact and electricity production cost are by considering several aspects such as pre-combustion, ongoing combustion, and post combustion. In the pre-combustion step, the coal quality and the efficiency of coal transportation should be increased. In the ongoing combustion step, new clean coal technologies such as Fluidized Bed Combustion (FBC), Integrated Gasification Combined Cycle (IGCC), and Lime Direct Injection (LDI) could be applied to increase the efficiency, as well as to produce cleaner combustion. Finally, the post combustion step is to reduce emissions from coal combustion by-product by using technologies such as electrostatic precipitators and flue gas desulfurization.

Combining affordable energy sources in terms of price by using abundant domestic resources and advanced techno-logies would help Indonesia to increase its energy security in the long term as well as sustainability of the environment.

7. Acknowledgements

The authors would like to acknowledge The Joint Graduate School of Energy and Environment (JGSEE) at King Mongkut's University of Technology Thonburi (KMUTT) for providing scholarships and Sirindhorn International Institute of Technology (SIIT) at Thammasat University for providing the facilities during the study. We are grateful to PT. Coalindo Energy, Indonesia for providing some data required in this study. We also would like to thank Dr. Charlie Heaps from Stockholm Environmental Institute (SEI) for his kind advice in LEAP modeling in this study.

8. References

[1] Centre for Data and Information on Energy and Mineral Resources (CDI-EMR). Key Indicator of Indonesia Energy and Mineral Resources. Ministry of Energy and Mineral Resources, Jakarta, Indonesia, pp. 4-7, 2007.

[2] World Coal Institute (WCI). Coal Facts 2008. Available online: http://www.worldcoal.org/pages/content/index.asp?PageID=188 (May 26, 2009).

[3] Centre for Data and Information on Energy and Mineral Resources (CDI-EMR). Handbook of Indonesia's Energy Economic Statistics, Jakarta, Indonesia, pp. 56-66, 2007.

[4] International Energy Agency (IEA). 2005. Projected Costs of Generating Electricity: Update, OECD Publication, Paris, France, pp. 35-52. International Energy Agency (IEA). 2007. Coal Information 2007, OECD Publication, Paris, France, pp. I.23-I.26, 2005.

[5] Nakawiro, T. and Bhattacharyya, S.C., High Gas Dependence for Power Generation in Thailand: The Vulnerability Analysis, Energy Policy. 35, pp. 3335–3346, 2007.

[6] Energy Information Administration (EIA). 2009. Forecasts & analyses of Energy Information. Report #: DOE/EIA-0383(2009) Early Release. Available online: http://www.eia.doe.gov/oiaf/forecasting.hhtm (February 25, 2009).

[7] Stockholm Environment Institute (SEI). Long-range Energy Alternative Planning System; User Guide, Boston, USA, pp. 1-8, 2006.

[8] Swicher, J.N., Jannuzzi, G.M. and Redlinger, R.Y. 1997. Tools and Methods for Integrated Resources Planning: Improving Energy Efficiency and Protecting the Environment. UNEP. Riso National Laboratory. Denmark, pp. 132-148, 1997.

[9] Sathaye J. and Phadke A., Cost and Carbon Emissions of Coal and Combined Cycle Power Plants in India: Implications for Costs of Climate Mitigation Projects in a Nascent Market, Lawrence Berkeley National Laboratory, Berkeley, U.S.A., pp. 5-12, 2004.

[10] Ministry of Energy and Mineral Resources (MEMR), National Electricity Planning 2006-2026, Jakarta, Indonesia, pp. 29-35, 2006.

[11] Ministry of Research and Technology (MRT), White Book of Indonesia 2005-2050: Research, Development, and Application of Science and Technology in New and Renewable Energy Source to Support Energy Security in 2025, Jakarta, Indonesia, pp. 22-11, 2006.

[12] National Nuclear Energy Agency (BATAN), Comprehensive Assessment of Different Energy Sources for Electricity Generation in Indonesia (CADES) Phase I, Jakarta, Indonesia, pp. 1-4, 2002.

[13] State Electricity Company (PLN), Statistics 2005, Jakarta, Indonesia, 2005. Available online: http://202. 162.220.3/statistik/statistik.asp (June 02, 2009).

[14] Sanyal, S. K. 2005. Cost of Geothermal Power and Factors that Affect it. Proceedings of World Geothermal Congress 2005, Antalya, Turkey, April 24-29, 2005, pp. 90-100.

[15] National Nuclear Energy Agency (BATAN). 2006. Study on Economics, Funding and Ownership Structure in the Preparation of the First Nuclear Power Plant in Indonesia, Jakarta, Indonesia.

[16] Chatzimouratidis, A.I., Pilavachi, P.A. , Technological, Economic and Sustainability Evaluation of Power Plants Using the Analytic Hierarchy Process. Energy Policy. 37, pp.778–787, 2009.

[17] Intergovernmental Panel on Climate Change (IPCC). Climate Change 2007: Synthesis Report, pp. 13-15, 2007.