Potential of refused derived fuel in Jakarta

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Abstract. Refuse Derived Fuel (RDF) is a formed from Municipal Solid Waste combustible material that has a high heating value fraction to produce energy. The study aimed to explore the potential of RDF from Jakarta as the energy raw material. For this purpose, 24 samples of RDF were taken from Bantar Gebang for briquetting and the analysis of moisture, ash, and calor in the physical chemistry laboratories. The calor difference of 1,815.8 cal/g between briquettes and the total component of RDF is based on analysis errors of the homogenization process. With the 25% efficiency from RDF to energy, 8,051.25 cal/g results 2,339.3 kWh/ton. The conversion of energy (kWh) per day= 8,291.650 tones/day x 2,339.335 kWh/ton = 19,396,902.46 kWh/day or as much as energy needed by 905,213 middle-class households with energy needs of 642.84 kWh/month. 34% of waste in Jakarta can be recycled meanwhile the other 66% in form of waste residue is transported and processed at final processing facility.

1. Introduction
Waste management requires technology and data of waste source, type of waste, waste composition, and waste characteristics [1]. The current waste management method applied in Indonesia is a mixture of convensional system and additional system known as Integrated Waste Treatment Plant (IWTP). In IWTP facility, a number of waste sorting systems into organic and non-organic waste and waste recycling are already applied. Usable waste component will be resold, meanwhile organic waste is processed into compost and its residue is reprocessed into Refuse Derived Fuel (RDF) that has large potential to produce energy [2].

Refuse Derived Fuel (RDF) is a Municipal Solid Waste (MSW) based fuel where metal, glass, and other non-organic compounds are removed by filtering them through 2 inches filtration system with 95% of particle size [3,4]. Other RDF standards [4,5] are determined based on their heat, water content, and ash content as shown in the following Table 1.

2. Research objective
The objective of this research is to acknowledge heat potential of Refuse Derived Fuel generated from waste residue as energy source, by compressing it into briquettes.
Table 1. Quality standard RDF in Europe.

| Parameter         | Finland | Italy | United Kingdom |
|-------------------|---------|-------|----------------|
| Heat Value (MJ/kg)| 13 - 16 | 15    | 18.7           |
| Water Content (%/w)| 25 - 35 | 25 maks | 7 - 28         |
| Ash Content (%/w) | 5 - 10  | 20    | 12             |
| Sulphur (%/w)     | 0.1 - 0.2 | 0.6 | 0.1 - 0.5      |
| Chlorine (%/w)    | 0.3 - 1.0 | 0.9 | 0.3 - 1.2      |

3. Research methods

Waste samples are taken from the Bantargebang Final Processing Site which receives waste from DKI Jakarta area. The generation, composition and heat value of waste is processed based on primary and secondary data which includes: measurement of waste density, composition of waste residue, measurement of water content and ash content of residual waste and measurement of heat value of waste residue [6,7].

The measurement of waste density and composition of waste follows the rules in SNI 19-3694-1994 [5]. For the calculation of the composition of waste used wet units, do the separation of components of paper waste, plastic bottles, glass bottles, tetrapack paper, styrofoam, sanitary pads/pampers, organic waste, food scraps, plastic bags, cloth, and rubber [8].

The mass balance of waste is made to see the recycling potential of each type of waste. The recycling percentage of each type of waste is obtained from research and interviews with waste scavengers or waste goods collectors. Based on this percentage, the amount of waste that can be recycled and the residue generated and needs to be disposed at Final Processing Site (FPS) is obtained [9].

Water content determination is defined according to SNI 03-1971-1990. 10 grams samples were placed in a porcelain cup, heated at 105°C for 3 hours and weighed after 30 minutes cooling in the desiccator [5].

Ash content determination is according to ASTM E 830-87 standards [4]. 200-grams of RDF briquettes made from high color waste residues and organic waste components that have been treated on carbonization process to produce charcoal, then treated on 50 mesh, mixed with starch adhesive with a ratio of 20% of briquette mixture weight [2]. Mixed briquette mixture is put into a cylindrical mold then manually pressed to reduce water content, dried in the sun for 7 days, weighed and tested for water content, ash content, and calor [1,10,11].

4. Results and discussion

The analysis result from Jakarta areas is also shown in the following Table 2.
Table 2. Waste residue from Jakarta.

| No | Sample       | Calor Value (calori/gr) | Water Content (%W) | Ash Content (%W) |
|----|--------------|-------------------------|--------------------|------------------|
| 1  | Textile 1    | 7,194.1375              | 21.7927            | 23.2381          |
| 2  | Paper 1      | 5,869.8341              | 14.1268            | 24.1388          |
| 3  | Plastic 1    | 5,364.6905              | 10.9891            | 23.2924          |
| 4  | Styro foam 1 | 5,581.9653              | 12.3452            | 25.3772          |
| 5  | Organic 1    | 6,776.1492              | 24.8475            | 21.8920          |
| 6  | Pampers 1    | 6,184.8216              | 28.7819            | 24.8195          |
| 7  | Textile 2    | 7,087.0985              | 21.3215            | 21.3215          |
| 8  | Paper 2      | 5,790.2706              | 16.9628            | 23.5623          |
| 9  | Plastic 2    | 6,419.8345              | 11.9903            | 19.9877          |
| 10 | Styro foam 2 | 5,526.0056              | 12.8629            | 24.6629          |
| 11 | Organic 2    | 6,927.8943              | 27.0270            | 24.6961          |
| 12 | Pampers 2    | 6,206.0265              | 28.8235            | 24.5829          |
| 13 | Textile 3    | 7,402.1374              | 23.7722            | 20.8776          |
| 14 | Paper 3      | 6,371.1377              | 14.8871            | 23.5837          |
| 15 | Plastic 3    | 5,612.4709              | 15.0194            | 24.9433          |
| 16 | Styro foam 3 | 5,826.0052              | 18.0835            | 24.1106          |
| 17 | Organic 3    | 6,899.9830              | 27.6984            | 24.8915          |
| 18 | Pampers 3    | 6,387.8944              | 27.6875            | 22.9878          |
| 19 | Mix 1        | 6,496.0263              | 18.1162            | 23.2188          |
| 20 | Mix 2        | 6,382.1375              | 16.9780            | 23.5809          |
| 21 | Mix 3        | 6,471.1377              | 16.5668            | 23.4714          |

Table 3. Average water content, ash content, and heat value of waste components in Jakarta.

| Components                        | Water Content (%) | Ash Content (%) | Heat Value (kal/gr) |
|-----------------------------------|-------------------|-----------------|---------------------|
| Plastic Bag                       | 12.43             | 23.27           | 6,216.6             |
| Tetrapack Paper                   | 15.79             | 23.88           | 5,951.21            |
| Styrofoam                         | 13.86             | 25.11           | 5,686.2             |
| Fabric                            | 22.72             | 22.33           | 7,036.9             |
| Organic and Food Wastes           | 19.94             | 24.3            | 5,926.83            |
| Sanitary Pads/Diapers             | 27.13             | 23.31           | 6,171.9             |
| Rubber                            | 23.05             | 26.17           | 6,808.57            |
| Total                             | 134.92            | 168.37          | 43,798.21           |
| Average                           | 19.27             | 24.05           | 6,256.89            |

4.1. Briquette heat value potential analysis

The following table shows laboratory analysis of heat value, water content, and ash content of briquette sample.

Table 4. Waste residue briquette analysis result.

| Components        | Analysis Result |
|-------------------|-----------------|
| Water Content     | 33.86 %         |
| Ash Content       | 44.72 %         |
| Heat Value        | 9,867.10 (kal/gr) |
Water content and organic component are highly affecting heat value and ash content. The estimated analysis deviation of 22.55% because of different difficulty level of each components during homogenization process [12].

By acknowledging the utilized briquette heat value of 8051.25 kal/gr. The Total waste sampling residue in DKI Jakarta is at 8,291,650 kg/hari, therefore, the potential heat value of the produced briquette is: Briquette Heat Value = 8,051.25 kal/gr = 9,357.3416 kWh/tons.

According to Central Bureau of Statistics Jakarta is occupied by 9,607,787 people. This research acts as preliminary research on waste residue processing into energy source in form of Refuse Derived Fuel (RDF), by forming the residue into briquettes [7].

A good briquette comes with a smooth surface and does not leave black marks. Besides that, as fuel, briquette should be able to fulfill the following criterias: 1. Easy to ignite, 2. Gas emission from combustion process is non toxic, 3. Waterproof and not moldy if stored for a long period, and 4. Demonstrates good combustion force.

Briquettes are widely used as cooking fuel to replace oil and gas fuels. The advantages of using briquettes are more economical (inexpensive), tasteless and odorless, high flame heat, non-toxic, environmentally friendly, not fast becoming ash, and the raw material for making briquettes is easily available.

Briquettes are categorized according to its type, namely non-carbonized briquettes and carbonized briquettes.

4.1.1. According to its type (treatment):
- Non-carbonized briquettes
- Carbonized briquettes

4.1.2. According to its shape. Briquettes are formed according to the needs of its users, so there are various kinds of briquettes based on their shape, namely egg shape, pillow shape, dome shape, ellipse shape, walnut shape, jengkol seed shape, wasp nest/hexagon shape, cube shape, cylindrical round shape, and other shapes.

4.1.3. According to its material
- Coal briquettes
- Biocoal briquettes
- Biomasses briquettes

The factors that need to be considered in briquette making are materials and adhesive compound. Briquette can be formed from one or several types of high heat value materials. As comparison, minimum standard heat value of coal is 4.400 Kal/g (Minister of Energy and Human Resource Regulation Number 047 Year 2006).

The following Table 6 contains survey result on tenement occupants regarding electricity monthly payments required to be paid off to National Electricity Company.

With the assumption that conversion efficiency into electricity is as much as 25%, therefore = 25% x 9,357.3416 kWh/tons = 2,339.3354 kWh/tons.

### Table 5. Briquette heat value.

| Location       | Heat Value per Component (kal/gr) | Briquette Heat Value (kal/gr) | Average Heat Value (kal/gr) | Heat Value Difference (kal/gr) | Analysis Deviation (%) |
|----------------|----------------------------------|-----------------------------|-----------------------------|--------------------------------|------------------------|
| DKI Jakarta    | 6,235.39                         | 9,867.12                    | 8,051.25                    | 1,815.86                       | 22.55%                 |

With the assumption that conversion efficiency into electricity is as much as 25%, therefore = 25% x 9,357.3416 kWh/tons = 2,339.3354 kWh/tons.
Waste residue generation from sampling result is as much as 224.5 kg/day or 2,245 tons/day, therefore, energy potential (kWh) per day = 8,291.650 tons/day x 2,339.335 kWh/tons = 19,396,902.46 kWh/day.

Table 6. Electricity utilization in tenements.

| No | Electricity Bill (Rp)/month | User ID    |
|----|----------------------------|-----------|
| 1  | 111,227                    | 5471.0239.700 |
| 2  | 236,933                    | 5471.0238.7063 |
| 3  | 210,068                    | 5471.0238.7048 |
| 4  | 61,363                     | 5471.0238.7089 |
| 5  | 30,95                      | 5471.0234.8292 |
| 6  | 81,132                     | 5471.0238.7071 |
| 7  | 88,735                     | 5471.0238.9830 |
| 8  | 44,319                     | 5471.0237.3790 |
| 9  | 162,929                    | 5471.0234.0476 |
| 10 | 53,76                      | 5471.0238.9814 |
| 11 | 385,697                    | 5471.0236.1308 |
| 12 | 45,143                     | 5471.0234.8306 |
| 13 | 8,357                      | 5471.045.3860 |
| 14 | 68,46                      | 5471.0245.3878 |
| 15 | 8,703                      | 5471.0280.5455 |
| 16 | 16,896                     | 5471.0280.5463 |
| 17 | 355,369                    | 5471.0245.3886 |
| 18 | 54,267                     | 5471.0247.3693 |
| 19 | 32,978                     | 5471.0247.3723 |
| 20 | 17,633                     | 5471.0247.3731 |
| 21 | 58,829                     | 5471.0247.3749 |
| 22 | 64,404                     | 5471.0247.3756 |
| 23 | 46,664                     | 5471.0247.3685 |
| 24 | 65,925                     | 5471.0247.3707 |
| 25 | 117,12                     | 5471.0247.3715 |
| 26 | 5,069                      | 5472.0001.7792 |
| 27 | 18,432                     | 5471.0234.8314 |
| 28 | 102,927                    | 5471.0233.6455 |
| 29 | 213,733                    | 5471.0239.0718 |
| 30 | 507,003                    | 5471.0239.0734 |
| 31 | 118,641                    | 5471.0234.8322 |
| 32 | 5,242                      | 5471.0236.1294 |
| 33 | 53,253                     | 5471.0238.9806 |

Average 104,6109394

If assumed that electricity consumption in simple household is 642.84 kWh/month or 21.428 kWh/day, the total energy potential can provide electricity needs for = 19,396,902.46 kWh/day: 21.428 kWh/day/house = 905,213 houses.

5. Conclusion
- 34% of waste in Jakarta can be recycled meanwhile the other 66% in form of waste residue is transported and processed at final processing facility.
- We can see a difference between heat value per component with briquette heat value of 1,815.86 kal/gr. From this difference, we can say that the probability of analysis mistake is as
much as 22.55% caused by sample homogenization. Based on that the average briquette heat value is at 8,051.25 kal/ gr.

- If we assume that electricity requirement in simple housing is as much as 642.84 kWh/month or 21.428 kWh/day, the potential energy can provide = 19,396,902.46 kWh/day: 21.428 kWh/day/house = 905,213 houses.
- The number of simple tenements that can be fueled by RDF is = 19,396,902.46 kWh per day: 1.47 kWh per day = 13,854,930 tenements.

After conducting this research, there are several suggestions which are: A further research on waste component heat residue, briquette heat value, waste residue heat value, and waste residue processing into briquettes, including its economic calculation are recommended as alternative fuel development.

References
[1] Ganesh T, Vignesh P and Arun Kumar G 2013 Refuse derived fuel to electricity International Journal of Engineering Research & Technology (IJERT) 29
[2] Muthuraman M, Namioka T and Yoshikawa K 2010 A comparative study on co-combustion performance of municipal solid waste and Indonesian coal with high ash Indian coal: A thermogravimetric analysis. Fuel Processing Technology 91(5) 550-558
[3] Brás I, Silva M E, Lobo G, Cordeiro A, Faria M and de Lemos L T 2017 Refuse derived fuel from municipal solid waste rejected fractions-a case study Energy Procedia 120 349-356.
[4] Gold J 2012 Waste to Energy: Europe and the United States. Submitted as Coursework for PH240 (Stanford University, Fall 2012)
[5] National Standardization Agency 2008 SNI 3242:2008: Waste management in Settlements Republic of Indonesia Government Regulation Number 81 Year 2012 (Management of Household Waste and Wastes Similar to Household Waste)
[6] Annisa B 2016 Scenarios tackling municipal solid waste (MSW) flow into landfill based on MFA-STAT integrative method towards building sustainable city in Indonesia In 2nd International Conference on Civil Engineering Research (ICCE)
[7] Damanhuri E and T Padmi 2010 Waste Management (Module: Institut Teknologi Bandung)
[8] National Standardization Agency 1995 SNI 19-3964-1995: The method of taking and measuring examples of the generation and composition of urban waste
[9] M Chaerul and A K Wardhani 2020 Refused derived fuel (RDF) from urban waste using biodrying process: review Jurnal Presipitasi: Media Komunikasi dan Pengembangan Teknik Lingkungan 17(1) 62-74
[10] Zahra F 2012 Analysis of Depok Waste into Refuse Derived Fuel (RDF) (Case Study: Pondok Terong and Kampung Sasak Waste Processing Units) (Universitas Indonesia)
[11] Paramita W, Hartono D M and Soesilo T E B 2018 Sustainability of Refuse Derived Fuel Potential from Municipal Solid Waste for Cement’s Alternative Fuel in Indonesia (A Case at Jeruklegi Landfill, in Cilacap) In IOP Conference Series: Earth and Environmental Science 159(1) 012027
[12] Arifianzi Q O, Abidin M R, Nugrahani E F and Ummatin K K 2018 Experimental Investigation of a Solar Greenhouse Dryer Using Fiber Plastic Cover to Reduce the Moisture Content of Refuse Derived Fuel in an Indonesian Cement Industry In 2018 International Conference and Utility Exhibition on Green Energy for Sustainable Development (ICUE) 1-5