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Review and Analysis of Coal Substitution with Refuse Derived Fuel (RDF) in Cement Plant using System Dynamic

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Regarding to the depletion of fossil fuel issue, one of the biggest cement industry in Indonesia, PT. XYZ has a program by substituting 30% of the total coal with RDF. This policy is related to the company's commitment to support Corporate Social Responsibility (CSR) program to reduce the amount of Municipal Solid Waste (MSW) in Gresik city. However, in the implementation, several problems were found, for example, a high percentage moisture content and also impurity (sand, gravel) in RDF. To solve those problems, in the present study, the RDF usage in PT. XYZ is evaluated by building a system dynamic model. A Vensim software is used to simulate the problem. The general result shows that the quantity and quality of RDF determine how much of coal substitution. Some policy scenarios have been created by modifying the RDF's machine production, for example, adding rotary screen and drying equipment. Those actions can improve quantity and quality of RDF.

Keywords: MSW in Gresik City, RDF, Substitution, System Dynamic

1. INTRODUCTION

Cement industry is a fast growing company along with the development of a country. A large amount of heat are required to support this company. Mostly, cement industry uses coal as fuel to meet up the daily energy needs. A higher tendency of coal usage causes the cement company sensitive to the rise of fossil fuel price. Whereas, the energy cost component (include the electricity cost) reached 51 percent to a total of production cost.

In Indonesia, the total amount of estimated coal reserves is only 7.6 billion tons. As the coal reserves continue to decrease, the coal prices tend to be higher, and further it will influence the industry that use coal as fuels.

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On the other hand, along with the rapid economic growth, the amount of Municipal Solid Waste (MSW) generated is higher. According to some experiments that have been conducted by [1], [2], [3], [4], and [5], the waste can be used to produce energy. Therefore, the utilization of the waste might be a solution to the problems of limited fossil fuel in cement industry.

The product of the waste utilization is called Refused Derived Fuel (RDF). There are various investigation about RDF. A.K. Dalai et al. [6] found that the major components in RDF were carbon and hydrogen based on the proximate and ultimate analysis. C.S. Chyang et al. [1] investigated the pollutant emissions from co-firing of RDF and coal. S. Singh et al. [2] performed pyrolysis of RDF using two thermogravimetric analyzer (TGA). The characteristic of RDF utilization in different kind of reactor were also studied, for example, in a down draft gasifier [7], a fluidized bed incinerator [8], a continuously stirred batch reactor [3], so forth.

RDF could be used as an alternative fuel in cement manufacturing since RDF provides a high calorific value for the cement kiln [9]. The caloric value of RDF is around 5178 kcal/ kg. These value is higher than that of coal which is only 4800 kcal/kg. Based on this fact, substituting coal with RDF in cement plant can be possibly executed.

One of the biggest cement plants in Indonesia, PT. XYZ has substituted 30% coal with RDF. This policy is related to the company's commitment to support Corporate Social Responsibility (CSR) program to reduce the amount of MSW in Gresik city. Unfortunately, as PT. XYZ continues to operate, the RDF could not be produced constantly. It is occurred because of some factors related to the RDF machine. Accordingly, in the present study, the coal substitution with Refused Derived Fuel (RDF) in PT. XYZ were reviewed and analyzed to define the parameter which influence the RDF production. Moreover, by using those parameter, the solution to optimize the RDF production would be provided.

In many complex system, system dynamic can be used to represent the information related the problem, thus the solution (some scenarios) can be generated systematically. Many researchers had applied system dynamics. For example, F. Li et al. [10] built a system dynamic model to simulate CO_2 emission trends in traditional industrial region with large CO_2 emission. B. Dyson and N. B. Chang [11] applied system dynamic to predict solid waste generation in a fast-growing urban area. E. Suryani et al. [12] developed system dynamic model to forecast air passenger demand. Therefore, in the present study, to describe the problem in RDF production and also obtain a better understanding about its relationship to another issue, a model was created by using system dynamics in Vensim simulation.

The remainder of this paper is organized as follow: the methodology is described in details in the section 2. The experiment result is explained in the section 3. At last, conclusion is discussed in the last section.

2. METHODOLOGY

To obtain the coal substitution model, the variables related to cement production were identified. The input variables are shown in Table 1. The data used in the present simulation comprises primary and secondary data. The primary data was based on the result of focus group discussion (FGD) conducted with department of energy and material of PT XYZ. While, the secondary data obtained from literature study and annual work summary of PT XYZ.

Table.1. Input Variables Related to Cement Production

No.	Variables
1	Kiln production capacity
2	Coal demand
3	RDF production capacity
4	RDF calorie
5	Coal price
6	RDF price

The following step was operating the Vensim software to build the model. Vensim is an industrial strength simulation software to improve the performance of real systems [13]. After the model was created, the next procedure was running the simulation based on the defined time period. The simulation result showed the significant level of coal substitution with respect to financial and environment aspect in PT XYZ. Subsequently, this output were validated and analyzed.

3. ACTUAL CONDITION RDF PRODUCTION MODEL

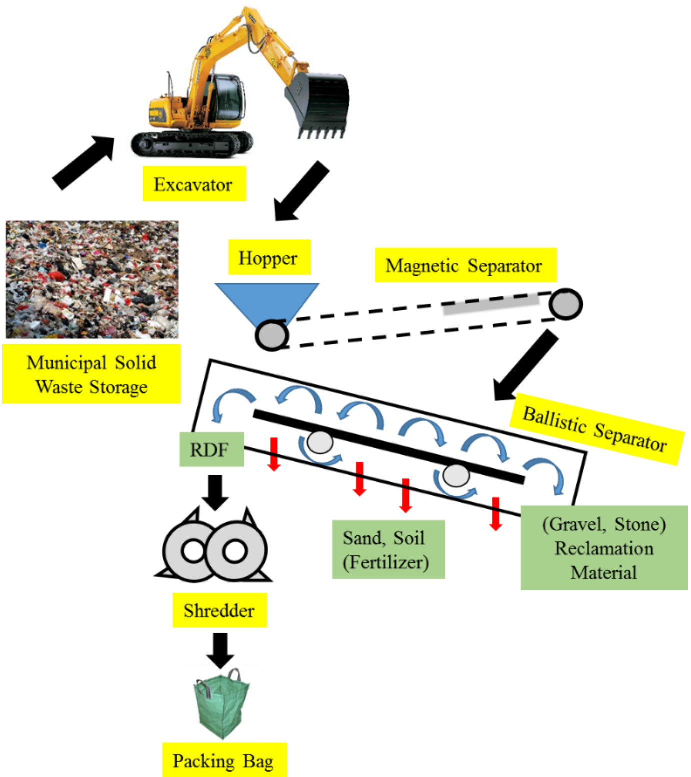

Figure 1. RDF Production Process

Figure 1. RDF Production Processshows the RDF process production. The first step, MSW is moved from landfill using excavator to hopper. Then, the MSW is transported to ballistic separator using belt conveyor. In belt conveyor, there is a magnetic separator, this component is used to extract any magnetic material from the MSW. The separation process will be continued in ballistic separator. In the ballistic separator, the MSW is classified into three kinds of composition. This equipment

separates the waste using the movement of inclined screen. The RDF is then shredded into the smaller part. The final composition from those process comprises around 35% reclamation material, 37% fertilizer (37%), and 28% RDF.

The coal substitution program have been applied since May 2016. The raw material of RDF is Municipal Solid Waste (MSW). RDF is produced in final disposal of waste site in Gresik city (about 84 km from PT. XYZ). The final disposal site has been established since 1998 and the area is about 6 ha. Approximately 217 ton of garbage ended up in the landfill per day. The composition of the garbage contains around 51% organic garbage, and 49% inorganic garbage. The detail composition can be shown in Table 2.

Table 2. The Garbage Composition in Final

Material	Percentage
Plastic	17%
Textile	2%
Paper	28%
Wood	2%
Organic Garbage	51%
Total	100%

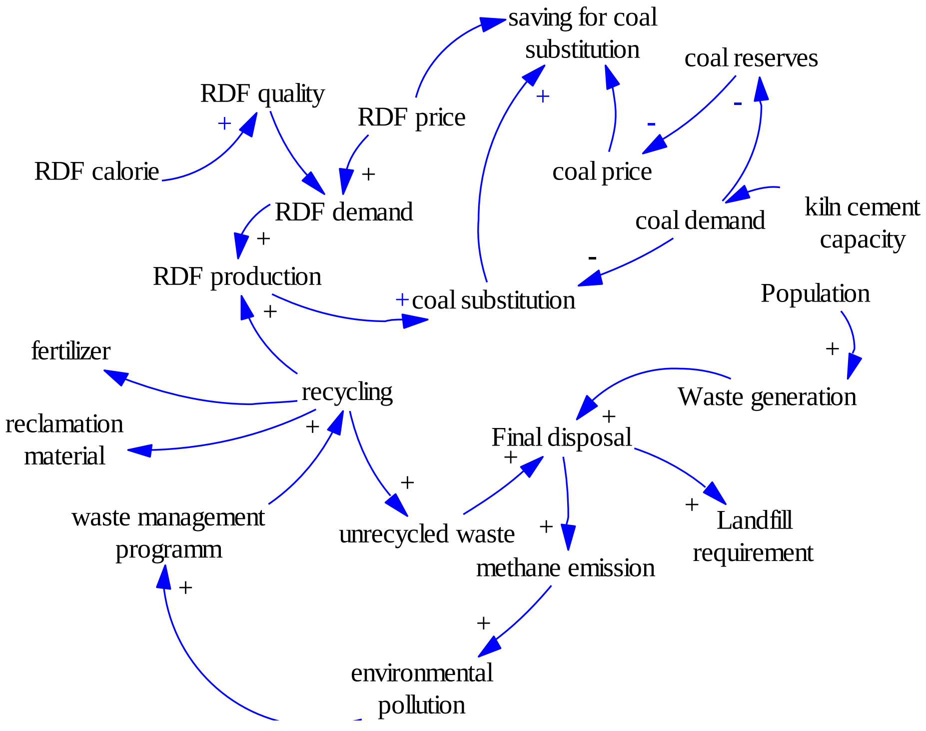

Figure 2. Influence Diagram for Coal Substitution

To process the waste, municipal solid waste treatment plant were installed in final disposal site. However, this plant operated out of the specification since only 3 ton of RDF could be produced each day (35 operating hours a week). The machine was expected to generate 3.3 ton of RDF per hour. On the other hand, the amount of coal substitution in PT XYZ was around 270 ton/ day. Thus, to fulfill the 30% coal substitution, the company also mix RDF with rice husk and coconut shell. An imbalance between supply and demand of RDF was occurred not only due to the low RDF capacity, but also the quality of RDF itself. The quality of RDF was poor since the RDF did not meet the minimum criteria for moisture. The company stated that the moisture content could not exceed 10%. According to the data collected, the moisture level of RDF reached almost 30%.

Figure 2. Influence Diagram for Coal Substitution describes influence diagram for coal substitution. The kiln cement capacity influences coal demand. The rise of kiln cement capacity leads to the increase of coal demand. The coal demand affects coal reserves. Increasingly scarce supply of coal, coal prices will increase. Coal price and RDF price influence saving for coal substitution. The greater substitution of coal, the greater the saving. However, to achieve production targets, quality RDF must be met, by keeping moisture content to achieve calorie criteria.

4. MODIFIED SCENARIO RDF PRODUCTION MODEL

Based on the model of RDF production systems that have been developed, it is known that MSW management answer the problem of the need for landfill that is growing due to the increasing amount of MSW in Gresik city. Figure 3 below shows that final disposal in landfill will increase as the population increase. If the amount of waste that is processed is not proportional to the increase of municipal waste in Gresik, that is a problem.

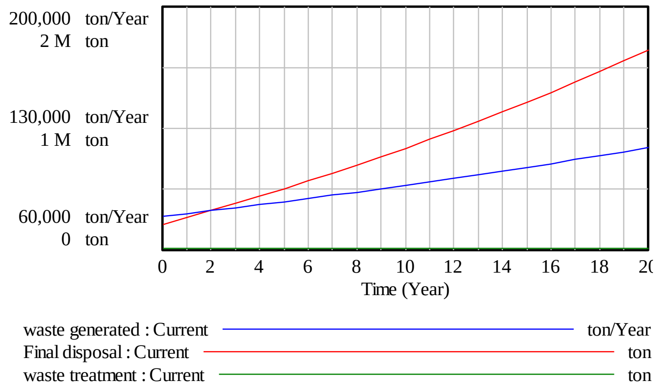

Figure 3 Projection of Final Disposal and Waste treatment

The model shows that RDF production capacity determined by its quality. Several factors that affect the quality of RDF are percentage moisture content and also impurity (sand, gravel) in RDF.

Those two factors also affect the quantity of RDF production due to the production time. Some machine problem was detected because of its moisture level of waste is too high. It cause stoppage of the machine so that the machine is switched off and need to be cleaned first.

The moisture content also affect the calorie of RDF. the higher the moist lower the calories produced.

An improvement is required to optimize the RDF production. It could be completed by doing some procedures:

1. Adding the rotary screen

In previous RDF production, sand and soil were still included in RDF. PT. XYZ as a consumer tested the quality of RDF and found that the mixture decreased the heating value of RDF. To overcome this problem, a rotary screen would be added in the RDF production system. The principle of the rotary screen is to separate the RDF raw material with undesirable material (e.g. sand and soil) by their size. Later, each fraction is collected separately. The concept of rotary screen is presented in Figure 4. Rotary Screen Mechanism4.

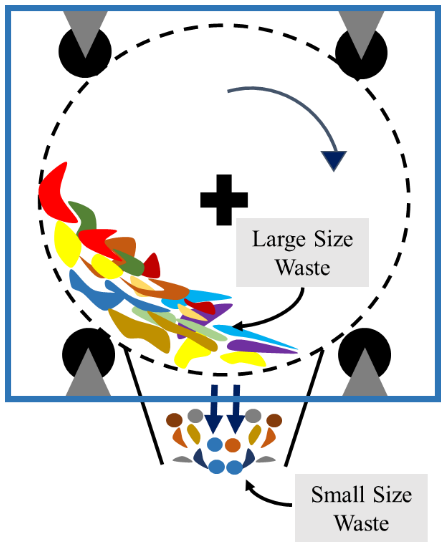

Figure 4. Rotary Screen Mechanism

2. Adding the Drying Equipment

The drying system is used to decrease the moisture content. It plays a role to increase the combustion efficiency in the kiln. Although the RDF raw material tends to have a low moisture content, but during the rainy season, the rain water drop falling to the material. Thus, the drying system must be installed.

5. CONCLUSIONS

In the present study, a system dynamic model of RDF production with some improvement was carried out. To achieve this objective, a model was created in Vensim software program. The improvements could be executed by adding rotary screen and drying mechanism. The result showed that those additional system could significantly increase the quality and quantity of RDF production. It could be proven from the output model. By applying drying mechanism, the moisture content of RDF be guarded at 10 % that the calorie is 4906 kcal/kg. That 10% moisture content also saving production time. The quantity of RDF production incresing by 198 ton per year.

That quantity and quality of RDF affect the amout of coal substitution, and how much profit that company can saving. The coal price is about Rp. 480.000. Meanwhile, the RDF price is Rp. 285.000, have not been taken into account in this system.

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