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THE ENERGY POTENTIAL OF MUNICIPAL SOLID WASTE FOR POWER GENERATION IN INDONESIA

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ABSTRACT

Utilization of municipal solid waste (MSW) as fuel in power plants in Indonesia has gained the attention of the government and investors. For this study, the estimation of energy potential of MSW was conducted to determine the potential of electrical energy that can be generated in each city and the economic value of MSW as a fuel in the power plant in Indonesia. In estimating the energy potential of MSW in Indonesia, ten cities with large population which produce large volume of MSW were selected. The MSW energy potential estimation was 2,991,905 MWhr/year of ideal electrical energy, 1,172,380 MWhr/year of actual electrical energy, 343 MW for capacity of power plant, 2,034,510 tons/year (about USD 170,898,840) for economic potential of MSW; coal - equivalent and of 1,130,405 tons/year (about USD 678,243,000); oil - equivalent. *Combustion of one ton of MSW can produce about 2.5 tons of steam, about 0.5 MWhr of electrical energy, and about 0.021 MW or 21 kW of power. Based on the calorific value of the fuel, one ton of MSW would be equivalent to 0.3 tons of coal or 0.2 tons of oil. Based on the results obtained, it can be concluded that MSW in ten cities in Indonesia has the energy and economic potential to be used as fuel in power plants. Utilizing MSW as a fuel in power plants is one solution that can overcome environmental issues and the shortage of electrical energy in Indonesia.*

Keywords: *Energy potential, Municipal solid waste, Electrical energy, Power plant.*

1.0 INTRODUCTION

Indonesia is one of the developing countries in Asia that has the fourth biggest population in the world. Though having dense population, Indonesia has problems of managing municipal solid waste (MSW) and shortages of electricity energy. MSW is a source of environmental pollution and health issues. Untransformed organic wastes do rot and would bring about various diseases, pollute the water, soil and air with their toxic substances. Around 20% of the total methane emissions is associated with sources of greenhouse gases from landfills (Lino and Ismail, 2012). Piles of MSW in landfills produce toxic gases that can damage the ozone layer 21 times of the CO2 (Salis, 2013).

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An estimated 900 tons of methane gas from all landfills in Indonesia are spread into the air each year. In addition, about 123 landfills cannot be used because they are already full and need to be closed. Only about 160 landfills can be used until 2020. Similarly, transport services are very limited, in which about 44% of Indonesia's population do not get MSW disposal services from the government (Australia Indonesia Partnership, 2011).

Another issue in Indonesia is that in 2010, the Western and Eastern Indonesia still experienced electric energy crisis that was caused by the limited capacity of the energy plants of PT PLN (Persero) in producing electricity. This was characterized by the frequent blackouts that happened quite often in urban areas. Meanwhile, in rural areas, there are still many people who do not get access to electricity. National electrification ratio in Indonesia is still low, averaging below 65% except for the island of Java. This suggests that the availability of electricity in Indonesia is still lacking. Projection of electric energy in Indonesia in the period 2010-2019 has increased an average of 12.25% per year. Thus, on average, the need for fuels increases annually, i.e. about 17.8% for coal, 16.8% for LNG, and gas 1.5% for gas (PT PLN - Persero, 2010).

Based on these problems, a study was conducted to obtain an overview of the energy potential of MSW as fuel at power plants in several cities in Indonesia. Currently, the use of MSW as a fuel in Indonesia has begun to receive attention from the government and investors to develop a MSW power plant (MPP) some areas that have the MSW potential. Thus, utilization of MSW as fuel is expected to become a solution to the problems of MSW disposal, the problems of energy electricity shortage, and shortage of coal in Indonesia.

2.0 MATERIALS AND METHODS

2.1 Location and sample

In this study, Indonesia is taken as a sample country currently still having problems of handling MSW and experiencing shortages of electric energy. In estimating the energy potential of MSW (EP_{MSW}) as fuel for power plants, ten large cities were selected in Indonesia. The locations were determined based on the size of the population and the quantity of MSW generated every day. In this case, the ten provincial capitals chosen were Jakarta, Surabaya, Bandung, Medan, Palembang, Makassar, Padang, Pekanbaru, and Despiser. These cities represented the 39 provinces in Indonesia with a population of approximately 235.5 million.

The data used for estimating the potential energy of MSW (EP_{MSW}) as a fuel at power plants was secondary data from 2006-2010, which consisted of: 1) the amount of MSW in Indonesia (Statistics Indonesia, 2011a); 2) Indonesia's population number (Statistics Indonesia, 2011b); 3) projection of electric energy needs in Indonesia based on the type of fuels (PT PLN - Persero, 2010); 4) calorific value of fuels based on the results of previous research, and 5 other relevant data from available literatures.

2.2 Estimation of MSW potentials

The method applied was referred to relevant available literature and previous research. In estimating the EP_{MSW} as fuel for power plants, there were several mathematical formulas used, namely:

a. Conversion from the V_{MSW} (m^3) to W_{MSW} (kg)

   Conversion from the V_{MSW} (m^3) to W_{MSW} (kg) was determined by using the following equation:

$$W_{MSW} = \rho_{MSW} \times V_{MSW} \tag{1}$$

where ρ_{MSW} is the density of MSW = 240 kg/m^3 (Kathirvale *et al.*, 2004; Leão and Tan, 1997).

b. Energy potentials of MSW (EP_{MSW})

Estimation of EP_{MSW} was made based on the W_{MSW} produced and the CV of MSW. EP_{MSW} was calculated by using equation:

$$EP_{MSW} = W_{MSW} \times CV_{MSW} \tag{2}$$

where EP_{MSW} in Joule or kWh (1 kWh = 3.610^6 J), W_{MSW} is the number of MSW, CV_{MSW} is calorific value of MSW = 9,240 kJ/kg (Kathirvale *et al.*, 2004; MGM Engineering and Contracting, 2009).

c. Production of steams (P_{Steam}) and ideal electric energy (EE_{Gross})

P_{Steam} and EE_{Gross} produced was calculated based on MGM Engineering and Contracting (2009), ASME (2008), Porteous (1997), Lee (2011), and Young (2010) with equation:

$$P_{Steem} = W_{MSW} \times 2.5 \tag{3}$$

$$EE_{Gross} = W_{MSW} \times \frac{500kWh}{1{,}000kg} \tag{4}$$

where P_{Steam} in kg and EE_{Gross} in kWh

d. Actual electric energy (EE_{Net})

EE_{Net} was achieved based on EE_{Gross} and overall efficiency of power plants. EE_{Net} was calculated using equation:

$$EE_{Net} = EE_{Gross} \times \eta_{Overall} \tag{5}$$

where $\eta_{Overall}$ is the overall efficiency of power plants. The overall efficiency about 20 - 40% (Klein *et al.*, 2003) and about 20 – 27% (Delivand *et al.*, 2011).

e. Capacity of power plant (C_{pp})

The production of C_{pp} was obtained based on the amount of EE_{Gross} in 24 hours,

$$C_{PP} = \frac{EE_{Gross}}{24h} \tag{6}$$

where C_{PP} in Watt (W)

f. Equivalence with coal (Eq_{Coal}) and the equivalent with oil (Eq_{Oil})

Equivalence with coal (Eq_{Coal}) was estimated by using equation:

$$Eq_{Coal} = \frac{EP_{MSW}}{CV_{Coal}} \tag{7}$$

where CV_{Coal} is the coal calorific value = 27 MJ/kg (United Nations Environmental Programme, 2009). Equivalent value with oil (Eq_{Oil}) was estimated by using equation:

$$Eq_{Oil} = \frac{EP_{MSW}}{CV_{Oil}} \tag{8}$$

CV_{Oil} is the calorific value of oil = 48.5 MJ/kg (Environmental and Plastic Industry Council, 2004).

3.0 RESULTS AND DISCUSSIONS

3.1 Growth of population and MSW potential distribution in Indonesia

Based on the Population Statistic of Indonesia and Environmetal Statistic of Indonesia 2011, Indonesia had a population (NOP) around 235.5 million people and W_{MSW} around 38.5 million tons in 2010, which were spread in 39 provincial cities in Indonesia. In this study, the potential energy of MSW as fuel was estimated by using the population data (Statistics Indonesia, 2011b) and the amount of MSW generated per day (Statistics Indonesia, 2011b) for ten cities in Indonesia in duration of five years (2006-2010), as displayed in Table 1.

To facilitate the calculation of the estimated potential energy, conversion from V_{MSW} (m^3) into W_{MSW} (kg) was calculated using equation (1) with density MSW ρ_{MSW} = 240 kg/m^3 (Kathirvale *et al.*, 2004) and (Leão and Tan, 1997).

Table 1. Data of NOP and W_{MSW} per day in ten cities in Indonesia.

No.	City	Year	NOP (person)	V_{MSW} (m^3)	W_{MSW} (kg)	W_{MSW} (kg/person)
1	Jakarta	2006	8,949,716	26,444	6,346,560	0.7
	(Jkt)	2007	9,064,591	27,654	6,636,960	0.7
		2008	9,146,181	29,217	7,012,080	0.8
		2009	9,223,000	28,268	6,784,320	0.7
		2010	9,607,787	27,906	6,697,440	0.7
		Avr	9,198,255	27,898	6,695,472	0.7
2	Surabaya	2006	2,784,196	8,179	1,962,960	0.7
	(Sby)	2007	2,829,552	8,700	2,088,000	0.7
		2008	2,903,382	8,708	2,089,920	0.7
		2009	2,938,225	8,718	2,092,320	0.7
		2010	2,929,528	8,708	2,089,920	0.7
		Avr	2,876,977	8,603	2,064,624	0.7
3	Bandung	2006	2,340,624	6,904	1,656,960	0.7
	(Bdg)	2007	2,340,624	6,904	1,656,960	0.7
		2008	2,390,120	7,500	1,800,000	0.8
		2009	2,414,704	7,500	1,800,000	0.8
		2010	2,393,633	7,450	1,788,000	0.8
		Avr	2,375,941	7,252	1,740,384	0.8
4	Medan	2006	2,067,288	5,495	1,318,800	0.6
	(Mdn)	2007	2,083,156	5,495	1,318,800	0.6
		2008	2,102,105	5,236	1,256,640	0.6
		2009	2,102,105	5,129	1,230,960	0.6
		2010	2,097,610	5,918	1,420,320	0.7
		Avr	2,090,453	5,455	1,309,104	0.6
5	Semarang	2006	1,434,025	3,500	840,000	0.6
	(Smg)	2007	1,454,594	3,880	931,200	0.6
		2008	1,481,640	4,160	998,400	0.7
		2009	1,506,924	4,257	1,021,680	0.7
		2010	1,555,984	4,603	1,104,720	0.7
		Avr	1,486,633	4,080	979,200	0.7

6	Palembang (Plb)	2006	1,369,239	4,837	1,160,880	0.9
		2007	1,394,239	4,981	1,195,440	0.9
		2008	1,417,047	3,829	918,960	0.7
		2009	1,439,938	3,150	756,000	0.5
		2010	1,455,284	3,150	756,000	0.5
		Avr	1,415,149	3,989	957,456	0.7
7	Makassar (Mks)	2006	1,216,746	5,918	1,420,320	1.2
		2007	1,235,279	3,662	878,880	0.7
		2008	1,253,656	3,813	915,120	0.7
		2009	1,271,870	3,680	883,200	0.7
		2010	1,338,663	3,781	907,440	0.7
		Avr	1,263,243	4,171	1,000,992	0.8
8	Padang (Pdg)	2006	819,740	1,520	364,800	0.5
		2007	838,190	1,678	402,720	0.5
		2008	856,815	2,688	645,120	0.8
		2009	875,548	2,828	678,720	0.8
		2010	833,562	2,763	663,120	0.8
		Avr	844,771	2,295	550,896	0.7
9	Pekanbaru (Pkb)	2006	754,467	1,903	456,720	0.6
		2007	779,899	2,903	696,720	0.9
		2008	799,213	3,000	720,000	0.9
		2009	802,788	2,501	600,240	0.8
		2010	897,768	2,563	615,120	0.7
		Avr	806,827	2,574	617,760	0.8
10	Denpasar (Dps)	2006	458842	2,300	552,000	1.2
		2007	465159	2,500	600,000	1.3
		2008	475,080	2,414	579,360	1.2
		2009	508,339	2,500	600,000	1.2
		2010	788,589	2,567	616,080	0.8
		Avr	539,202	2,456	589,488	1.1

Table 1 presents the development of NOP and W_{MSW} each year for five years (2006-2010). The NOP of the ten cities generally increased every year, whereas the W_{MSW} tended to fluctuate. This was due to the policy and people's improved awareness of recycling so that the amount of generated MSW decreased (Kuo *et al.*, 2008). Based on the NOP and W_{MSW} produced, the volume of W_{MSW} produced by each person in every city in Indonesia was, on average, 0.6 -1.1 kg/day. This value is higher if compared to the production of MSW per capita in several countries, including in Brazil, which is about 0.4 - 0.7 kg/day (Salomon and Lora, 2009), in India about 0.2-0.5 kg/day (Jain and Sharma, 2011), in Malaysia about 0.5-0.8 kg/day (Kathirvale *et al.*, 2004), and in Thailand about 0.4 - 0.6 kg/day (Udomsri *et al.*, 2011). In some developed countries, each person produces MSW volume greater than in Indonesia, such as in Germany about 1.5 kg/day, in the Netherlands about 1.7 kg/day, in Denmark about 2.2 kg/day, in France about 1.5 kg/day, and in Italy about 1.5 kg/day (Usón *et al.*, 2012). Distribution of MSW energy potential and production per capita of MSW per day for the ten cities in Indonesia is presented in Figure. 1.

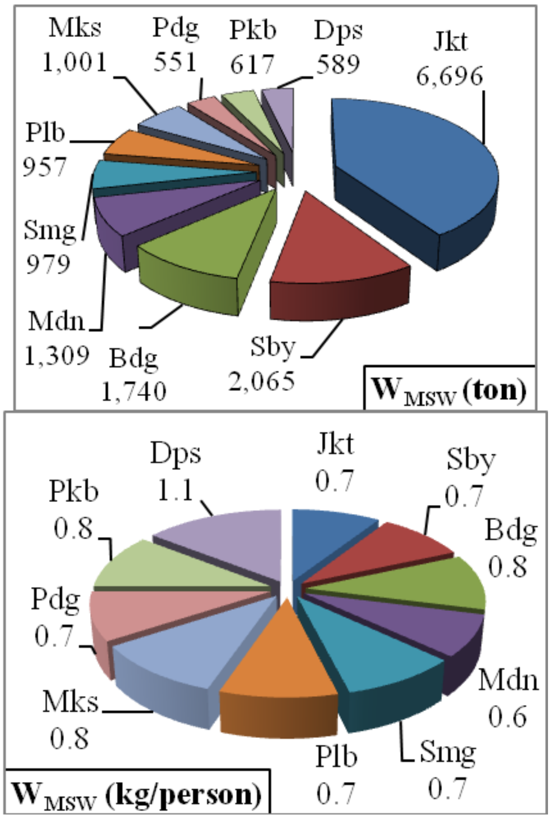

Figure. 1. Distribution of MSW energy potential and production per capita of MSW per day in Indonesia.

As shown in Figure. 1, the biggest W_{MSW} and EP_{MSW} were found in Jakarta, about 41%, whereas the smallest ones were found in Padang and Pekanbaru, about 3%. The EP_{MSW} in Java island was about 70%, existing in Jakarta, Surabaya, Bandung, and Semarang; whereas only about 30% of the EP_{MSW} was dispersed outside Java island, namely in Medan, Palembang, Makassar, Padang, Denpasar, and Pekanbaru.

3.2 Fuel and electric energy needs in Indonesia.

Projection of fuel and electricity demand in Indonesia in 2010-2019 is shown Table 2. It appears that the demand for coal and energy increases every year. This suggests that coal would be a top priority in the provision of electric energy in Indonesia.

Table 2. Composition of electric energy need in Indonesia based on fuel type (PT PLN - Persero, 2010).

Year	HSD (GWh)	MFO (GWh)	Gas (GWh)	Coal (GWh)	Hydro (GWh)	Geo-thermal (GWh)	Total energy (GWh)	Energy demand (GWh)
2010	22,811	5,095	43,239	78,453	9,771	10,318	169,687	147,100
2012	9,550	3,968	55,247	104,055	10,145	12,627	200,858	176,400
2014	6,667	1,196	61,998	123,842	11,332	30,016	240,970	212,700
2016	6,488	1,095	63,425	160,984	12,735	38,924	289,961	256,300
2018	7,952	975	67,868	194,376	15,328	45,524	346,903	306,900
2019	8,642	958	67,492	220,410	16,506	49,853	378,493	327,300

In Table 2, it appears that the electrical energy needs in Indonesia was around 147.100 GWh, and the need for coal was around 78.453 GWh or approximately 10,460,400 tons in 2010. Meanwhile, the total amount of MSW for ten cities in Indonesia was 6,023,960 tons of MSW or equivalent to 2,052,609 tons of coal, based on the calorific values of the fuel. If MSW is used as a fuel, it can reduce the use of coal by 2,052,609 tons or can save the use of coal by 19.5%. The percentages of coal usage in Indonesia were about 53% and 59% of national energy demand in 2010 and 2012, respectively. This values indicate that the use of coal in Indonesia is high because it is larger than the standard use of coal for energy consumption in developing countries, developed countries, and the world, which is about 26-47% (Jain and Sharma, 2011). Although the supply of coal in Indonesia reaches 90.5 billion tons and 18.7 billion tons of reserves (Kusdiana, 2008), it will run out in a short time if coal is used continuously in large quantities every year. Due to this matter finding alternative sources of energy to replace the use of coal in power plants is vital.

Indonesia consists of six large islands, namely: Sumatra (1), Java (2), Kalimantan (3), Sulawesi (4), Papua - West Papua (5), and NTT - NTB (6). Availability of electrical energy in Indonesia is still lacking, while demand is increasing every year. This is caused by population and economic growth as well as industry expansion. The availability of electrical energy on average is still about 76.96% in 2012 (Directorate General of Electricity, 2013). Map of Indonesia and the national electrification ratio in Indonesia is shown in Figure 2.

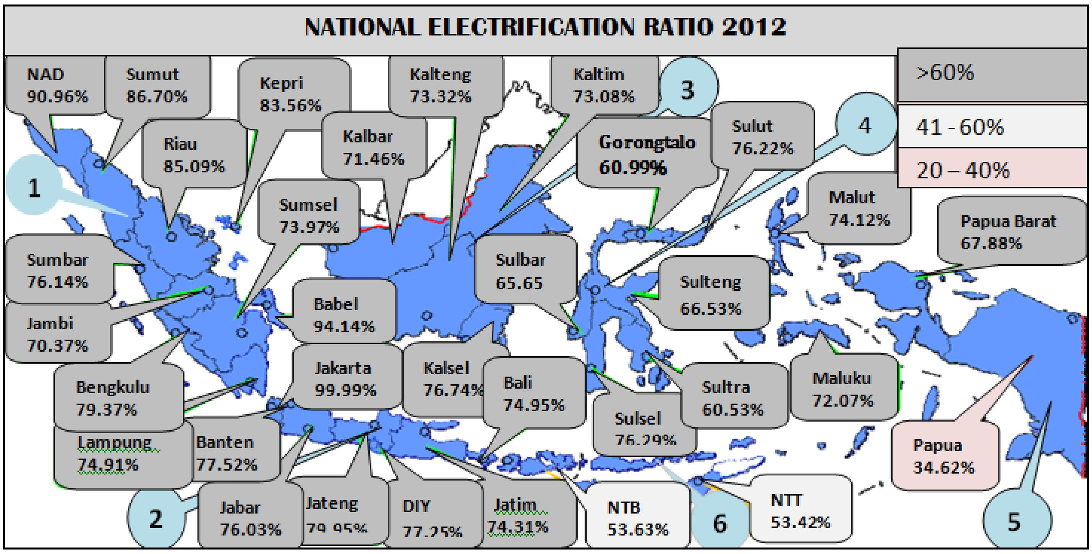

Figure 2. Map of Indonesia and national electrification ratio in 2012 (Directorate General of Electricity, 2013).

3.3 ELECTRIC ENERGY POTENTIAL OF MSW

3.3.1 Process energy recovery of MSW as fuels

In the process of MSW energy recovery, besides generating electricity, it also generates waste in the form of ash, fly ash, and flue gas. Each 1,000 kg of MSW incineration produces steam around 2,500 - 3,000 kg and can generate electrical energy around 500 - 600 kWh (MGM Engineering & Contracting, 2009; ASME, 2008) or generate around 660 kWh, therefore the overall efficiency is only around 20% (Klein *et al.*, 2003). According to Porteous (1998), in the MSW power plant, the significant relation is 1 ton of

MSW is equivalent to 2.5 tons of steam (400^{0}C, 40 bar), equivalent to 200 kg of oil, equivalent to 200 kg of coal, and equivalent to 500 kW of electricity.

Based on the above statement and the data in Table 1, EP_{MSW} was estimated by using Equation (2), P_{Steam} by using Equation (3), E_{Gross} by using Equation (4), EE_{Net} by using Equation (5), and C_{pp} by using Equation (6). The estimation results are presented in Table 3.

Table 3. Estimations of P_{Steam}, EE_{Gross}, EE_{Net}, and C_{PP} produced from MSW per day.

No.	City	Average value from Year 2006-2010					
		W_{MSW} (ton)	EP_{MSW} (MWhr)	P_{Steam} (ton)	EE_{Gross} (MWhr)	EE_{Net} (MWhr)	C_{PP} (MW)
1	Jakarta (Jkt)	6,696	17,186	16,739	3,348	1,339	139
2	Surabaya (Sby)	2,065	5,300	5,161	1,032	413	43
3	Bandung (Bdg)	1,740	4,466	4,357	872	284	37
4	Medan (Mdn)	1,309	3,360	3,273	655	262	28
5	Semarang (Smg)	979	2,513	2,448	490	196	20
6	Palembang (Plb)	957	2,456	2,394	479	191	20
7	Makassar (Mks)	1,001	2,569	2,502	501	200	21
8	Padang (Pdg)	551	1,414	1,378	276	110	11
9	Pekanbaru (Pkb)	617	1,584	1,245	249	99	11
10	Denpasar (Dps)	589	1,512	1,474	295	118	13
	Total	16,504	42,360	40,971	8,197	3,212	343

Table 3 presents the results of estimation of EP_{MSW}, P_{Steam}, EE_{Gross}, EE_{Net}, and C_{PP} in ten cities per day. MSW was generated by the ten cities with an average of approximately 16,504 tons/day (6,023,960 tons/year) in five years. In this case, EP_{MSW} was about 41.836 MWhr/day (15,270,140 MWhr/year), P_{Steam} about 40,971 tons/day (14,954,415 tons/year), EE_{Gross} about 8,197 MWhr/day (2,991,905 MWhr/year), EE_{Net} approximately 3,212 MWhr/day (1,172,380 MWhr/year), and C_{PP} about 343 MW. Thus, it was concluded that the incineration one ton of MSW can produce about 2.5 tons of steam, approximately 0.5 MWhr of electrical energy, and power of about 0.021 MW or 21 kW.

3.3.2 Distribution of MSW energy potential available in ten cities

Based on the analysis of Table 3, the distribution of energy potential, electrical energy potential, and power plant capacity of MSW available in ten cities, is presented in Figure 3.

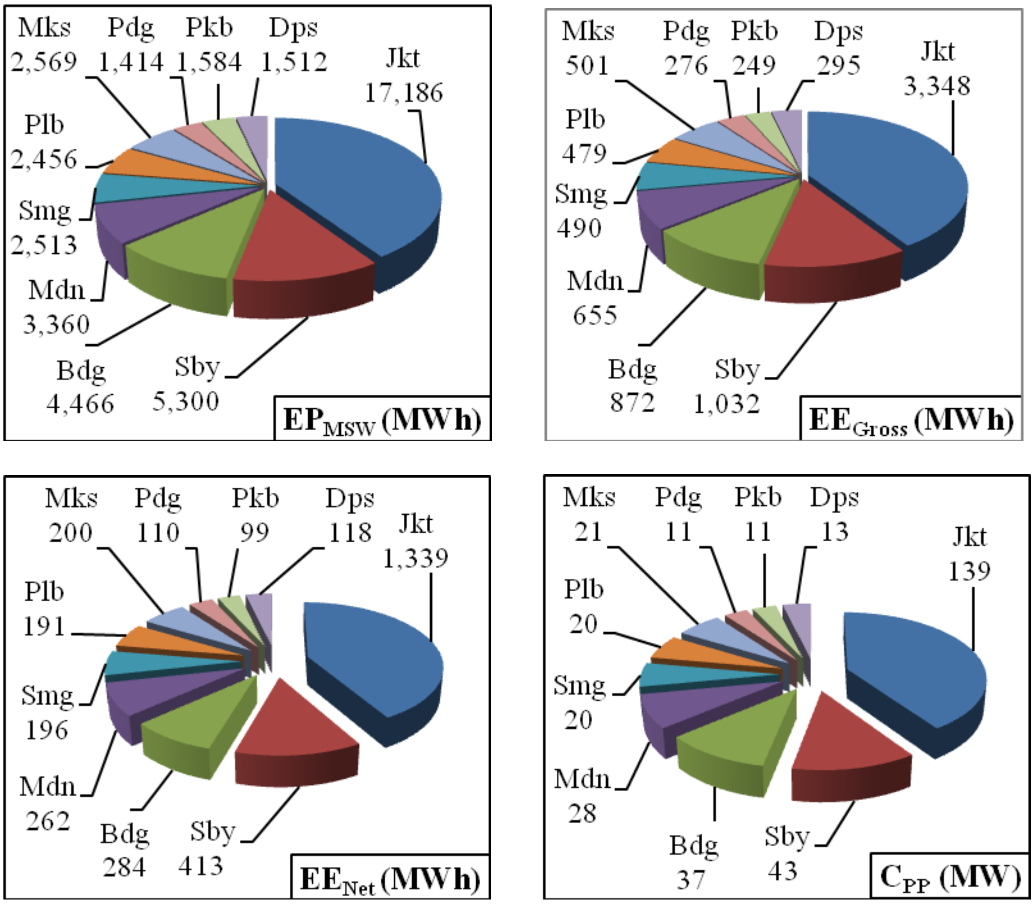

Figure 3. Potential distribution of EP_{MSW}, EE_{Gross}, EE_{Net}, and C_{PP} in ten cities in Indonesia.

Figure. 3 shows the distribution of EP_{MSW}, EE_{Gross}, EE_{Net}, and C_{PP} produced from the utilization of MSW in ten cities in Indonesia. Electrical energy potential of MSW greatest in Jakarta was found to be around 139 MW (40%) and the smallest in Pekanbaru and Padang was found to be about 11 MW (3%). This capacity was almost equal to one unit of MPP in Pudong, Shanghai with C_{PP} of approximately 2 × 8.5 MW. MSW incinerator with average capacity processing of 1,000 tons/day, can generate 100,000 MWhr/year (Kefa, 2002). This shows that in Pekanbaru and Padang, MPP can potentially operate with capacity up to 11 MW. According to Hendri (2013), a MPP will be built in Pekanbaru with C_{PP} of about 10 MW. The main goal is to overcome the MSW problem that occurs every year, in addition to tackling the shortage of electrical energy in Pekanbaru.

Based on the data, PT Pertamina will build the MPP in Bekasi with a capacity of about 120 MW, or around 87.6% of the potential energy available. The MSW that will be used will be around 5,300 - 6,000 tons/day generated in Jakarta. The MPP will be the largest in the world with an investment of about USD 180 million and will be completed in 2014 (Maulia, 2012) and (Purwanto, 2012). Furthermore, PT Pertamina will also develop a MPP in Sulawesi (Yazid, 2013), although the MPP capacity is unclear, but the known potential of MSW available in Makassar is approximately 21 MW. Similarly, in Surabaya, the MSW potential was estimated to have a capacity of about 43 MW. This potential will be developed by PT Navigat Energy Indonesia, which will build a MPP with capacity of approximately 10 MW (Wahyuni, 2011), or around 30.3% of the energy potential of MSW available in Surabaya. Meanwhile in Bandung, EP_{MSW} was found available with a capacity of about 37 MW, but the MPP capacity to be built would be about 7 MW or around 18.92% of the potential energy available. The MPP is expected to burn waste around 500 - 700 tons/day (Kompas, 2012).

Based on data analysis obtained from the ten cities, there are four cities in Indonesia that are planning to build MPP with a total capacity of approximately 147 MW or 42.4% of the available capacity. Utilization of MSW as a fuel in the power plant around 42.4% is a great value compared to some countries in Europe, such as Denmark about 53%, Sweden 47%, Netherlands 38%, France 36%, Germany 35%, Belgium 34%, Italy 11%, Spain 10% (Usón *et al.*, 2012).

In this case, the utilization of MSW will reduce the volume of MSW pile of approximately 42.4% or about 2,554,270 tons/ year. This value is equivalent to 870,344 tons of coal. This means that it can replace the use of coal or save approximately 870,344 tons or 5.3% of the coal needs of about 16,512,267 tons in 2014. The value of 5.3% is still smaller than the energy potential of MSW in Britain which is equivalent to about 25% of coal consumption (Yang *et al.*, 2004).

The other findings consisted of the potential of MSW in Medan (28 MW), Semarang (20 MW), Palembang (20 MW), Padang (11 MW), and Denpasar (13 MW), with a total capacity of about 92 MW, which is very significant to be developed as a MPP, based on the available potential. As a comparison, the MPP in Kajang, Selangor, Malaysia, utilizing MSW volume of 700 tons/day to produce about 8.9 MW of electrical power, where 5.5 MW is exported to the National Power Grid (Core Competencies Sdn Bhd, 2010). The description indicates that the potential of MSW from ten city is significantly to be developed as fuel in MPP, it can fulfill the need for electrical energy without the use of coal completely. Thus, it can save the use of coal and can reduce the volume of MSW in Indonesia.

3.4 Economic value of MSW as fuels

The economic value of MSW can be estimated by converting the energy value of MSW into coal and oil, by referring to the calorific value of coals and oils (Abu-Qudais and Abu-Qdais, 2000), where CV_{Coal} = 27 MJ/kg (United Nations Environmental Programme, 2009) and CV_{Oil} = 48.5 MJ/kg (Environmental and Plastic Industry Council, 2004). Coal price in August 2012 was around USD 84 per ton and the price of oil was around USD 600 per ton (Ministry of Energy and Mineral Resources Republic Indonesia, 2012).

The EP_{MSW} was obtained by using Equation (2), whereas the equivalent value of MSW to coal (Eq_{Coal}) was calculated by using Equation (7), and the equivalent value to oil (Eq_{Oil}) was obtained by using Equation (8). The analysis result on the economic potential of MSW is presented in Table 4.

Table 4. Estimates of the economic potential of MSW and Equivalent to coal and oil per day.

No	City	Average value from 2006 – 2010					
		W_{MSW} (ton)	EP_{MSW} (GJ)	Eq_{Coal} (ton)	Price of coal (USD)	Eq_{Oil} (ton)	Price of oil (USD)
1	Jakarta (Jkt)	6,696	61,598	2,259	189,756	1,258	754,800
2	Surabaya(Sby)	2,065	18,990	705	59,220	393	235,800

3	Bandung (Bdg)	1,740	16,034	597	50,148	332	199,200
4	Medan (Mdn)	1,309	12,044	446	37,464	248	148,800
5	Semarang (Smg)	979	9,008	326	27,384	181	108,600
6	Palembang (Plb)	957	9,008	336	28,224	187	112,200
7	Makassar (Mks)	1,001	8,861	354	29,736	197	118,200
8	Padang (Pdg)	551	5,068	180	15,120	101	60,600
9	Pekanbaru (Pkb)	617	4,579	161	13,524	90	54,000
10	Denpasar (Dps)	589	5,423	210	17,640	110	66,000
	Total	16,504	150,613	5,574	468,216	3,097	185,8200

Table 4 presents the number of MSW in ten cities, with total around 16,504 tons/day or 6,023,960 tons/year. If this potential is used to replace the use of coal, it will reduce the use of coal around 2,034,510 tons/year with a value of USD 170,898,840. Similarly, when the MSW is used to replace the use of oil, oil consumption will be reduced approximately 1,130,405 tons/year with a value of approximately USD 678,243,000. This means that the utilization of 1 ton of MSW is equivalent to the utilization of 0.3 tons of coal or equivalent to 0.2 tons of oil based on the calorific value of the fuel. Based on the description, it was found that saving the use of coal and oil will increase the value of exports of coal and oil, which also increases the state revenues. Indirectly, this can maintain the reserve of coal and oil in Indonesia for a longer time.

4.0 CONCLUSIONS

MSW in Indonesia a source of energy that can generate electrical energy. The amount of MSW generated in each city varies, depending on the population. Every person in Indonesia produces around 0.6 - 1.1 kg MSW/day. MSW production in ten cities in Indonesia produced an average of around 16,504 tons/day or 6,023,960 tons/year. The amount of potential electrical energy generated by every city also varies. In total, the energy potential MSW was estimated with EE_{Gross} about 8,197 MWhr/day (2,991,905 MWhr/year), EE_{Net} approximately 3,212 MWhr/day (1,172,380 MWhr/year), C_{PP} approximately 343 MW. Burning every ton of MSW can produce about 2.5 tons of steam, about 0.5 MWhr of electrical energy, and power of about 0,021 MW or 21 kW.

The economic potential of MSW was estimated equivalent to about 5,574 tons of coal/day (2,034,510 tons/year) with a value of approximately USD 170,898,840/year, and is equivalent to about 3,097 tons of oil/day (130,405 tons/year) with a value of approximately USD 678,243,000/year. Based on the calorific value of fuel, it was estimated that the utilization of 1 ton of MSW would be equivalent to the utilization of 0.3 ton of coal or 0.2 ton of oil. Utilization of MSW in Indonesia as a fuel in the MPP can contribute to the efficient use of coal, the provision of electric energy needs, MSW volume reduction, efficient handling of environmental problems, and tackling the shortage of electrical energy in Indonesia.

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