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ECONOMIC AND ENVIRONMENTAL EMISSION ANALYSIS IN INDONESIAN ELECTRICITY EXPANSION PLANNING: LOW-RANK COAL AND GEOTHERMAL ENERGY UTILIZATION SCENARIOS

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ABSTRACT
This paper examines the utilization of low-rank coal and geothermal energy resources in the long-term Indonesian electricity expansion planning in high populated islands, such as Java, Madura, and Bali up to 2027. The long-term electricity expansion of these areas meets several problems such as supply security, financial limitation, and environmental issues. Therefore, the modeling of long-term geothermal and low-rank coal utilization is examined in terms of expansion cost as well as the environmental impacts. In 2027, the required capacity to fulfill the future demand is estimated about 133 GW. Under the coal scenario, the domination of coal becomes bigger with 75.4 GW or 57% of total electricity generation mix. However, under the geothermal scenario, the installed power plant from geothermal sources increases to be 7 GW and coal utilization decreases to be only 67.6 GW or 51% of total electricity generation share. In the economic perspective, more geothermal power plant needs to be developed in order to reduce to coal utilization in power generation. In the end of the planning horizon, the coal scenario emits as much as 487 million tons of CO_2 equivalents, while the geothermal scenario succeeds to reduce emission by 43.3 million tons out of the coal scenario's emission.

Keywords: Long-term electricity supply planning, Indonesia, Low-rank coal, Geothermal, CO_2 Emission.

1. INTRODUCTION

There is a common belief of mutual interdependence between electricity demand growth and economic development of a country due to electricity's vital role for the country's development. It is the task given to the electricity utility to meet electricity demand appropriately either in short term or long term timeframe by making an accurate load forecasting and generation expansion planning. In turn, government can synchronize the national policy in utilizing primary energy resources whether they are renewable or non-renewable required in electricity generation. Like any other countries, Indonesia is now facing a great challenge on supply security. The improvement of Indonesian supply security particularly in Java, Madura, and Bali, or known as JaMaLi, has been discussed previously (Wijaya and Limmeechokchai, 2009), in which geothermal energy utilization would contribute toward the total installed capacity reduction up to 6.7 GW and mitigate 75 million tons of CO_2 equivalent emission. Another paper has discussed the simulation of electricity production cost in Indonesia by relying largely on coal as a fuel under the influence of dynamics of world oil prices (Wijaya and Limmeechokchai, 2011). In this paper, system expansion cost and environmental effect in terms of CO_2 emission mitigation up to 2027 for JaMaLi interconnection system is examined with respect to Business as Usual, geothermal utilization, and low-rank coal utilization scenarios in order to ensure the security of electricity supply and clean energy supply.

2. POWER SECTOR CONDITION, NATIONAL ENERGY PLANNING AND POLICY, AND RESOURCES

2.1. Overview of Indonesian and JaMaLi Power Sector

In 2009, Regulation No. 30 governing national electricity has been issued. The law stipulates that the regional government enterprise as well as enterprise formed by Non-Government Organization will be welcomed into services. The electricity tariff will be decided differently throughout regions. However, in the years to come, PT. Perusahaan Listrik Negara or PLN, which is a state-owned electricity enterprise, will still play significant roles in provisioning electricity services throughout the country. In 2009, national electricity production amounted to 156,797 GWh or 4.93% increase from 2008, which reached 149,437 GWh (PT. PLN, 2010a). Meanwhile, the JaMaLi areas consumed almost 78% of the total national electricity sales. In 2007, total installed capacity in JaMaLi was 22,906 MW or about 70% to the total national. The new additional power plants entered into the JaMaLi interconnection system was 910 MW, consisting of a 110 MW Wayang Windu geothermal plant, a 300 MW Labuan steam-fired plant, and a 500 MW Muara Karang repowering gas-steam fired plant. In 2009, provided the net peak load of 17,211 MW, it has resulted a load factor of 77.7%. In addition, the electrification ratio was 69.8% (PT. PLN, 2010b).

2.2. National Energy Planning and Policy

The national energy policy is initially stated in the Presidential Regulation No. 5/2006. It is followed by the Energy Law No. 30/2007. In 2010, The Directorate General of New Renewable Energy and Energy Conservation has proclaimed the energy vision 25/25, which is a vision to achieve the target of 25% share of renewable energy in national energy mix in 2025, or 8% higher than that stated in the previous regulation (MEMR, 2011). The government's main policy includes conservation of Energy to improve the efficiency of the use and utilization of energy on the demand side, and diversification of Energy to increase the share of renewable energy in national energy mix on the supply side. Currently, Indonesian government policy is to diversify the primary energy sources for electricity generation by gradually reducing oil to others before 2012 (Wijaya and Limmeechokchai, 2009). The government policies in electricity expansion include coal utilization and promoting geothermal resources. The “Fast Track Program” through 10,000 MW coal power plants development acceleration was initiated in 2006 and continued up to now with the second phase. Nevertheless, the power plant capacity target is not yet reached due to several obstacles. Meanwhile, geothermal energy utilization is being promoted as it is stated in the national energy management blueprint 2006-2025 (MEMR, 2005). The current phase remains to deal with the supportive regulation issued by the government as the implementation to the Energy Law.

2.3. Low-Rank Coal and Geothermal Energy Potential

Indonesia has two abundant energy resources, which are coal and geothermal energy that can be utilized to support economic development of the country. As per 1 January 2009, the coal reserves dominated by low-rank coal were 18,780 Million tons (MEMR, 2010). None of this reserve is located in the JaMaLi areas. The most abundant is located in the South Sumatra Province with 9,542 Million tons and followed by East Kalimantan and South Kalimantan with 3,633 Million tons and 3,523 Million tons, respectively. Meanwhile, Indonesian geothermal potential and reserves as per February 2009 is presented in Table 1 (Saptadji, 2010).

Table 1 Indonesia geothermal resources potential, reserves, and installed capacity

Location	Potential resources (MW)	Reserves (MW)	Installed capacity (MW)
Sumatra	7,396	6,240	12
Java-Bali	4,076	6,191	1,117
Sulawesi	1,092	1,210	60
Rest islands	1,521	1,089	-
Total	13,440	14,730	1,189

Potential resources and reserves are estimated 28,170 MW or almost 40% of the world potential. Besides, potential resources is comprised of speculative and hypothesis resources, meanwhile reserves consists of probable, possible, and proven reserves. Despite the huge potential, the total system installed capacity in early 2009 was only 1,189 MW or 2.24% of the total national installed capacity.

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 which was developed by the Stockholm Environment Institute. The main concept of LEAP is the end-use driven scenario based analysis. 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 and so on. The LEAP model contains the technology and environmental database (TED) that is used to estimate the environmental emission of energy utilization (SEI, 2006). Unlike macroeconomic models, LEAP does not attempt to estimate the impact of energy policies on employment or Gross Domestic Product (GDP), although such models can be run in conjunction with LEAP.

3.2. Demand Assumptions

Electricity sales in 2007, according to data from Ministry of Energy and Mineral Resources (MEMR, 2008), in JaMaLi were 34 TWh of residential sector, 41 TWh of industrial sector, 15 TWh of commercial sector and 5 TWh of public sector. The annual electricity demand growth is expected to increase as much as 12.6%, 3.4% 11.4%, and 11.4% for residential, industrial, commercial and public sectors, respectively from 2008 to 2027. In the same period, the economic development is projected to be about 6.1% per year. Meanwhile, the population growth is assumed to be 1% per year and the electrification ratio is expected to be 100% in 2020.

3.3. Supply Assumptions

In order to meet vast electricity demand, the power generation is planned by following the demand requirement. The planning reserve margin to secure the electricity supply must be meeting 30% by 2027. The transmission and distribution losses in 2007 are 13.6%. This will be reduced to be 12% by 2027. The dispatch of power plant in JaMaLi system is ordered as follows; coal-steam, geothermal and combined cycle power plants in the base load; hydropower and gas turbine power plants in the middle load; and diesel-engine power plants in the peak load. Moreover, the efficiencies of power plant are 80% for hydropower and geothermal, 22% for gas turbine, 35% for combined cycle, 37% for diesel engine, and 32% for coal steam.

4. RESULT AND DISCUSSION

4.1. Electricity Demand Projection

Slowly but sure, the domination of the industrial sector from the base year will be overtaken by the residential sector in 2010 and thereafter. Figure 1 presents the electricity demand projection in JaMaLi system from 2008 to 2027. In 2008, the industrial sector consumes 42 TWh, and in the end of the period will consume about 79.4 TWh. While, the residential sector only consumes 38 TWh in 2008, but later, the consumption increases significantly to be 362 TWh in the end of planning horizon.

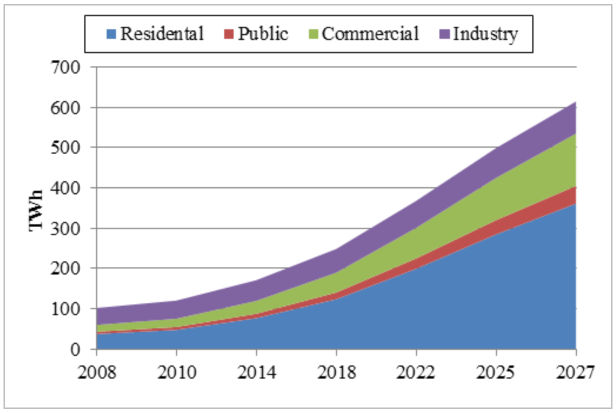

Figure 1 Electricity demand forecasting in JaMaLi system from 2008-2027

Electricity demand growth of the industrial sector is projected being constant in the near future in JaMaLi area; this is due to the application of decentralization policy in Indonesia, including the economic development. It means that the economic growth will not only be focused in JaMaLi, but also spread out to the whole country. The change of the demand dominator in the future is a good opportunity to put concern in applying energy conservation in the residential sector. As a consequence to the increasing of electricity demand in the future, the power generation capacity in JaMaLi system must also be increased. Because of the efficiency of power plants, losses during the transmission, and also the reserved margin, in 2027, the required capacity to fulfill future demand is 133 GW.

4.2. Coal Scenario

In this scenario, coal is used to be main backer of electricity generation mix in the future. Coal scenario dominates the total generation share since the first period until the end of period. In 2008, coal takes 44% of total power generation share, or about 10.5 GW. It is followed by the natural gas with 9.8 GW or accounted as much as 41%. In the end of the period, the domination of coal becomes bigger with 75.4 GW or 57% of total electricity generation mix, while the share of natural gas becomes smaller, it is about 52.7 GW or 39%. Figure 2 shows detail of electricity generation mix from 2008 to 2027. The optimization of coal resources in power generation is in accordance with the government plant to promote cheap and abundant energy resources in Indonesia.

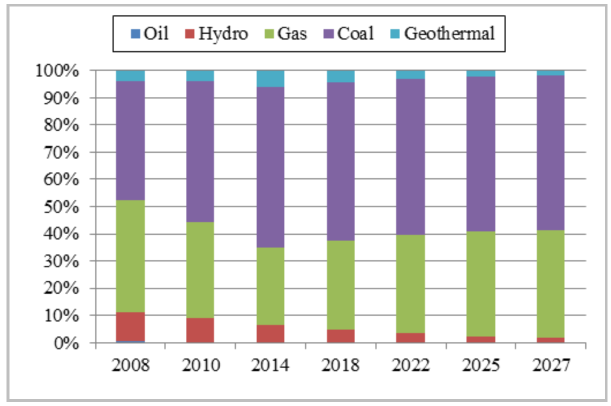

Figure 2 Electricity generation mix in the coal scenario

4.3. Geothermal Scenario

To optimize the abundant geothermal potential in Indonesia, particularly in JaMaLi area, the second scenario of long-term electricity planning is to enlarge the power generation capacity from geothermal. Figure 3 presents the electricity generation mix under the geothermal scenario. In year 2027, the installed power plant form geothermal sources increase to be 7 GW. It should be noted as a significant growth from only 1.2 GW in the base year. Furthermore, the increasing geothermal utilization in power sector reduces the use of coal and gas. As compared to the coal scenario, in year 2027, the coal utilization decreases to be only 67.6 GW or 51% of total electricity generation share. Similarly, the natural gas also decreases to be 55.6 GW, even though it takes bigger electricity generation share by 42%.

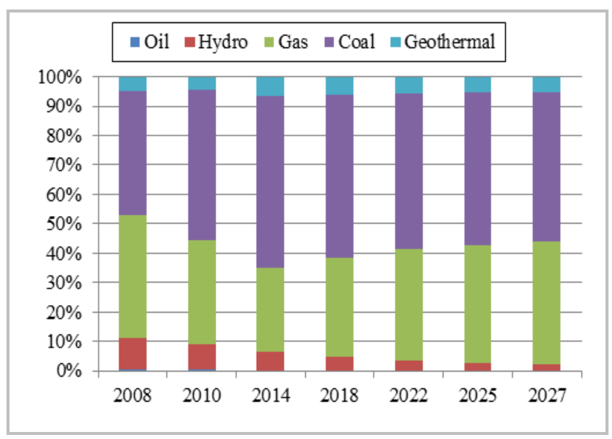

Figure 3 Electricity generation mix in the geothermal scenario

4.4. Economic Perspective

Costs are one of the sensitive parameters that should be considered in the power development. All required production costs are presented in Table 2. For capital cost, the geothermal power plant has the highest cost, which is US$ 1.8 million, and gas turbine power plant requires the lowest capital cost by about US$ 0.6 million. The coal steam power plant requires the lowest fuel cost and operating and maintenance (O&M) cost among the others, which are US$ 26.76 and US$ 2.15 per MWh, respectively.

Table 2 Components of cost in all scenarios

Type of power plant	Capital cost (US$/MW)	Fuel cost (US$/MWh)	O&M Cost (US$/MWh)
Coal steam	1,126,000[a)]	26.76[b)]	2.15[b)]
Gas turbine	550,000[b)]	86.47[b)]	11.69[b)]
Combined cycle	600,000[c)]	53.34[b)]	5.37[b)]
Geothermal	1,800,000[d)]	48.19[b)]	3[b)]

Source: a) BATAN (2002), b) PLN (2005), c) IEA (2005), d) Sanyal (2005)

The calculated total costs of all scenarios are presented in Table 3. In 2008, coal fired power plant required US$ 0.54 billion whereas geothermal power plant required US$ 0.79 billion. In general, the geothermal scenario tends to require more cost than the coal scenario from 2008 to 2027. At the end of observation period, there is a difference of US$ 0.38 billion between two scenarios. Thus, it is clear that in geothermal scenario, more geothermal power plant needs to be developed in order to reduce to coal utilization in power generation.

Table 3 Comparison of total cost in all scenarios (Billion US$)

Scenario	2010	2014	2018	2022	2025	2027
Coal	0.77	1.44	2.21	3.36	4.72	5.91
Geothermal	0.79	1.46	2.30	3.53	5.00	6.28

4.5. Environmental Impact

The power generation is always associated with the greenhouse gases. The energy production releases emission to the atmosphere, and then it causes the global warming. The global warming potentials are always expressed relatively to level of CO_2. Figure 4 presents the environmental emission of the coal and geothermal scenario. It can be seen that from year 2014 the emission from the geothermal scenario starts to get lower than the emission from the coal scenario. In the end of planning horizon, the coal scenario emits as much as 487 million tons of CO_2 equivalent, while the geothermal scenario succeeds to reduce emission by 43.3 million tons from the coal scenario`s emission.

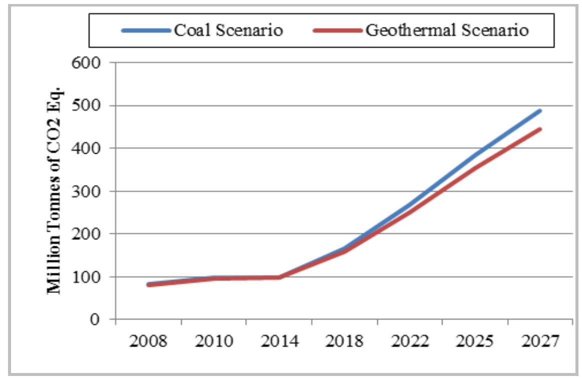

Figure 4 Environmental emissions of both scenarios

5. BARIER AND POTENTIAL SOLUTION

5.1. Clean Coal Development

Clean coal, one of many alternative fuels under development worldwide, is created by gasifying, washing or burning standard coal to remove sulfur dioxide, minerals and other impurities. The coal is then re-burned to recover the carbon dioxide. The technology has been seen to enhance efficiency and reduce carbon dioxide and other greenhouse gasses emission. The low rank coal is the major type subjected to the clean coal technology. Indonesia currently consumes around 20% of the country's majoring low rank coal production for power generation and industry while the remaining 80% is exported. The prospect for domestic steam coal is good as the demand for electricity is ever growing up. As the energy policy is move toward renewable and sustainable energy with respect to increasing awareness in the environmental concern, the prospect for clean coal technology implementation in Indonesia is becoming brighter. Clean coal technologies do not yet become priority as the country struggles to meet nationwide power demands. However, clean coal technologies such as coal upgrading, coal gasification, and coal liquefaction, are currently considered to be applied for power generation (Bukin, 2009). Those technologies are manifested under several pilot projects and other research activities. Development on several Upgraded Brown Coal (UBC) pilot plants has resulted upturn in low rank coal calorific value. Study on Coal Water Mixture (CWM) using low rank coal and bituminous coal is currently under way. Starting in 2008, study market on CWM utilization is carried out under joint cooperation with foreign partner. Basically, Indonesia is interested in developing clean coal technology from the utilization of low rank coal. Nonetheless, its commercialization is facing major barriers in terms of financial scheme issue and supportive regulations to boost faster development and commercialization of clean coal technology. Facing this circumstance, international cooperation as well as bilateral agreement should also be further explored and initiated. Technology transfer program as well as possible financial scheme should be further explored and initiated. Meanwhile, stringent regulation can be applied in provisioning and utilizing coal. Imposing tax and penalties in utilizing low rank coal up to certain quantity is one way to up lift clean coal technology. On the other hand, supportive regulations involving incentives and technical assistances can be beneficial for both clean coal producer and major customers, i.e. State Power Company, Independent Power Producer, and industry.

5.2. Geothermal Development

Indonesia has the largest geothermal resources in the world. However, if it is compared to the other countries, the development of the geothermal resources is quite slow. This is due to the fact that Indonesia still relies on fossil fuel to generate electricity. Merely 3% of the total capacity comes from the geothermal energy. The slowness of geothermal development is caused by several factors:

- Geothermal development is a high risk type of investment. Although the long-term costs are low, geothermal development needs extensive upfront capital for survey and site development.
- Producing electricity from geothermal source is more expensive than other types of electricity generation. Moreover, Indonesian government subsidizes oil fuel.
- PLN as a single buyer has financial limitation to purchase electricity from geothermal energy. It is certainly not competitive.
- Most of geothermal resources are located in remote areas with tremendously low electricity demand. Consequently, it needs extra cost to connect the electricity production to the main grid.

Trying to overcome those problems, the government has issued several regulations to support development of geothermal industry. In 2003, Indonesia issued a geothermal Law (Law No. 27/2003) to promote the participation of private sector in geothermal power business. It also gave many powers to regions in particular with respect to licensing. This is a good opportunity for investors as they can now deal directly with the regions. Then, in 2007, the Law was translated in the government regulation No. 59 of the geothermal business activities. Under these regulations, 22 Mining Work Areas (MWA) have been enacted, consisting of 8 MWA in Sumatra, 7 MWA in Java, 2 MWA in Sulawesi, 3 MWA in Nusa Tenggara and 2 MWA in the Moluccas. To support geothermal investment, the government is also preparing a program to complete the restructuring decision about buying and selling electricity from the geothermal power plant. It is explained in the regulation of the Minister Energy and Mineral Resources (MEMR) No. 2/2011. Minister gives an assignment to PLN to purchase electricity produced from geothermal power plant derived from auction come from the MWA and permit holders. Ministerial Regulation sets the highest benchmark price of 9.70 cents USD/kWh for power purchase by PLN. In accordance with this regulation, the purchase price of electricity by PLN from the plant according to the auction of MWA shall be final. Another potential way to accelerate geothermal plant development includes infrastructure extension to the remote area where the geothermal resources are found. This effort should be conducted in parallel with establishing supportive regulations for encouraging region economic development, such as easiness in applying investment permit for manufacturing company and implementation of tax holiday up to certain extent. Such combination would be a great incentive for private sectors in making contribution and in the same way to increase electricity penetration in the remote areas. It is expected through those regulations and other breakthroughs issued by government along with the consistency in the implementation stage, in the near future, the geothermal development could meet the expected target, particularly increasing the installed geothermal capacity called "MEMR's Road Map Development Planning of Geothermal Energy" by at least 6,000 MW geothermal resources in 2020 and 9,500 MW in 2025.

6. CONCLUSION

Following the high electricity demand growth, Indonesia is facing the electricity supply dilemmas; on one side, it needs to improve electricity infrastructure for which the ultimate goal is to provide reliable supply with affordable price, and, on the other side, is to be concerned with the environmental protection. Two scenarios have been presented in this paper; coal and geothermal scenarios. The coal scenario has advantage in the economic point of view, while the geothermal scenario is better for the environment. The specific policies need to be issued by Indonesian government to stimulate clean energy development, such as giving incentive or subsidy to geothermal developer, and supporting research and development in clean coal technology. By issuing such policies, the government aims to realize the clean electricity generation in an affordable price can be achieved.

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