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Geothermal Power Plant Emissions in Indonesia

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ABSTRACT

Indonesia has one of the largest potential geothermal capcity in the world, and currently has one of the largest installed capacities. The geothermal potential in Indonesia is about 28,000 MW distributed in 299 potential spots from western to eastern of Indonesia. The current installed capacity of geothermal power plants in Indonesia is 1341 MW distributed in nine locations across the nation. This represents an increase of more than 150 MW compared to 2010. Indonesia is targeting to develop up to 9,500 MW of geothermal power plant installed capacity by the year 2025, which is expected to contribute roughly 5% of the national energy mix.

An emissions calculation method develop by K.K. Bloomfield and J.N. Moore was used to calculate CO_2 and H_2S emissions from geothermal power plants in Indonesia. The result is in gr/kw-hr. The study reveals that geothermal power plants in Indonesia emit gasseous (CO_2 and H_2S) emissions. However, the CO_2 and H_2S emissions attributed to geothermal are small compared to fossil fuel. The emission level from geothermal power plant depends on the Noncondensable Gases (NCG) content. CO_2 emissions are influenced by the steam supply type. The CO_2 emissions from dry steam reservoirs are higher than those from two-phase reservoirs. In addition, the H_2S emissions are influenced not only by steam supply but also reservoir characteristics. The emissions from geothermal power plants in Indonesia contributed 47,273.34 tonnes of CO_2 and 1,575.26 tonnes H_2S in 2013.

1. INTRODUCTION

Indonesia has abundant geothermal resources and one of the largest potential geothermal capacities in the world. The geothermal potential in Indonesia is mainly volcanic-type systems. This makes sense because Indonesia has more than 119 volcanoes along the the ring of fire (MEMR,2008). Based on data from Ministry of Energy and Mineral Resources (2013), Indonesia has a potential of more than 28,000 MW distributed in 299 potential spots across the nation from Sumatera, Java, Bali, Nusa Tenggara, Maluku and Sulawesi. To this point, the Government of Indonesia has declared a total of 58 Geothermal Working Areas. As of December 2013, the total installed capacity of geothermal power plants in Indonesia is 1,341 MW in nine locations, including Sibayak, Ulubelu, Salak, Darajat, Kamojang, Wayang Windu, Dieng, Lahendong and Ulumbu. This number means only 4.5% of the total potential are currently generateing electricity.

Even geothermal energy is known as green energy and clean energy, it does not mean that there is no pollution produced from geothermal exploitation. The Geothermal power plant is still producing green house gas emission, but it is lower than the others types of power plant (see Figure 1).

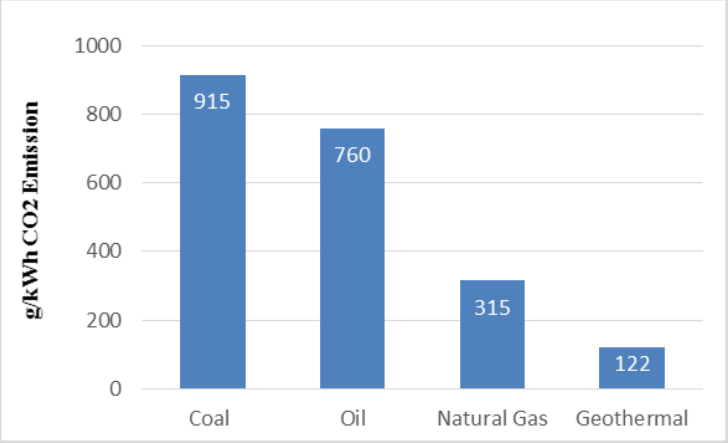

Figure 1. CO_2 emission rate in g/kWh for different Power Plants (Bertani and Thain, 2002).

Steam from geothermal fields contains Non-Condensable Gas (NCG) such as Carbon Dioxide (CO_2), Hydrogen Sulphide (H_2S), Ammonia (NH_3), Nitrogen (N_2), Methane (CH_4) and Hydrogen (H_2). Among them, CO_2 is the largest element within the NCG's discharged. CO_2 constitutes up to 95 to 98% of the total gases, H_2S constitutes only 2 to 3%, and the other gasses are even less abundant.

In 2002, Bertani and Thain conducted a survey to quantify the CO_2 emissions from operating geothermal power plants around the world on a macro basis. Results of the survey are presented in Table 1. The survey shows that geothermal Power plants have an environmental advantage compared to fossil fuel power power plant in terms of CO_2 emissions.

Table 1. CO_2 emission data in g/kWh with total running capacity in nine categories (Bertani and Train, 2002).

Emission Category (g CO2/kWh)	Running Capacity (MWe)	Weight Avarage (g CO2/kWh)
>500	197	603
400-499	81	419
300-399	207	330
250-299	782	283
200-249	346	216
150-199	176	159
100-149	658	121
50-99	1,867	71
<50	2,334	24

At the room temperature, CO_2 is a colorless, odorless, non-flammable gas. Exposure to CO_2 can produce a variety of health effects depending of the levels of it in the air. Exposure to the gas at high concentrations can affect the lungs, skin, and cardiovascular systems. The average concentration of carbon dioxide in air is approximately 0.03% or 300 parts per million (ppm)

Geothermal power plantd also emit H_2S to the air in relatively high amounts. Hunt (2001) compiled the emission of H_2S from various geothermal fields in the world as presented in Table 2.

Table 2. H_2S emission from some geothermal plants (Hunt, T.M, 2001).

Field	H2S emission (g/kWh)
Wairakei, NZ	0.5
The Geyser, USA	1.9
Lardello, Italy	3.5
Cerro Prieto, Mexico	4.2
Krafla, Iceland	6.0
Ohaaki, Japan	6.4

H_2S is a colorless, flammable, and extremely hazardous gas. It causes a wide range of health effects, depending on concentration. Low concentrations of the gas irritate the eyes, nose, throat and respiratory system (e.g., burning/tearing of eyes, cough, shortness of breath). Safety threshold for hydrogen sulfide in humans can range from 0.0005 to 0.3 ppm.

CO_2 and H_2S are the dominant chemical compounds in geothermal steam, thus this paper delivers calculations of CO_2 and H_2S emission from geothermal power plants in Indonesia.

2. METHODOLOGY

Based on the methodology published by Bloomfield et.al (1999), the calculation of emissions from geothermal power plant could be predicted based on noncondensable gases (NCG) contained in geothermal steam. In the calculation, the assumptions are that power plant steam consumption is homogeneous and the steam is being gathered in one single gathering system. The calculation consists of four steps, as can be seen in Figure 2.

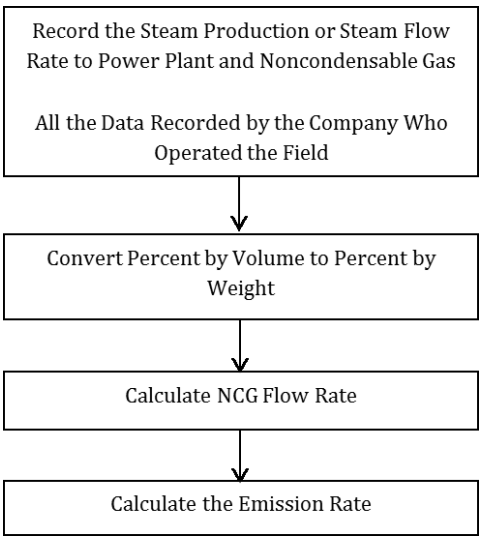

Figure 2. Methodology for calculating emission rate.

3. RESULTS AND DISCUSSIONS

As of December 2013, the total installed capacity of geothermal power plant in Indonesia 1,341 MW scattered in nine locations. Geothermal power plants contribute about 4.4 % of the total electricity supply in Indonesia. All geothermal power plants that are currently generating electricity are derived from volcanic systems. Based on the steam supply, geothermal power plants in Indonesia consist of two types of geothermal steam: dry steam and two-phase steam.

For this study, three fields have been chosen to represent geothermal power plants in Indonesia. Both of the fields, Kamojang and Wayang Windu, produce dry steam and the other, Ulubelu, produces two-phase steam. Kamojang is the first geothermal field developed in Indonesia with a total installed capacity of 200 MW. The field was commissioned in 1983. The Wayang Windu field was commissioning in 2000. The field has two 110 MW turbines to generate electricity. All of the fields produce dry steam. In addition, Ulubelu field, which produce two-phase steam, was commissioned in 2012. Its capacity is 110 MW.

Table 3. CO_2 emission and H_2S emission from geothermal power plant in Indonesia.

Power Plant	Capacity (MWe)	Emission (gr/kw-hr)	
		Co2	H2S
Wayang Windu	227	73.48	2.54
Kamojang	200	72.57	0.14
Ulubelu	110	42.64	1.68
Average		62.90	1.45

NCG concentrations from each geothermal field are different. NCG emissions from Wayang Windu field are 1.1 %, and emissions from Kamojang field are 0.98 %. Both of the fields produce dry steam. Ulubelu (two-phase steam) has NCG concentrations of 0.68%. The average NCG emissions from the three fields is 0.92 %.

Table 3 shows the emissions concentrations of CO_2 and H_2S from three commissioned geothermal power plants in Indonesia. The numbers in the table are the calculation result based on the method as explained in the methodology section. From the table, emissions of CO_2 range from 42 to 73 gr/kW-Hr with average value in 62.90 gr/kW-Hr. For H_2S, the values range between 0.14 to 2.54 gr/kw-hr with average value in 1.45 gr/kW-Hr. In addition, when separate analysis for CO_2 emissions is conducted between steam supply types which are dry-steam and 2-phase steam, there are two trends that can be seen in Figure 1. The average value for dry-steam is around 73.03 gr/kW-Hr and for two-phase steam is around 42.64 gr/kW-Hr.

The trend in CO_2 emission data could not be seen in those of H_2S because each field has different values. When the analysis considers not only steam supply type but also reservoir type, the interpretation becomes easier. The numbers depict three characters. Wayang Windu is characterized as a water-dominated reservoir with dry steam supply power plant. Whereas Kamojang is characterized as a steam-dominated reservoir with dry steam supply power plant. Furthermore, Ulubelu is characterized as between Wayang Windu and Kamojang. Its reservoir is defined as water-dominated reservoir and its steam supply is two-phase steam. The graph of CO_2 emissions vs capacity and H_2S vs capacity can be seen in Figures 3 and 4.

For further study, more fields and more data is needed. The study should have considered the time and location where the emissions data was collected due to weather conditions as explained by Sahzabi Te. La (2011). Therefore, specific weather and wind conditions are needed. In addition, up to now, there are seven geothermal fields in operation. It would be a huge advantage to interpret the field data from all sites.

Geothermal power plant emissions in Indonesia are shown in Table 3. Emissions of CO_2 from geothermal power plants in Indonesia range from 42 gr/kw-hr to 73 gr/kw-hr with average of CO_2 emission 62.90 gr/kw-hr. H_2S emissions range from 0.14 gr/kw-hr to 2.54 lbs/kw-hr with an average emission 1.45 gr/kw-hr. Based on this calculation, emissions from geothermal power plant in Indonesia are still in line with the CO_2 survey in 2002. With the total production of electricity from geothermal power plants in Indonesia of 9332.32 GWh in 2013, geothermal power plants contributed 47.132,81 tonnes of CO_2 and 1.089,08 tonnes of H_2S emissions to the atmosphere.

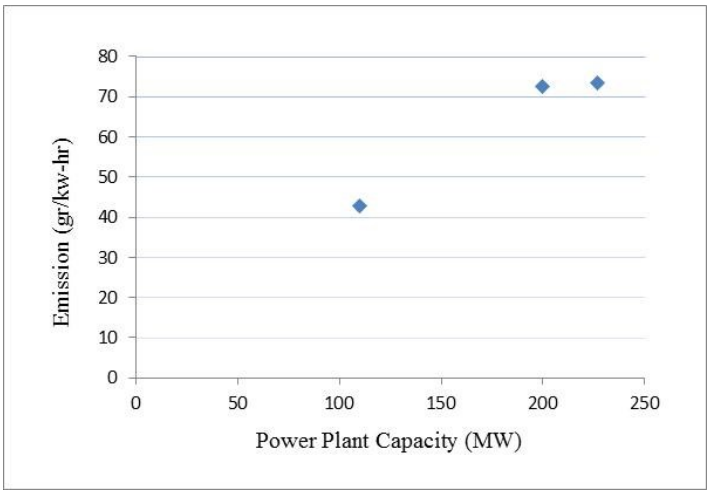

Figure 3. CO2 emission rate in g/kWh for different Power Plants in Indonesia.

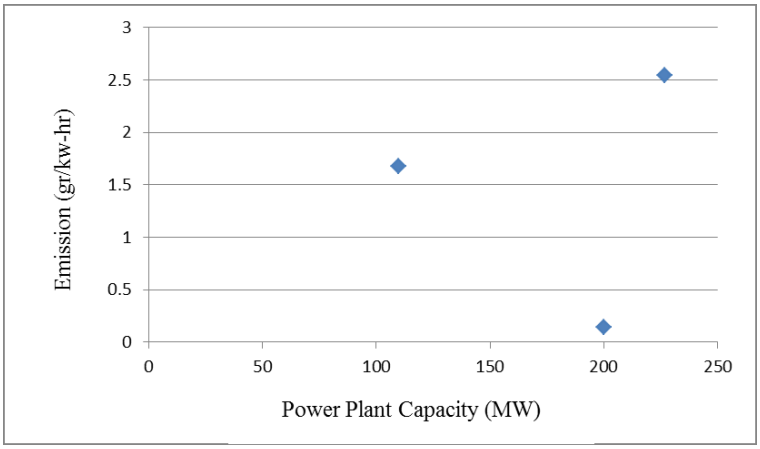

Figure 4. H_2S emission rate in g/kWh for different Power Plants in Indonesia.

4. CONCLUSIONS

This study revealed that geothermal power plants in Indonesia emit gasses such as CO_2 and H_2S. However, compared to fossil fuels, geothermal power emits a relatively small amount of these gasses. The emission levels from geothermal power plant depends on the noncondensable gas (NCG) content.

CO_2 emissions are influenced by the steam supply type. The CO_2 emissions from dry steam reservoirs are higher than those from two-phase steam. In addition, the H_2S emissions are influenced not only by steam supply but also reservoir characteristics.

The emissions from geothermal power plants in Indonesia contributed 47,273.34 tonnes of CO_2 and 1,575.26 tonnes H_2S in 2013.

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APPENDIX

KAMOJANG

Steam Consumtion	1,103,930	TON/month
	35,611	TON/day
	1,484	ton/hr
	1,483,776,881.72	gr/hr
POWER PLANT OUT	200	MW
% NCG	0.98	%

NCG Component	**% by Volume**
CO2	0.998
H2S	0.002
Total	1.00

Component	*yi* Volume fraction	*Mi* molecular weight	*yiMi*	*yiMi/∑yiMi weight fraction*
CO2	1.00	44.01	43.92	1.00
H2S	0.00	34.08	0.07	0.00
			43.99	**1.00**

NCG flowrate	**14,549,916**	**gr/hr**	
CO2	**14,519,701**	**gr/hr**	**for 200 MW**
H2S	**30,215**	**gr/hr**	**for 200 MW**
plant steam rate	**296,755,376,344**	**gr steam/Mwe**	
	296,755,376	**gr steam/kw-hr**	
CO2 emission rate	72598.507	gr/hr/MW	
	72.599	gr/hr/kw-hr	
H2S emission rate	151.074	gr/hr/MW	
	0.1511	gr/hr/kw-hr	