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The Potential Energy of Plastic Solid Waste as Alternative Fuel for Power Plants in Indonesia Abstract. Studies on the potential of plastic solid waste (PSW) as a fuel supplement for power plant was conducted to determine the potential energy and economic value in Indonesia.

In analyzing the potential energy and economic value of PSW, 15 cities provinces having municipal solid waste production of greater than 1,000 tons/day were selected. The study showed that with the total potential of PSW of around 693 tons/day, the electrical energy potential available is around 7,987 MWh/day. The PSW equivalent with coal is approximately 1,065 tons/day, and its equivalent to the oil is around 593 tons/day.

In conclusion, the PSW is an environmental pollution material but have the energy and economic potential to be used as a fuel supplement for the power plants. Thereby, it can save the use of coal by means co-combustion with PSW and at the same time be able overcome the environmental problems caused by pollution PSW in Indonesia. Keywords: Potential energy; plastic solid waste; alternative fuel; power plant.

Introduction Plastic solid waste is dangerous to the environment because it pollutes the environment and cannot decompose completely in a short time; it takes ten to hundreds of years to decompose. At the time of degradation, plastic particles will contaminate soil and groundwater. If it is burnt in landfills, incomplete combustion will produce toxic fumes and it is hazardous to one's health because the plastic will break down as dioxin.

Dioxin compounds are very dangerous, if inhaled by humans could cause cancer, hepatitis, inflammation of the liver and nervous system disorders. At the stage of landfill

disposal, plastic wastes emit greenhouse gases if the plastic bags are left on the landfill ground [1]. While the use of plastic bags in Indonesia cannot be avoided and there is no alternative to that can be used by the public for the purposes of day-to-day activities.

Although PSW is a source of pollution, but it also have an economic and energy potential that is, it could be used as fuel due to it high calorific value [2]. To overcome these problems, one alternative that needs to be done so that the plastic waste does not contaminate the environment, the PSW should be utilized as fuel in power plants. The utilization of PSW can be controlled so as to minimize harmful gases produced during combustion.

For PSW combustion in boilers, the exhaust emissions can be minimized by using exhaust emission control system [3]. This study was conducted to obtain an overview of the potential of the PSW in Indonesia and is expected to provide information to policy makers and the competent authorities of exploiting energy potential of plastic bags in Indonesia as a fuel supplement on the power plant.

It is expected to be one of the methods to overcome the problems of plastic solid waste (PSW) and reduce the use of coal at the power plant in Indonesia. Materials and Methods The PSW is selected as the study samples are plastic bags of municipal solid waste (MSW) generated each day. Sample locations were selected as many as 15 cities that have MSW production is more than 1000 tons/day, namely Jakarta, Surabaya, Bandung, Madan, Semarang, Palembang, Makassar, Padang, Denpasar, Pekanbaru, Samarinda, Menado, Pontianak, Kupang, dan Mataram. The city represents the 33 provinces cities in Indonesia.

The data used are the statistical data on the average for the year 2008 - 2010, includes data of MSW production in Indonesia 2008 - 2010 [4] and PSW calorific value data can be obtained from the results of literatures. The data is analyzed to obtain the available potential of PSW in Indonesia. Result and Discussion Potential Energy PSW. Energy potential of each fuel is different depending on the calorific value.

PSW has the potential energy to be used as a fuel because it has a large calorific value. Calorific value indicate that energy content of PSW (plastic bags and film) about 41.5 MJ/kg which is higher than the other fuel, except fuel oil, Calorific values for several types of fuel can be obtained from the results of previous researches [2, 5-7], as presented in Fig. 1. This indicates that the PSW in particular plastic bag has potential as a fuel or fuel supplement on the power plant. Fig. 1.

Calorific values of several types of fuel PSW potential as reflected in the fuel utilization

and production PSW generated every day. In general PSW consumption per capita in each country is different and has increased every period. But in Indonesia PSW production tends to fluctuate during the period 2006 - 2010.

In general, the use of plastics in the world increased significantly during the period 1980 - 2010. In 2010, the USA using the largest plastic which is about 150 kg/capita/year, then Western Europe around 120 kg/capita/year and Japan about 100 kg/capita/year [8]. Meanwhile, in Indonesia tend to fluctuate during the period of 2006 - 2010, on average is around 22 kg/capita/year [9].

This value is smaller than the plastics world consumption on average is about 30 kg/capita/year in the period 2000 - 2010 [8], as presented in Fig. 2. Per capita consumption of plastics in kg/year Fig. 2. Comparison of per capita consumption of plastics in Indonesia and several countries in the world The amount of volume PSW (VPSW) produced can be estimated based on the percentage content of PSW (PP) in the volume of MSW (VMSW), by using the Eq.1.

VPSW = PP × VMSW (1) The percentage content of the PSW in the MSW is varied, namely in Malaysia is about 8% [10], in Portugal is around 11% [11], and in United States is around 12% [5], as presented in Fig. 3. Fig. 3. Composition of MSW in a. Malaysia, b. in Portugal and c. in United States Conversion of total volume PSW (VPSW) in m3 into total mass of PSW (WPSW) in kg, can be determined by using Eq. 2.

WPSW = ?PSW × VPSW (2) where ?PSW = density of PSW is around 112 kg/m3. This value is obtained from the current experiments at the Laboratory of Thermodynamics, Faculty of Mechanical Engineering, UTM. The potential energy PSW (EPPSW) can be determined by using Eq. 3.

EPPSW = WPSW × CVPSW (3) where WPSW = amount of mass in kg PSW and CVPSW = calorific value of PSW, e.g. type of plastic bags and film = 41.5 MJ/kg [2]. The determination of the volume of PSW (VPSW) in 15 cities in Indonesia refers to the value of 8% of VMSW [10]. Thus, the volume PSW of each city can be obtained by using Eq. 1. Meanwhile, the conversion of the volume (m3) to mass (kg) is calculated using Eq.

2 with a density of PSW (?PSW) = 112 kg/m3, as well as EPPSW obtained by using Eq. 3. The estimation results are presented in Table 1. Economic Potential of Utilization the PSW as Fuel Supplements The economic value of PSW utilization as fuel in a power plant can be determined by the equivalence of the energy content of the fuel.

Equivalence of the energy content of the PSW with the energy content of the coal and

oil can be performed by using the calorific value of the fuel. The value equivalent to coal (EqCoal) can be determined by using Eq. 4: EqCoal = EPPSW ÷ CVCoal (4) where CVCoal = calorific value of coal is about 27 MJ/kg [12]. Meanwhile, the value of oil equivalent (EqOil) can be determined by using Eq. 5: EqOil = EPPSW ÷ CVoil (5) where CVOil = calorific value of oil around 48.5

MJ/kg [5]. Furthermore EqCoal and EqOil value can be obtained by using Eq. 4 and Eq. 5. The estimated potential energy and economic values of the PSW can be seen in Table 1. Table 1 presents the potential energy and economic potential of PSW of each of the 15 cities in the analysis.

The potential energy of the PSW is the largest in Jakarta, and the smallest in Mataram. In total, the potential production of PSW (WPSW) is around 693 tons per day with the potential energy (EPPSW) produced is around 28,752,528 MJ/day. This means that if the PSW is used as an alternative fuel for coal, it can save about 1,065 tons/day of coal and about 593 tons/day of oil.

The description indicates that if the PSW is used to replace coal in a power plant, it will reduce the operational costs of power plant every day. The potential energy can produce electrical energy (EEPSW) is around 7,987 MWh/day. Meanwhile, the economic value of PSW is equivalent to coal (EqCoal) with around 1,065 tons/day and equivalent to oil (EqOil) is around 593 tons/day.

The potential energy can be used to substitute the use of coal at the power plant with the principle of co-firing with coal for improving the power plant capital costs [13], or can be used as a PSW supplement coal to save the use of coal [14]. Table 1. Potential energy and economic value of PSW is generated every day in 15 cities in Indonesia __ Average value from year 2008-2010 No.

_City _VMSW _VPSW _WPSW _EPPSW _EEPSW _EqCoal _EqOil _ _ _ _[m3] _[m3] _[ton] _[MJ] _[MWh] _[ton] _[ton] _ _1 _Jakarta _28,464 _2,277 _255 _10,583,496 _2,940 _392 _218 _ _2 _Surabaya _8,711 _697 _78 _3,239,656 _900 _120 _67 _ _3 _Bandung _7,483 _599 _67 _2,784,152 _773 _103 _57 _ _4 _Medan _5,428 _434 _49 _2,017,232 _560 _75 _42 _ _5 _Semarang _4,340 _347 _39 _1,612,856 _448 _60 _33 _ _6 _Makassar _3,758 _301 _34 _1,399,048 _389 _52 _29 _ _7 _Palembang _3,376 _270 _30 _1,254,960 _349 _47 _26 _ _8 _Pekanbaru _3,188 _255 _29 _1,185,240 _329 _44 _24 _ _9 _Padang _2,760 _221 _25 _1,027,208 _285 _38 _21 _ _10 _Denpasar _2,494 _200 _22 _929,600 _258 _34 _19 _ _11 _Manado _1,636 _131 _15 _608,888 _169 _23 _13 _ _12 _Samarinda _1,604 _128 _14 _594,944 _165 _22 _12 _ _13 _Pontianak _1,498 _120 _13 _557,760 _155 _21 _11 _ _14 _Kupang _1,439 _115 _13 _534,520 _149 _20 _10 _ _15 _Mataram _1,131 _91 _10 _422,968

_118 _16 _9 _ _ _Total _77,310 _6,186 _693 _28,752,528 _7,987 _1,065 _593 _ _ Utilization of PSW as fuel in power plants PSW utilization as fuel in a power plant in Indonesia is still under study.

Based on the data obtained as in Table 1, it appears that some areas that have great potential for PSW, such as Jakarta, Surabaya, Bandung, Medan, and Semarang that have the electrical energy potential of around 448 - 2,940 MWh/day. The potential energy of PSW can be utilized as fuel supplement by co-combustion with coal and biomass at power plants [15].

Similarly, can be used as mono-fuel combustion at power plant in Malaysia which produces 8.9 MW of electricity [16]. Conclusion The plastic solid waste (PSW) in Indonesia is one of the materials of environmental pollution, but it has potential energy that can generate electrical energy. PSW has potential as an alternative fuel because it has a calorific value of about 41.5

MJ/kg greater than the calorific value of other fossil fuels and waste materials except fuel oil. Potential PSW available in 15 cities, the amount varies on each city depends on the amount of MSW generated. PSW potential analysis results are available in 15 cities is varied, which is about 10 - 255 tons/day which can generate electrical energy is around 118 - 2,940 MWh/day.

In total, PSW potential energy obtained is about 693 tons/day, electrical energy is around 7,987 MWh/day, equivalent to coal (EqCoal) is around 1,065 tons/day, and equivalent to oil (EqOil) is around 593 tons/day. The PSW utilization as fuel in the power plant can be done by co-combustion with coal, co-combustion with biomass, or mono-combustion.

In conclusion, though PSW is a hazardous contaminant, otherwise it has the potential energy and economic potential to be used as an alternative fuel in the power plant. Thus, it can save the use of coal and can overcome the environmental problems caused by pollution of PSW in Indonesia. Acknowledgment The authors are grateful to the Research University Grant, Universiti Teknologi Malaysia, Vot 05H25 for the financial support to attend ICE-SEAM 2013 in Malacca and Research Management Centre, UTM for the management support. References Agusputra, Dangers of plastic solid waste for environment and health. http://agusputra6661.wordpress.com/2013/02/24/, (2013). Thermal methods of municipal waste treatment, programme on sustainable resource use, C- Tech Innovation Ltd, 2003. A. Tabasová, J. Kropác, V. Kermes, A.

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