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Micro Review

Contribution of Coal Mine and Coal Fired Power Plant to CO_2-Emission in Indonesia

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Indonesia is one of important coal exporter country in the world, with its total resources 104 billion tons (2008) of measured, indicated, and inferred category. Most of the resources are mined by surface mining method. Indonesia's coal production is increasing from 178.93 MT in 2008, 228.81 MT in 2009, and 280 MT in 2010, and only about 12 % were used for domestic electricity generation. The electricity demand is increasing by years, in the next 10 years the government plans to build 2 × 10,000 MWe new coal fired power plants. It means more coal will be burned, decreasing more forest, and increasing CO_2 emission. Despite of coal burning, open pit mine operations caused large amount of CO_2 emission. As an example, an open pit mine with 48 MT annual production is emitted about 1.46 MT of CO_2, from deforestation and fuel combustion of mining equipment. To reduce the CO_2 emission, diversification of electric generation (i.e. increasing geothermal energy use), and minimizing open areas by rapid revegetation program, should be done.

1. Introduction

Coal is one of the important fossil energy resources in the world, together with oil and natural gas. Another energy sources are non-fossil energy i.e. nuclear, hydropower, geothermal, and in a small scale are solar, wind, and wave energy. Fossil energy, especially coal, is the main resource of CO_2 emission, which responsible to the green house effects or global warming.

Most of the electric generation in the world was generated from coal fired power plants. Another important source for power plants are oil and natural gas, hydropower, and for only several countries, nuclear. To fulfill domestic energy demand, Indonesia use hydropower, oil and natural gas, coal, and geothermal (still in small portion). The use of coal as energy resources in 2008 is about 34.2 % (20,599,521 tons) of the total electric generation (Table 1 and Table 2) [1,2].

Coal burning for electricity has very important role in the CO_2 emission. A study of Hong and Slatick shows that the CO_2-emission factor from coal burning is nearly twice of natural gas, and crude oil is between coal and natural gas[3]. In fact, the CO_2 emission caused by coal burning is not only come from the coal burning itself, but it also comes from coal mining operation. In this case, the land clearing activities (deforestation) and the use of mining machineries will emit CO_2, too.

There are two ways that contribute to reduce the CO_2 emission cause by coal utilization, first is substitute coal fired power plants with geothermal power plants; and the second is progressive reclamation program at the coal mines. For the first way, the ministry of Energy and Mineral Resources of Indonesia has planned an energy source diversification by using the geothermal resources. The other way, the mine operators should do progressive reclamation program and grow plantation that can effectively absorb CO_2 at the mine area.

2. Indonesia's Coal Reserve

Indonesia's coal resources were spread out nearly all the country's islands (Fig. 1) [1], but mostly concentrated in Sumatera and Kalimantan island. Most of the coal resources in Indonesia were deposited in tertiary sedimentation basin in different periods[2]. Some of the important coal basins are Ombilin and Central Sumatera Basin (central part of Sumatera), Palembang and Bengkulu Basin (south part of Sumatera), Barito and Pasir Asem-asem Basin (South Kalimantan), Lower Kutai and Tarakan Basin (East Kalimantan). The newest data of the resources is from year 2010, published by the Indonesian Geological Survey Board, Ministry of Energy and Mineral Resources (Table 1) [1]. Indonesia's coal resources have many different types and qualities depend on its location, sedimentation period, and geological conditions. The quality is spread from very high calorie to very low calorie, with different sulfur, ash, and water content. The known resources are classified as low calorific value (21,000 million tons); 69,500 million tons have medium calorific value; 13,000 million tons of high calorific value; and 1,000 million tons have very high calorific value.

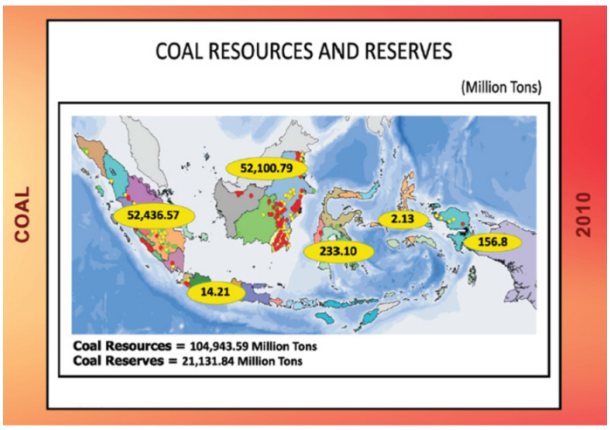

Fig. 1 Map of Indonesian coal resources (2010) [1].

Table 1 Indonesia's coal resources based on its calorific value in million tons (2008) [2)]

Calorific Value	Hypothetic	Inferred	Indicated	Measured	Total
Very High	90.11	482.93	5.80	422.81	1,001.64
High	1,708.18	6,187.4	1,069.29	4,056.6	13,021.5
Medium	27,764.43	18,888.0	10,941.8	11,956.2	69,550.6
Low	5,057.68	6,588.2	3,721.16	5,815.9	21,183.0
Total	34,620.40	32,146.8	15,738.1	22,251.6	104,756.8

Note:
1) Calorific value: Very High: > 7100 kcal/g; High: 6100-7100 kcal/g; Medium: 5100-6100 kcal/g; Low: <5100 kcal/g
2) Up to maximum depth of 100 meter

More detailed exploration programs are still needed to ensure the total coal reserve (measured). Most of the measured coal reserves are situated near the ground surface, the condition make the current operating coal mine in Indonesia are surface mines (open pits). With the current annual production more than 250 million tons, it is predicted that in the next 15 to 20 years, the coal mine operation should switched to underground mining system.

3. Coal Mining and CO_2-emission

3.1 Coal Mining

Most of the known coal reserves in Indonesia are situated near the surface, only up to about several hundred meters depth, then, the existing coal mine are dominantly surface mines (open pits). The operation of an open pit mine start with land clearing to remove the vegetation, followed by excavation of over burden and coal seams. Because of the removal of vegetation, the capacity of the open area to absorb CO_2 will decrease to zero. The deforestation by mining activities is also increase the CO_2 emission.

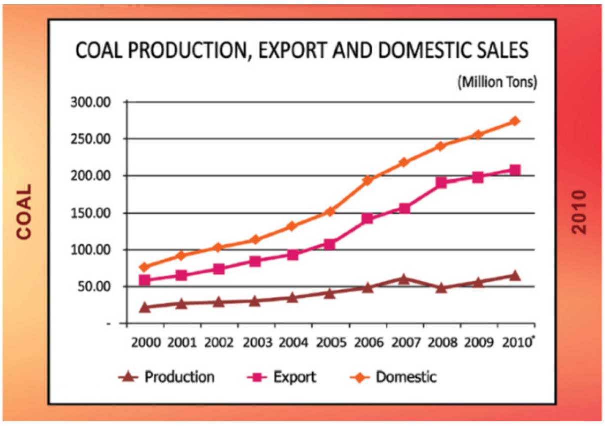

Fig. 2 Indonesia's coal production, export, and domestic use[1)].

To clear the area and to excavate over burden and coal seam, and also to haul/ transport the material to dumping area or stock yard, the mine operates digging, hauling, and transport equipment (bucket wheel excavators, bulldozers, shovels, dump trucks, light vehicles, belt conveyor, coal processing plants, etc), which need fuel oil or electricity. This activity emits CO_2.

3.2 CO_2-emission from Mining Operation

A research about CO_2 emission from mining activities has been carried out at an open pit mine in East Kalimantan in 2005, it conclude that for 30 million tons coal production and 284 million BCM of over burden excavation and dumping, the total CO_2 emission is about 1,454,612 tons/year. The distribution of CO_2 emission is 774,630 tons (51.3 %) come from mining operation and services, and 734,100 tons (48.7 %) come from land clearing (deforestation). The uptake of CO_2 by revegetation program is ca. 54,120 tons (3.7 %) [4)].

Another research at an open pit mine in South Kalimantan (in 2006) shows, for annual coal production of 34 million tons in 2006, its total emission is 961,933 tons/ year; with CO_2-emission from mining operation and services is 574,746 tons (59.75 %), and from land clearing (deforestation) is 387,186 tons (40.25 %). The amount of absorbed CO_2 by re-vegetation program is 8,961 tons (9.3 %) [5)].

Researchers also reported that a revegetation program at an open pit coal mine Air Laya, South Sumatera Province, using eucalyptus tree (Indonesian: *pohon kayu putih*) as the main plantation (ca. 52.5 % of the total vegetation), shows that the CO_2 absorb capacity of 2 years old eucalyptus trees is 2,776 kg/ha/year[6)].

The different absorb capacity of each re-vegetation campaign is caused by the difference of mine's location, local climate, and types of plantation be used. By a progressive re-vegetation program and suitable plantation types, the CO_2 absorb capacity will increase, and that means reduce the total CO_2- emission at the mine site.

3.3 CO_2-emission from Coal Fired Power Plants

The role of coal in electricity generation in Indonesia is quite important. The share of coal sources in electricity generation is about 34.24 % of the total electricity production. Together with hydropower, oil, and gas, coal is one of the main energy sources of Indonesia. According to the Government's Electric Company (PT PLN), in 2008, the total installed capacity of coal fired power plants is 8,674 MWe (Table 2) [7)], consuming 20,999,521 tons of coal (Table 3) [7)].

Table 2 Installed Capacity of PLN's Electric Power Plant (MWe) [7)]

Year	Hydropower	Oil & Gas	Coal	Geothermal	Total
1998	3,006.76	10,443.40	6,770.60	360.00	20,580.76
1999	3,013.99	10,447.75	6,770.00	360.00	20,591.74
2000	3,015.24	10,616.44	6,770.00	360.00	20,761.69
2001	3,105.76	10,673.06	6,900.00	380.00	21,058.83
2002	3,155.17	10,677.06	6,900.00	380.00	21,112.24
2003	3,167.93	10,858.36	6,900.00	380.00	21,206.29
2004	3,199.44	10,975.97	6,900.00	395.00	21,470.41
2005	3,220.96	11,999.14	6,900.00	395.00	22,515.09
2006	3,529.11	12,702.10	8,220.00	395.00	24,846.21
2007	3,501.54	12,772.94	8,534.00	415.00	25,223.48
2008	3,504.28 (13.70 %)	12,910.64 (50.44 %)	8,764.00 (34.24 %)	415.00 (1.62 %)	25,593.92 (100.00 %)

Table 3 Fuel type and consumption for PLN's electric power plant[7)]

Year	Oil (HSD)	Oil (IDO)	Oil (MFO)	Total	Coal	LNG
	1000 liter	1000 liter	1000 liter	1000 liter	ton	MMSCF
1998	2,856,272	26,440	1,253,285	4,135.99	10,634.5	222,055
1999	3,253,219	20,942	1,429,003	4,703.16	11,414.1	236,612
2000	3,141,917	23,146	1,858,568	5,023.63	13,135.6	228,838
2001	3,575,348	30,457	1,793,283	5,399.09	14,027.7	222,421
2002	4,625,521	40,682	2,300,603	6,966.81	14,054.4	192,927
2003	5,024,362	31,573	2,557,546	7,613.48	15,260.3	184,304
2004	6,299,706	36,935	2,502,598	8,506.42	15,412.7	176,436
2005	7,626,201	27,581	2,258,776	9,912.56	16,900.9	143,050
2006	7,586,916	23,977	2,387,622	9,998.51	19,084.5	157,894
2007	7,874,290	13,558	2,801,128	10,688.9	21,466.3	171,209
2008	8,127,546	28,989	3,163,954	11,320.5	20,999.5	181,661

Note:
HSD = High Speed Diesel
IDO = Industrial Diesel Oil
MFO = Marine Fuel Oil
LNG = Liquid Natural Gas
MMSCF =Million Metric Standard Cubic Feet

3.4 Substitution of Coal by Geothermal Energy Source to Reduce CO_2-emission

Indonesia has quite big geothermal resources, about 27,510 MWe. The resources are spread out along the *Indonesia's Ring of Fire* from Sumatra, Java, Nusa Tenggara, Sulawesi, Maluku, and Papua as shown in Figure 3a and 3b. There are about 256 geothermal potential areas has been identified, namely in Sumatra (84), Java (76), Nusa Tenggara (21), Kalimantan (5), Sulawesi (51), Maluku (15), and Papua (3). Most of them are high temperature (> 225 °C), which is suitable for electric generation. The total potential of those geothermal fields are estimated about 27,510 MWe, which 14,172 MWe categorized as reserve (proven of 2,287 MWe, probable of 1,050 MWe, and possible of 10,835 MWe) [8)].

Until now, only 7 geothermal fields (2.7%) of the total geothermal potentials had been used to generate electricity. The total installed capacity of the geothermal power plants is 1189 MWe; i.e. Kamojang field-West Java (200 MWe), Darajat field-West Java (260 MWe), Awibengkok field-West Java (375 MWe), Wayang Windu field-West Java (217 MWe), Sibayak field-North Sumatra (12 MWe), Lahendong field-North Sulawesi (60 MWe) and Dieng field-Central Java (60 MWe) [8)].

Most of Indonesia's big cities and population are in Java island, likewise the industries which need more electricity are also located in Java island (Figure 3b). Consequently, most of electric power plants were built in Java island. With the availability of geothermal resources in Sumatera, Java, and Bali islands, Indonesia has the opportunity to use geothermal energy to build new power plants or substitute some of the existing coal fired power plants. Electricity which generating from those geothermal sources can be connected to the existing Sumatera-Java-Bali electricity interconnection system. The other remote or small geothermal resources can be used to supply electricity for their surroundings cities and communities, then the existing (if there are) coal or oil/gas fired power plants can be closed. With this policy, then the increasing CO_2 emission from coal burning can be reduced.

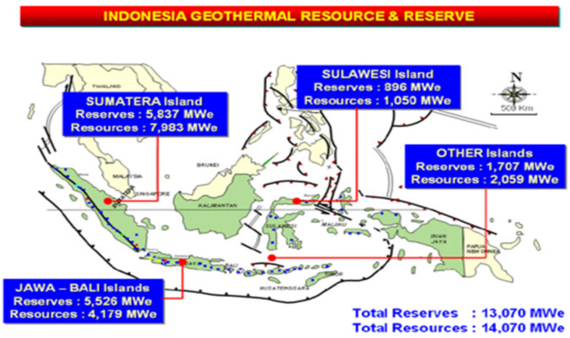

Fig. 3a Map of geothermal resources of Indonesia[8)].

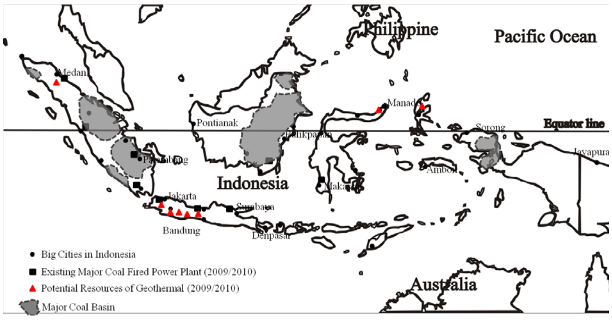

Fig. 3b Map of cities, coal basins, and geothermal fields of Indonesia.

4. Discussion

With the decrease of Indonesian oil reserve and resources, Indonesia will become a net oil importer country. The use of oil as the main energy source will be very expensive. Because Indonesia has big coal resources, then the government of Indonesia should change its energy policy and switching the energy source from oil to coal. On the other hand, referring to International Energy Agency (2011) report of CO_2-emission due to human activity for 2008 (only consider to CO_2-emission from the burning of fuels and cement manufacture, not include emission from land use/ deforestation), Indonesia was ranked as the 16th most CO_2- emitting country (1.28 % of global emission) [9)].

Coal resources are still the main and important energy source of Indonesia in the future. Fortunately, Indonesia has very big coal reserve, even most of them are classified as medium to low categories (lignite to sub-bituminous coal). Because coal has higher CO_2-emission factor than oil, the switch of energy source from oil to coal, of course, will give higher CO_2-emission. The consequence of coal as main energy source is the increase of CO_2-emission. A CO_2 reduction program should be arrange/ planned to manage the raise of CO_2-emission.

CO_2 emission is not only produced by coal fired power plants, but also produced by mining operations such as fuel oil burning, land clearing and others. To reduce CO_2 emission at coal mine sites, the absorb capacity of land cover plantation should be increased. And one of the practice and executable way is progressive reclamation/revegetation. The problem is, plantation which can grow fast in one mine site may not have a good CO_2 absorb capacity. On the other hand, plantation with a good CO_2 absorb capacity and suitable in one mine location may not grow well in another mine location. Efforts to find the suitable types of plantation which has high CO_2 absorb capacity and fast growing capacity should be carried out continuously.

Indonesia has an opportunity to reduce the CO_2 emission by extracting its 27,510 MWe geothermal resources as its energy source to replace other energy sources. If the total substitution of the electricity generated from geothermal source is about 25,000 MWe, it will give a CO_2 reduction of about 16,000 million tons compare to those from coal resources. However, the choice is not such simple, there are still some serious difficulties to use geothermal energy. Those are electric pricing policy, investigation policy, and lack of skilled man power.

In Indonesia, other new energy resources likes nuclear, wind, solar, and sea wave/current, in the near future, are unlikely feasible because of the lack of the technology, human resources, and also too expensive.

5. Conclusion

1. With the decrease of its oil reserve and production, coal and geothermal resources will be the important energy sources of Indonesia
2. The use of coal to substitute oil in the electric power plants will increase CO_2 emission. The source of emission is not olnly from coal burning but also at the mine sites.
3. Rapid or progressive reclamation program with suitable types of plantation at ex mine pits and waste dump areas will increase the CO_2 absorption capacity and contribute CO_2 reduction at the mine sites area
4. The benefit of geothermal resources will reduce the use of coal as energy source in Indonesia. If 25,000 MWe electricity from geothermal resources could be built; it will contribute CO_2 reduction of about 16,000 million tons compare to those from coal burning

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