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VOL. 11, NO. 6, MARCH 2016 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences ©2006-2016 Asian Research Publishing Network (ARPN). All rights reserved. www.arpnjournals.com ELECTRICAL ENERGY POTENTIAL OF RICE HUSK AS FUEL FOR POWER GENERATION IN INDONESIA 2 Muhammad Anshar 1 1 , Farid Nasir Ani 2 and Ab Saman Kader Politeknik Negeri Ujung Pandang, South Sulawesi, Indonesia Department of Thermodynamics and Fluid Mechanics, UniversitiTeknologi Malaysia, Skudai, Johor, Malaysia 3 Marine Technology Centre, UniversitiTeknologi Malaysia, Skudai, Johor, Malaysia E-Mail: M.Anshar60@yahoo.com 3 ABSTRACT This study was conducted to determine the potential of electrical energy of rice husk as fuel for power generation in Indonesia.

The estimated potential of rice husk in each province of the country was calculated using the statistical data of rice production from 2011. The estimated annual potential of rice husk development was calculated using statistical data from 2001 to 2012. The results indicate that the development potential of rice husk, potential for electrical energy and economic potential increased by approximately 36.8% over 12 years; an average of about 3.1% per year. In 2011, the 33 provinces had rice husk potential of around 10.52 million tons, which is equivalent to about 5.24 million tons of coals, providing electrical energy and electrical power potentials of about 39,272 GWh and 4, 481 MW, respectively.

About 26 provinces had potential rice husk electrical energy greater than 100 GWh, providing a total electrical energy potential of approximately 39,076 GWh, and electrical power of around 4, 460 MW. This potential could be turned into fuel for small power plants with mono-combustion applications. The other seven provinces had very small rice husk potential and should apply co-combustion with other fuels for very small

power producers.

Use of rice husk as fuel for power plants could overcome the shortage of electrical energy, reduce the use of coal and decrease negative environmental impacts in Indonesia. Keywords: rice husk, fuel, energy potential, electrical energy, power generation. INTRODUCTION Rice is one of the most widespread crops in the world and is a staple food for more than half of the world's population (Calvo et al., 2004).

Indonesia is the third biggest rice producing country in the world after China and India (Umadevi, 2012) and is the fourth mostpopulated country in the world after China, India and the United States (Population Reference Bureau, 2012). The country experiences problems of shortages of electric energy. The electrification ratio and the availability of electrical energy are low, especially outside Java.

The national electrification ratio (NER) varies for each province in Indonesia. It is generally around 40% to 60% but there are four provinces in which it is only about 20% to 40% (PT PLN - Persero, 2010). Many people in these rural areas do not use electricity and in urban areas, rolling blackouts occur frequently.

This is due to the limited capacity of the power plants to meet the increasing demands of society and industry. In Indonesia, steam power plants generally use coal as their primary energy source because it is available in large quantities; around 61,365.86 million tons and reserves of approximately 6,758.90 million tons (Research and Development Center for Mineral and Coal Technology, 2006).

However, it will run out in the near future if its consumption in large quantities continues. Furthermore, using coal as fuel damages the environment. The negative impact on the environment results both from the mining and from its combustion. However, Indonesia has a huge potential source of renewable biomass energy in the form of rice husk (RH). The biomass potential in Indonesia is around 146.7

million tons/year, which is equivalent to 470 GJ/year. The largest biomass energy potential derives from rice residues, which is around 150 GJ/year (Hasan et al., 2012). RH is an important source of energy for generating electricity (Kapur et al., 1996). Several researches on RH have being done to convert into energy sources (Yusof et al., 2008, Islam and Ani, 2000, Islam and Ani, 1998).

The use of RH by direct combustion has been applied largely for efficiency and environmental reasons (Roy, 2013). Emissions of CO 3616 2 , SO X produced by burning RH are much less than those produced by combustion of coal and oil (Shafiea et al., 2012 ). Asian countries, such as Indonesia, contribute more than 92% of RH with a calorific value (CV) of approximately 12-18 MJ/kg, while European countries contribute only about 0.5% (Gómez et al., 2010).

The potential of RH in Indonesia extends to every province but it has not been used optimally to produce electrical energy; it is just discarded as waste that pollutes the environment. and NO In addressing the problems of electrical energy shortages and environmental pollution in Indonesia, an alternative course of action is to exploit the potential of RH as fuel for power plant.

Thus, this study was conducted to gain an overview of the energy potential of rice husks (EP ) available in Indonesia as fuel for power plants. It was expected that the results would indicate that RH is an alternative fuel that could be used in Indonesia's power plants to overcome the shortages of electrical RH X VOL. 11, NO. 6, MARCH 2016 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences ©2006-2016 Asian Research Publishing Network (ARPN). All rights reserved.

energy, reduce the use of coals and minimise negative environmental impacts. MATERIALS AND METHODS Study area and electrification ratio in Indonesia Indonesia is a unitary republic comprising thousands of small islands and six large islands: Sumatra, Java, Kalimantan, Sulawesi, Papua - Irian, and Bali - West Nusatenggara - East Nusatenggara. The NER of each province is generally low, i.e.,

less than 60% except for Java Island, which is greater than 60% (PT PLN - Persero, 2010). These data indicate that, in general, every province in Indonesia still lacks electrical energy, especially outside Java Island. However, each province has RH potential that could be used as fuel for power generation to overcome the shortages of electrical energy without relying on coal.

Indonesia comprises 33 provinces, about 27 of which produce more than 100,000 tons of rice per year. There are only about six provinces with rice production (RP) of less than 100,000 tons/year, i.e., Maluku, North Maluku, West Papua, Bangka Belitung, Jakarta and the Riau Islands (Statistic of Indonesia, 2013).

In Indonesia, there are about 14 provinces for which the NER exceeds 60% (only Jakarta has reached 100%) and another 14 for which it is around 41% to 60%. In fact, there are five provinces for which the NER is very low, only about 20% to 40%: West Nusatenggara, East Nusatenggara, Papua, West Papua (Irjabar), and Southeast Sulawesi. The data indicate that Indonesia lacks electrical energy, especially outside Java.

Proximate and ultimate analysis of rice husks A proximate, ultimate and calorific value analyses were performed to determine the quality of RH as fuel for power plants. Proximate analysis was conducted to ascertain the moisture, ash, volatile matter and fixed carbon. Whereas ultimate analysis was performed to determine the carbon, hydrogen, oxygen, nitrogen and sulphur contents.

A calorific value (CV) analysis was undertaken to determine the amount of energy contained in RH. The content of energyor CV is an important criterion for assessing the quality of fuel that can be used for power plants (Dear, 2013). The proximate analysis was performed under the ASTM D 3172 - 3175 and ISO 565 standard procedures, while the ultimate analysis was performed under the ASTM D 3176, ASTM D 4239 and ASTM D 5373 standard procedures. The testing of the CV of RH was based on the ASTM D.5865 standard procedure using a Bomb calorimeter.

This method is in line with previous studies (Maiti et al., 2006 ; Patel and Kumar, 2009). Estimated energy and economic potential of rice husk An estimation of RH potential was undertaken to establish the development of RH potential over 12 years. For this, RP data from 2001–2012 were analysed (Statistic www.arpnjournals.com of Indonesia, 2013).

The data of RP in 2011 were used to determine the RH potential distribution in each province. The potential of RH available in each province was calculated with reference to the production of RH and the value of husk-to-grain ratio (H ); this is about 0.2 (Blasi et al., 1997; Daifullah et al., 2003; Dasappa, 2011; Hiloidhari and Baruah, 2011; Thao et al., 2011) but it can reach 0.23 - 0.33 (Lim et al., 2012).

Accordingly, RP will produce around 20% to 33% RH. Ideally, it is assumed that all RH generated from RP is used as fuel. Therefore, the potential of RH could be determined by using the equation RH = H GR GR ×RP. However, some RH is lost during the milling process. It is assumed that the volume of lost RH is about 20%. This means that the potential of RH that could be used as fuel is only about 80% of RP.

Thus, the potential of RH that can be used as a fuel is calculated by the equation: RH = C E × H × RP (1) GR = collection efficiency of RH = 80%, RP = rice production, H where C E = husk-to-grain ratio = 20%. The EP RH GR and electric potential energy (EE ) can be estimated with reference to the methods of (Gómez et al., 2010) and (Yokoyama, 2009).

The EP can be determined using the equation: EP RH = W RH × CV (2) where W RH RH = the amount of RH and CV = the calorific value of RH, taken as 13.44 MJ/kg. The EE generated can be calculated using the equation: C EP RH RH F RH 3617 RH RH EE = (3) where C = conversion factor from joules to watthours. Thus, the electrical power potential of rice husk (PP RH F ) can be obtained using the equation: C EE PP = (4) RH RH FP where C = conversion factor to obtain electrical power potential..

FP The economic potential of RH asfuel for power plantscan be determined usingthe equivalence of energy content of RH with the energy content of coal. The equivalentvalue of RH with coal (Eq ) can be determined using the equation: Eq = CV EP RH Coal Coal Coal (5) RH VOL. 11, NO. 6, MARCH 2016 ISSN 1819-6608 where CV Coal ARPN Journal of Engineering and Applied Sciences ©2006-2016 Asian Research Publishing Network (ARPN). All rights reserved.

= calorific value of coal, taken as 27.0 MJ/kg. RESULTS AND DISCUSSIONS Calorific value of rice husk The low calorific value (LCV) of RH obtained by experiment was 13.44 MJ/kg, which was used to determine the EE . The LCV was in the range of values established in previous studies, i.e., 12.34 MJ/kg (Kuprianov et al., 2006), 13.30 MJ/kg (Rozainee et al., 2010), 13.42 MJ/kg (Sadhu et al., 1993), 13.48 MJ/kg (Butt et al., 2013) and 14 MJ/kg (Ahiduzzaman, 2007).

Clearly, the LCV of RH determined in previous studies varies from about 12.34 to 14 MJ/kg. The higher calorific values (HCV) of RH also varies from about 14.61 MJ/kg RH (Martínez et al., 2011), 14.98 MJ/kg (Madhiyanon et al., 2009), 15.84 MJ/kg (Lim et al., 2012), 16 kJ/kg (Chen and Wu, 2009), 16.05 MJ/kg (Kwong et al., 2007) and 16.59 MJ/kg (Yoon et al., 2012).The CV of RH and some types of fuel are presented in Figure-1.

Proximate and ultimate analyses The proximate and ultimate analyses illustrate the characteristics of RH as fuel. Table-1 presents the proximate and ultimate analyses obtained from the test results, which are within the range of results of previous studies (Kuprianov et al., 2006; Ghani et al., 2009; Rozainee et al., 2010; Chungsangunsit et al., 2013).

The values of the proximate and ultimate analyses vary because of different species of rice and different condition. The CV about 12.34 - 13.50 MJ and the ash content is high, about 12.99- 24.3%, but can be used as raw material for brick industry. Thus, suitable combustion techniques should be adopted for RH power plants.

Electrical energy and economic potential of rice husk Calorific Value [MJ/kg] 0 10 20 30 40 50 60 48.5 41.5 27 25.9 www.arpnjournals.com 25.1 17.5 The analysis and estimation of the potential ofRH for 12 years (2001-2012) were performed using Equation. (1). The energy potential development was as curtained using Equation. (2) with an LCV of 13.44 MJ/kg. The EE RH was calculated using Equation.

(3), PP determined using Equation. (4) and the economic potential analysed using Equation. (5). The results of the analysis of the energy and economic potentials of RH are presented in Table-2. It can be seen that the RP increased annually over the 12years (2001-2012), except in 2011 when it decreased by approximately 1.1% (it then increased by approximately 5% in 2012). In general, the RP and RH potential increased by approximately 36.8% over the 12 years, or by an average of approximately 3.1% annually. These data indicate that the increase of RP will enhance the energy potential ofRH.

3618 RH Table-2 presents the electrical energy and economic potential of RH in 2001. It can be seen that it was around 8.07 million tons with an EP of around 108, 448 TJ. This is equivalent to an EE RH RH of approximately 30.14 TWh, or equivalent to a PP of about 3.44 GW. In 2012, the potential of RH increased to 11.05 million tons with an EP RH RH of around 148, 485 TJ. This is equivalent to an EE RH of about 41.25 GWh, or equivalent to a PP of approximately 4.71 MW. The potential increased by approximately 36.8% over 12 years; an annual increase of approximately 3.1%.

The economic potential of RH in Indonesia can be obtained by comparison with the economic value of coal (Eq Coal ). The Eq can be estimated based on the CV of coal about 27 MJ/kg (United Nations Environmental Programme, 2009) and the price of coal (CP), taken as USD 84 per ton (Ministry of Energy and Mineral Resources Republic Indonesia, 2012). 17 16.1 15.5 Figure-1. Calorific values of some types of fuel. 15.1 13.4 12.6 9.2 Coal RH VOL.

11, NO. 6, MARCH 2016 ISSN 1819-6608 No Year RP (10 6 ton) ARPN Journal of Engineering and Applied Sciences ©2006-2016 Asian Research Publishing Network (ARPN). All rights reserved. www.arpnjournals.com Table-2. Electrical energy and economic potential of rice husk. RH (10 6 ton) Eq Coal (10 6 ton) EP RH (TJ) EE RH (TWh) PP RH (GW) USD) 1 2001 50.46 8.07 4.02 108,488 30.14 3.44 510.23 2 2002 51.38 8.22 4.10 110,530 30.70 3.50 520.40 3 2003 52.14 8.34 4.15 112,143 31.15 3.56 527.51 4 2004 54.09 8.66 4.31 116,337 32.32 3.69 547.84 5 2005 54.16 8.66 4.31 116,444 32.34 3.70 547.84 6 2006 54.46 8.72 4.34 117,197 32.55 3.72 551.90 7 2007 57.16 9.14 4.55 122,895 34.14 3.90 578.34 8 2008 60.33 9.66 4.81 129,777 36.05 4.11 610.86 9 2009 64.40 10.30 5.13 138,486 38.47 4.39 651.51 10 2010 66.47 10.63 5.30 142,894 39.70 4.53 672.86 11 2011 65.74 10.52 5.24 141,389 39.27 4.48 665.74 12 2012 69.05 11.05 5.50 148,485 41.25 4.71 698.26 Table-3. Electrical energy and economic potential of rice husk for each province in Indonesia in 2011. No.

Province RP (10 3 ton) RH (10 3 ton) Eq Coal (10 3 ton) EP RH (TJ) (MW) 1 West Java (Jabar) 11,634 1,862 927 25,020 6,950 794 2 East Java (Jatim) 10,577 1,692 842 22,741 6,317 721 3 JCentral Java (Jateng) 9,392 1,502 748 20,192 5,609 640 4 South Sulawesi

(Sulsel) 4,511 722 358 9,698 2,694 307 5 North Sumatra (Sumut) 3,607 577 287 7,752 2,154 246 6 South Sumatera (Sumsel) 3,382 541 269 7,268 2,019 230 7 Lampung 2,941 470 234 6,322 1,756 201 8 West Sumatera (Sumbar) 2,279 365 182 4,903 1,362 155 9 West Nusatenggara (NTB) 2,067 330 165 4,441 1,234 141 10 South Kalimantan (Kalsel) 2,038 326 163 4,387 1,218 139 11 Banten 1,950 312 155 4,194 1,165 133 12 Aceh 1,773 284 141 3,817 1,060 121 13 West Kalimantan (Kalbar) 1,374 220 110 2,957 822 94 14 Central Sulawesi (Sulteng) 1,039 166 83 2,237 622 71 15 Bali 858 138 69 1,850 514 58 16 Yogyakarta 843 135 67 1,817 505 58 17 Jambi 647 103 51 1,387 386 44 18 Central Kalimantan (Kalteng) 611 98 49 1,312 365 42 19 North Sulawesi (Sulut) 596 95 47 1,279 356 40 20 NusatenggaraTimur (NTT) 591 94 47 1,269 353 40 21 East Kalimantan (Kaltim) 554 89 44 1,194 331 38 22 Riau 536 86 43 1,150 319 37 EE RH (GWh) 3619 (10 CP 6 PP RH VOL. 11, NO.

6, MARCH 2016 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences ©2006-2016 Asian Research Publishing Network (ARPN). All rights reserved. www.arpnjournals.com 23 Southeast Sulawesi (Sultra) 492 78 39 1,054 293 34 24 Bengkulu 483 78 39 1,043 290 33 25 West Sulawesi (Sulbar) 366 58 29 785 218 25 26 Gorontalo 274 44 22 591 164 18 27 Papua 123 20 10 269 74 9 28 Maluku 88 14 7 194 54 6 29 North Maluku (Malut) 61 10 5 129 36 4 30 West Papua (Papubar) 29 5 2 65 18 2 31 Bangka Belitung (Bangbel) 15 2 1 32 9 1 32 Jakarta 10 2 1 22 6 1 33 Kepulauan Riau (Kepri) 1 0 0 0 0 0 Total 65,742 10,518 5,236 141,369 39,272 4,481 6,950 6,317 Figure-2.

Potential of electrical energy by rice husk in each province in 2011. Electrical energy and economic potential of rice husk The energy and economic potential of RH in every province in Indonesia in 2011 can be obtained using Equations. (1) to (5), as presented in Table-3. It is shows the RP, potential of RH, Eq Coal , EP RH , EE RH and PP in the 33 provinces.

In Indonesia, 26 provinces have PP greater than 10 MW and 7 provinces have PP less than 10 MW. The EE RH RH in the 33 provinces is around 39,272 GWh and the PP is about 4,481 MW. Ideally, 26 provinces could support the operation of power plants, i.e., those provinces that produce more than 20,000 tons of RH per year, or have PP RH greater than 10 MW.

Actually, the electrical energy generated by a power plant should take into account the overall thermal efficiency of the power plant. Biomass power plants generally have an overall thermal efficiency of around 20% to 27%, depending on the capacity (Delivand et al., 2011). RH 1,756 1,362 2,154 2,019 5,609 2,694 (GWh) RH 1,060 822 1,165 1,234 1,218 EE RH 622 514 RH 290 218 319 293 353 331 365 356 505 386 Figure-2 shows that the potential of EE in the 33 provinces of Indonesia; the largest is West Java (Jabar), which is about 6,950 MWh and the smallest is about 6 MWh in Jakarta.

EE could be used to generate electricity, especially in those areas that still lack electrical energy, i.e., those with an NER of around 20% to 40%: RH a. West Nusatenggara (NTB) and East Nusatenggara (NTT) that has an NER of approximately 31.99% with an available EE RH 54 36 18 164 74 3620 9 6 0 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 Bangbel Jakarta Kepri Maluku Malut Papubar Gortalo Papua Bengkulu Sulbar Riau Sultra NTT Kaltim Kalteng Sulut Yogya Jambi Sulteng Bali Aceh Kalbar Banten NTB Kalsel Lampung Sumbar Sumut Sumsel Jateng Sulsel Jabar Jatim Province of Indonesia RH of around 1,234 GWh/year. b. East Nusatenggara (NTT) that has an NER of approximately 24.24% with an available EE of around 353 GWh/year. c.

Southeast Sulawesi (Sultra) that has an NER of approximately 38.21% with an available EE of around 293 GWh/year. RH RH VOL. 11, NO. 6, MARCH 2016 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences ©2006-2016 Asian Research Publishing Network (ARPN). All rights reserved. d. Papua and West Papua that has an NER of approximately 32.05% with an available EE of around 92 MWh/year.

Exploiting the potential of RH energy is expected to increase the NER to about 40% to 60%. The available PP in each province of Indonesia varies (Table-3). It can be seen that the largest is West Java (Jabar) at about 1, 033 MW and the smallest is Jakarta at about 1 MW. These data can be the basis and reference for conducting feasibility studies regarding the construction of power plants in each province in Indonesia, particularly those provinces that still have an NER below 60%.

As a comparison, Thailand has developed small power producer for capacity of 10 - 90 MW and very small power producer for capacity of less RH than 10 MW programs to meet the target of 1,600 MW in 2012 (Suramaythangkoor and Gheewala, 2010). If Indonesia refers to these projects, then there are 26 provinces in Indonesia, from Gorontalo to West Java, which could support small power plant projects, while the other 7 provinces (Papua, Maluku, North Maluku, West Papua (Papubar), Bangbel, Jakarta and Riau) could support very small power plant programs using cocombustion with other biomass. Projected electrical energy need in Indonesia The electrical energy need in Indonesia is projected to increase annually from 2010 to 2019.

The energy needed will be provided by various types of fuel source, of which coal is the biggest. The use of coal appears to increase significantly each year; since www.arpnjournals.com RH 2011, the energy supplied by coal was greater than 50% (PT PLN - Persero, 2010).

This percentage ofcoal use,which tends to increase annually, suggests that the generation of electrical energy in Indonesia is fully focused on the use of coal, without appreciating the negative impacts this might cause. Table-4 shows that the use of coal is the primary source of energy in Indonesia. In 2011, coal accounted for approximately 54% of the energy total or about 62% of the energy needs in Indonesia.

Utilization of gas fuel is the largest energy source after coal is about 45.753 GWh or approximately 25% of the total energy. The percentage utilization of some types of primary energy sources is shown in Figure-3. Coal utilization since in 2010-2014 has increased every year and is projected to increase until 2019, as shown in Figure-4.

These conditions will continue to increase drastically if it is not anticipated by utilizing renewable energy sources as an alternative to coal. Utilization of biomass, especially RH is an alternative way of replacing coal with regard to the potential that is available and has been used as a source of electrical energy in other developing countries. The study shows that RH have characteristics that meet the eligibility as fuel in power plants (Anshar et al., 2015).

RH has not been considered seriously as a source of energy despite the huge potential of around 39,700 GWh, 39,270 GWh and 41, 250 GWh in 2010, 2011 and 2012, respectively, as shown in Table-2. These values constitute almost half of the energy produced by coal in 2011. Thus, the use of RH as a fuel source could reduce the use of coal significantly. Table-4.

Composition production of electrical energy needs (GWh) by fuel type in Indonesia. Year HSD MFO Gas LNG Coal Hydro Geother -mal Total energy 2010 22,811 5,095 43,239 - 78,453 9,771 10,318 169,687 147,100 2011 13,035 5,194 45,753 - 99,312 10,296 10,672 184,261 160,500 2012 9,550 3,968 55,247 5,266 104,055 10,145 12,627 200,858 176,400 2013 6,740 1,836 63,387 5,365 111,976 10,894 19,347 219,546 192,700 2014 6,667 1,196 61,998 5,441 123,842 11,332 30,016 240,970 212,700 2015 6,158 1,007 62,600 5,508 141,848 11,613 35,108 264,486 230,800 2016 6,488 1,095 63,425 5,585 160,984 12,735 38,924 289,961 256,300 2017 6,751 971 61,430 10,727 180,469 13,808 42,220 317,454 275,300 2018 7,952 975 67,868 13,456 194,376 15,328 45,524 346,903 306,900 2019 8,642 958 67,492 13,482 220,410 16,506 49,853 378,493 327,300 3621 Energy demand VOL. 11, NO.

6, MARCH 2016 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences ©2006-2016 Asian Research Publishing Network (ARPN). All rights reserved. Figure-3. Percentage use of fuel type in Indonesia, 2011 (Anshar et al., 2014). Figure-4. Projected use of coal in 2010-2019 (Anshar et al., 2014). CONCLUSIONS Indonesia has huge energy and economic potentials from RH, which increased by approximately 36.8 % over 12 years, or by an average of approximately 3.1% annually. In 2011, 33 provinces had RH potential that reached around 10.52 million tons, which is equivalent to about 5.24 million tons of coal.

This equates to an electrical energy potential of approximately 39, 272 GWh and electrical power potential of around 4,481 MW. Twenty-six provinces had an electrical energy potential from RH that was bigger than 100 GWh, offering a total electrical energy potential of approximately 39,076 GWh and electrical power potential of around 4, 460 MW.

This potential could be exploited as a mono-combustion fuel for the implementation of small power producer projects. The other seven provinces have very small potential of RH, such that it could only support the implementation of very small power producer projects based on co- www.arpnjournals.com combustion with other fuels.

The use of RH as fuel for power plants could overcome the shortage of electrical energy, decrease the use of coal and reduce the negative environmental impacts in Indonesia.
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