Sustainability of Refuse Derived Fuel Potential from Municipal Solid Waste for Cement’s Alternative Fuel in Indonesia (A Case at Jeruklegi Landfill, in Cilacap)

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Abstract This paper examines Refused Derived Fuel (RDF) potential from Municipal Solid Waste (MSW) as cement industry’s alternative fuel in developing country. Municipal solid waste remains an issues for city while cement industry are needed a sustainable alternative fuel resources. Jeruklegi Landfill, in Cilacap City, Central Java Province, Indonesia was selected as a research case, because its location is close to cement industry. Research’s approach is using triple bottom line sustainability; economic, social and environment. It investigates RDF potential from quality aspects (calorific value), economic aspect (RDF price), environment aspect (GHG emission) and social inclusion of waste picker. It is found that MSW on Jeruklegi Landfill has a potential for processing in to RDF, since its average calorific value is 3563 Kcal/kg, price is 293,000 IDR/ton, and avoided 2.9x10⁶ Nm³ methane emission. An inclusive approach should be taken into account in early stage to engage waste picker rather that marginalized them. This findings contributes to government as well as cement industry on RDF as a solution for waste management and fossil fuel conservation.

1. Introduction
Economic growth resulted a massive development in cities. UN predicts in 2050 three quarter of world population is living in city. In Indonesia, projection of population growth in 2025 is 271,227,000 people with 178,731,000 of them live in urban area and would have generated 151,921 ton/day Municipal Solid Waste (MSW)[¹]. Forty five regency/city in Indonesia are using open dumping system on its landfill some were found using open burning[²]. Methane is generated in landfills by the anaerobic biodegradation of organic matter [³], and also categorized as Green House Gas (GHG)[⁴]. Thus research on MSW is remained necessary and up to date to current issues. Cilacap city is also facing an issue with MSW. They project that their final disposal land would reach its maximum capacity in 2018 if there is no different approach rather than open dumping. Referring to waste management hierarchy, they decided to develop waste into energy, by processing MSW into RDF. Under current circumstances RDF is the most probable solution since their final disposal location is about 5 km from cement plant. Cement plant is the most ready and suitable user due to no need major modification on its equipment [⁵]. Existing practice, cement industry has been utilized rice husk as their alternative fuel, but its intermittent supply creating another issues.
Debate centers on the issue of RDF is its benefit to industry. Would RDF viable to be used as an alternative fuel if it has small differences on price than coal, with lesser heat value and requires specific handling? The preferable production of RDF is a result of bio-dried waste fractions with particle size higher than 45 mm that mainly composed of plastics and papers[6], and its utilization in cement industries will be financially viable if its price is lower than coal price [7]. Bio-drying is also could lower investment cost[6][7]. In developing countries are common to come across waste pickers on landfills. In Jeruklegi landfill there are approximately 100 waste pickers working there[8]. This paper differs from that of many other researchers in that it focuses on sustainability of RDF potential. Sustainability here is assessing four aspect, i.e; i). economical aspect by comparing RDF price with rice husk, ii). technological aspect by comparing its calorific value using bio-drying with minimum criteria, iii). environmental aspect by projecting Green House Gas (GHG) emission that can be avoided and iv). social aspect by analysing waste pickers perception and seek a proper engagement approach. Sustainability can only be achieved if all aspects are fulfilled.

2. Objective
This study aims to analyse a potential of RDF from Jeruklegi landfill’s municipal solid waste as cement industry’s alternative fuel.

The paper result will be helpful for developing renewable energy as well as integrated solid waste management strategy which is important as an input city/regency strategic plan in Indonesian local governments and can encourage cement industry to utilize RDF. Cilacap regency can extend their landfill lifetime while cement industry can reduce their fossil fuel consumption which will lead to reducing their CO$_2$ emission at the end.

3. Method

3.1. Location and time
The study was conducted at Cilacap City, Central Java Province for about 5 months, from June until October, 2017. The data was collected from the relevant institutions in Cilacap City, previous relevant researches cement industry and waste pickers.

3.2. Data collection
The primary data was collected by in-depth interview with Cilacap Environmental Agency officials, waste pickers at Jeruklegi landfill as well as cement industry by filling the questionnaires. Selection criteria for waste pickers are those whose permanently worked there and member of The Jeruklegi waste picker association. Interview with waste picker conducted by focus group discussion, and it consists of two different group which is women and men. Selection criteria for cement industry is an integrated cement plant located in Java and has been utilizing alternative fuel specifically rice husk for at least 3 years consecutively.

The secondary data were Study of Waste Specification in Cilacap by Ganesha Environmental and Energy Services, ITB 2015, Study of Social Mapping of Waste Pickers at Jeruklegi Landfill Cilacap by Gadjah Mada University 2016, and data from BPS (Statistical Center Agency) of Cilacap Regency.

3.3. Data analysis
This study investigates four aspect, namely; i). RDF pricing, ii) calorific value RDF, iii). avoided CO$_2$ emission by using RDF and iv). waste picker inclusion. The 1st and 2nd aspect were analysed by comparing results with criteria from cement industry, obtained from questionnaires and other country standards. Criteria standards is shown in Table 1. Avoided GHG emission was calculated based on projection of emission that could have been released if MSW is landfilled. Perception and inclusivity of waste picker is analyses descriptively.

Sustainability of RDF is analysed using Integrated Sustainability Waste Management (ISWM) approach[9]. Below (figure 1) is ISWM framework.
4. Results

Information and data from Environmental Agency were; i). capacity of RDF plant is 120 ton/day of waste, ii). bio-drying, is selected since waste has approximately 50% organic waste [10], iii) amount and scheme of funding [11], iv). amount of tipping fee [11], and v) amount of production cost of RDF plant [11]. Based on selection criteria, there 3 cement industry that eligible, however only 2 has responded. Firstly is Semen Gresik at Tuban, secondly is Semen Holcim Indonesia which covers Narogong plant, Cilacap plant and Tuban plant. Later on Semen Gresik will stated as respondent A and Holcim Indonesia as respondent B. Summary of questionnaires result is presented below(Table 2).

### Table 2. Questionnaires results

| Questions                          | Respondent A | Respondent B |
|------------------------------------|--------------|--------------|
| Target on fuel substitution        | 5-10%        | 10-15%       |
| Price rice husk (IDR/ton)          | 300.000-350.000 | 250.000-260.000 |
| Willingness to pay RDF per ton (IDR/ton) | 300.000-350.000 | Below 300.000 |
| Min calorific value (Kcal/kg)      | 3000         | 3000         |

Source: Questionnaires

4.1. RDF Pricing

Refuse Derived Fuel pricing is sum of total cost and profit[7][9]. Total cost is not only consist of investment and operational cost but also from tipping fee. Tipping fee/gate fee is sum of money that waste processor received from government. There was a foreign funding from Danish Government for machinery of IDR45 Bio, while land cost, IDR1.8 Bio, is also grant from Cilacap Regency [11]. Thus, both cost are not included on calculation. Investment cost consist of land preparation and construction, which is divided between Public Works & Settlements Ministry and Central Java Province budget, for IDR35Bio [11]. Tipping fee for Cilacap Regency has been decided for IDR100.000 per ton incoming waste [11]. Production cost is IDR272,000/ton RDF [11]. Assumptions profit for this study is 10% of total cost and 10 years project period. Investment cost per year is IDR3.5Bio. Therefore calculation of RDF price, can be seen below:
RDF production per year : 40% * 120 * 310 = 14,880 ton
RDF price (IDR) : \[\text{[Total investment – tipping fees]} + \text{profit}\] = 293,000 per ton

Comparing RDF price with maximum willingness to pay of industry, shows that RDF has a competitive price. Refuse Derived Fuel only financially viable if less price than coal[7], but this study shows that compared to rice husk, RDF still competitive.

4.2. RDF Calorific value
Experiment has been conducted for approximately 5 months from June – October. There were 3 batches of waste. This experiment investigates effectiveness of bio-drying to increase calorific value of waste. Result of experiments is shown in Table 3.

| Parameter      | Unit   | 1A     | 1B     | 2A     | 3A     | 3B     | Avg    |
|----------------|--------|--------|--------|--------|--------|--------|--------|
| Incoming moisture | %      | 58     | 58.2   | 60     | 58.2   | 59.6   | 58.8   |
| Duration       | days   | 46     | 41     | 27     | 27     | 40     | 36.2   |
| Final moisture  | %      | 26     | 20.3   | 25.1   | 21.5   | 28     | 24.2   |
| Calorific value | Kcal/kg| 3686   | 3602   | 3026   | 4064   | 3435   | 3563   |

Source: Holcim Indonesia, 2017

Minimum calorific value required by cement industry in Indonesia is 3000 Kcal/kg, thus bio-drying method is quite effective to increase calorific value of MSW. Compared to EU and Thailand standard from Table 1, experiment result also showing good outcome. Average calorific value is 3563 Kcal/kg[12]

4.3. Avoided GHG emission
Landfilling of MSW in certain period of time will triggered a methane gas released to air, theoretically 50 Nm³ methane released from one ton of landfilled MSW[13]. Refers on that number, this study concluded that avoided GHG emission by RDF initiative is 6000 Nm³/ton landfilled waste per day or 2,190,000 Nm³/ton waste per year.

4.4. Waste picker perception
The most probable affected community with RDF initiative is waste pickers. This study conduct FGD to two different groups, both groups are consist of 10 participants. Groups are divided as per gender category, since women waste pickers tend to afraid to speak up when among men waste picker[8]. Women group stated that they have no objection for RDF planning as long as Cilacap government gives them enough time to collect valuable waste. Differs from women group, almost all participants of men group wished to keep as current practice. Both of group concerns are losing income if time slot to collect waste is reduced. They also has no interest to work as employee at RDF facility, due to non-flexible working hours and stricter regulation. Although, most of participants said that they will obey how government rules. This statement is an opportunity to engage waste picker on government program.

5. Discussions
Integrated sustainability of solid waste management must take into account aspects, stake holders and solid waste process flow[9]. This study limited on four aspects (financial, technical, environment. social), three stakeholder (Cilacap government, cement industry, waste picker) and one process of solid waste, final disposal process. This study resulted that financially RDF has a competitive price compared to rice husk, it has met minimum requirements of calorific values, which is technically accepted, and converting waste to RDF also able to avoid about 2.9 x10⁶ Nm³ methane released to
ambient air but socially, currently waste pickers concerns about their livelihood being threatened with RDF. Waste picker is also one of key stakeholder at Jeruklegi landfill that needs to be engaged otherwise negative risk will rise. Historically there is no experienced of strike on Jeruklegi but the risk is remained. Based on Indonesian Public Works Minister Decree No. 13 year 2003, waste picker should be addressed on waste management strategy on final disposal area. However social inclusion of waste picker into structured working condition is also challenging. Partnerships are easier to set up if waste pickers are organized, and a task supported by advocacy group[14]. In Jeruklegi, waste picker has a simple organization, but has no legal entity and formal structure. Affirmative action is needed to strongly encourage waste picker to organize, in Indonesia the most common organization is cooperative. There should be a regulation to only allowed cooperative member of waste picker works at Jeruklegi, thus waste picker will agree to be organized. As Marello&Helwege, 2014 paper said that an advocacy team is needed to support, Jeruklegi also need a supporting team consist of cooperative agency, social agency and probably also labour agency to empower them. This paper suggests Cilacap government to develop a waste picking bay where waste picker cooperative could collect waste. A belt conveyor with appropriate working condition should be provided. Waste picker works on certain working shift where they are involved on deciding the group member and schedule. It will not be easy but with task supportive group, it will possible. Inclusivity program should be on priority list. Only by this, a sustainability of solid waste management is achieved.

6. Conclusions
This study concludes that municipal solid waste in Jeruklegi landfill has potential to be converted into RDF from financially aspect, RDF price is 283,000 IDR/ton, which is in a rice husk price range and under willingness to pay amount of cement industry; technically aspect, RDF calorific value is between 3026-4064 Kcal/kg and above minimum standard; environmentally sound, where can avoid approximately 2.9x10^6 Nm³ methane. Care should be taken for social aspect, where social inclusion of waste picker could be a solution for it. This study would like to propose; i). Cooperative for waste picker is necessary if Cilacap government would like to include waste picker on RDF initiative, ii). Task supportive team has to be assist during cooperative developing, iii). Further research may be needed to seek most appropriate mechanism of support.

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