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ASSESSMENT AND DECISION MAKING SCENARIO OF CARBON EMISSION IN SUGAR INDUSTRY BASED ON ENERGY CONSUMPTION USING SYSTEM DYNAMICS

CHAIRUL SALEH*, AFIFUDDIN THOIF*, RADEN ACHMAD CHAIRDINO LEUVEANO, MOHD NIZAM AB RAHMAN

[1,2]Department of Industrial Engineering, Universitas Islam Indonesia
Jl. Kaliurang, KM 14.5, Sleman, Yogyakarta, Indonesia
[3,4]Department of Mechanical and Material Engineering, Faculty of Engineering and Build Environment, Universiti Kebangsaan Malaysia, Malaysia
*Corresponding Author: chairul@uii.ac.id, afifuddinthoif@gmail.com

Abstract

This research is conducted to assess and create some scenarios in the sugar industry, which aimed to decrease the production of CO2 emissions in PT Madubaru. In this research, the assessment of CO2 emission is based on the energy consumption used in supply chain activities during the production period in 2014. The problem faced in this research is the used of energy for transportation and production in a complex condition. Thus, simulation modeling based on system dynamic has been proposed to build the assessment model and create a scenario. The result shows that PT Madubaru produces around 174,246,500 kg in 171 days or during the production period in 2014. It means that the amount of CO2 emission in a day is around 1,018,985 kg. Two scenarios haves been developeded in order to reduce CO2 emissions. First, changing the old type boiler with the new one by increasing 155% fuel efficiency. This scenario is proven to reduce the amount of CO2 by 44% or become 98,800,400 kg. Second, eliminating the use of lorry which reduce the 0.2% of CO2 emission or equal to 387,600 kg.

Keywords: Supply Chain, CO2 Emissions, System Dynamics, Sugar Industry.

1. Introduction

Global warming is becoming a hot issues discussed by experts in these last few years. Intergovernmental Panel on Climate Change (IPCC) declared that total anthropogenic greenhouse gases (GHG) which mostly composed of CO2 emissions have continued increase up to 78% from 1970 to 2010 [1]. It caused by fossil fuel combustion from industrial processes. Continuously, National Aeronautics and Space Administration (NASA) stated that the increase of global temperature is due to human activities [2]. The effect of rising temperature is now

occurring: loss sea ice, accelerated sea level rise and longer, more intense heat waves. According to Benhelal et al. [3], the rapid of industrial process, the increasing of public and individual transportation has reached concerned level.

In fact, industrialized countries have confessed that they shared the majority of GHG. However, the growth of industry in developing countries have surprisingly shared lot emission and believed to keep rising rapidly. Based on this condition, a comprehensive effort worldwide should be conducted in order to create low-carbon emission. Many developing countries, such as Brazil, Chile, China, Columbia, Costa Rica, India, Indonesia, Mexico, Morocco, Peru, South Africa, Thailand, Turkey, Ukraine and Vietnam are currently implementing countries to reduce their gas emissions based on the agreement of Kyoto Protocol [4].

According to World Bank [5], Indonesia is ranked 14 in the world of countries with CO2 emission released to the atmosphere around 433.989 million tones and the emission per capita is 1.8 metric tons in 2010. The production of carbon emission is caused by energy consumption of liquid, solid, gas and gas flaring fuels. Furthermore, Indonesia publishes a presidential regulation for a national action plan to reduce carbon emissions by 26% in 2020. Thus, CO2 emissions become a very important issue relates to industrial process (supply chain) which led to global warming. Thereby, it is important to discuss about CO2 emission which causes of global warming and create restrictions on the amount of CO2 emission release from all industrial activity to reduce global warming. European countries have limited the expenditure of carbon emission, but Indonesia has not applied this regulation, especially in the manufacturing industry.

Based on literature study, the supply chain is contributing on CO2 emission. While, supply chain management is an integrated process wherein a number of various business entities (i.e., Suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers. This chain is traditionally characterized by a forward flow of materials and a backward flow of information [6]. By concerning many factors, assessment and creating scenarios to reduce CO2 becomes very complex. Many researchers have developed a model to predict CO2 emission such as using Log-Mean Divisia Index [7-9]. All of them run with the aid of scenario analysis by using various decomposition methods to quantify the impact of different factors on the change of energy consumption and CO2 emissions. This condition is difficult to analyse the dynamic evolution and intrinsic behavior of many vital elements inside the energy consumption. In this context, system dynamics (SD) can be adopted to describe the inner interactions and structure impacting energy consumption and identify the desirable and undesirable interventions, this capable of illuminating the evolving process and predicting the energy consumption development trend based on supply chain activity inside the company [10]. Furthermore, research about CO2 emission has also been done using the system dynamic [10-12]. This research explores the intrinsic relationship between supply chain activities inside a sugar company. Besides, the objective of this research is to assess and make a scenario to decreasing CO2 emissions from sugar industry in Yogyakarta. Based on those three researchers who use system dynamic, a scenario to reduce CO2 emission from the sugar industry has not been found. Therefore, this research attempts to analyze the CO2 emission from the sugar industry.

The problems encountered in this research is to assess CO2 emissions caused by the use of energy, such as bagasse for boiler, electrical, etc. As well as the energy generates by boiler, where the energy can be used for production activity. CO2 emission is also caused by transportation of raw material, distribution, plastic and bag supply. As the presence of feedback on this condition, one direction model cannot be made. Thus, the appropriate model is a system dynamic model. The other problem encountered is many equipment contribute to CO2 emission. Where the equipment is possibly to be updated or eliminated to reduce CO2 emission, but still be able to increase new investments. Thus, an appropriate policy is necessary.

2. Literature Review

The increasing carbon emission in earth's atmosphere, has already given effect on climate change. The effect that can be seen now are loss sea ice, accelerated sea level rise and longer, more intense heat waves [12]. IPCC [13] stated that human is responsible for this condition, because human activities causes global warming.

The industry is one cause among others, which produce CO2 emissions. Many researches haves been conducted related with to CO2 emission caused by the supply chain activities inside the industrial process. A model has been stated to calculate the carbon emission from both of stationer and non-stationer supply chain [14]. The calculation of carbon emission on supply chain management also conducted in Hyundai Motor [15]. Ozawa-Maida et al [16] stated that the carbon emission can be done with calculating its energy consumption. Akbontanci et al. [8] has studied the use of energy emission for 57 manufacturing industries in Turkey, and it stated that the used of coal and fuels is the main determining factor in industrial sectors.

Another research about energy consumption and carbon emission using system dynamic approach also has been studied. Liu et al. [17] developed a model to forecasts the energy consumption, gross CO2 emissions and CO2 emission intensity in China from 2013 to 2020 via system dynamics simulation. Onat et al. [18] assessed the energy consumption in residential buildings as one of the major sources of greenhouse gas (GHG) emissions in the U.S. Feng et al. [10] developed a model of system dynamic to perform energy consumption and carbon emission trend in the city of Beijing. System dynamic model has been used to be decision support of making tools, considering on the future carbon emission trend [12]. Assessing and estimating the carbon emission with policy option scenarios need to be developed in order to mitigating the carbon emission in the future [11].

The previous research shows that carbon emission can be calculated based on the energy consumption and the related variables are different among others based on the object of the research. System dynamic become one among others approach to investigate a policy development in order to mitigate and control the effect of the carbon emission in the future.

3. Methodology

This research done with implementing system dynamics simulation to know the condition of CO_2 emission resulted from the supply chain activities in PT Madukismo during 2014 milling period. The step of this research is begin with the identification of supply chain system in PT Madukismo (Fig. 1) and analyzing the activities resulted CO_2 emissions. To create system dynamic modelling, the next step is formulating the cause and effect between the variable in form of causal loop diagram. Then continued by building flow diagram, validate the model, and design improvement.

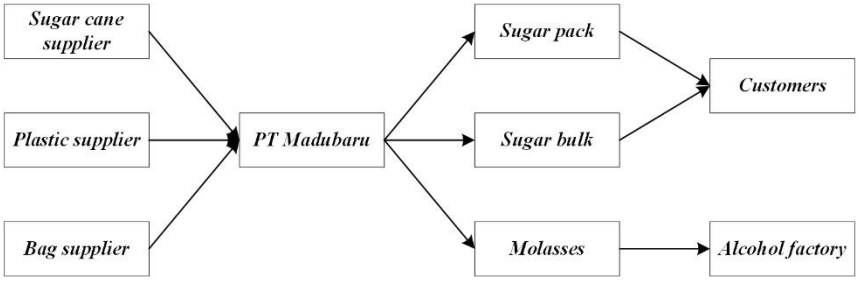

Fig. 1. Identification of supply chain activities.

3.1. Problem identification

Supply chain activity from the company involves the raw material transportation of sugar cane, plastic and bag by the suppliers. Truck is used to transport these raw materials. Those raw materials are then process in PT. Madubaru to become finished product of sugar pack, sugar bulk, and also molasses. Product of sugar pack and sugar bulk will distribute to customer and the molasses is distributed to the alcohol factory. Those transportation and production activities are energy consuming which affect to the expenditure of CO2 emission.

There are two main problems identified from the existing system. First is the boiler machine, boiler machine is uses bagasse as the main fuel to generate steam. This steam will then be converted to electrical power. This electrical power will be distributed for production purposes. From conversion calculation of material, 25.5 kg bagasse can generate 1 kWh electricity. In one day, bagasse consumption reaches approximately 35,000 tones cane per day. It is equivalent with 1,372,549 kilo watt per day. However, the required electricity per day is up to 1,500,000 kWh in average. It means, there is shortage of electricity around 127,451 kWh. This shortage is fulfilled by using electrical from National Electricity Company. The problem is the conversion of 25.5 kg bagasse for 1 kWh is too big, it causes by the old type of boiler. It should be 10 kg bagasse for 1 kWh. Moreover, the use of bagasse fuel will lead to production of CO2 emission.

Second is transportation, the main transportation is designated for sugar cane and sugar products. However, it is conducted dynamically. It depends on the material that should be loaded as scheduled or unscheduled. Thus, the CO2 emission produced is based on the frequency of the transportation. The use of different truck capacity and the sugar cane production capacity will then produce

the frequency of transportation. The problem is emerged by the different distance of each transportation, so this distance is the main cause for the amount of CO2 emission that produced by from the transportation activity.

3.2. System dynamics modelling

System dynamic is a methodology to learn and manage feedback from existing variable in a complex system [19]. In a system dynamics model, the simulations are essentiallytime-step simulations. The model takes a number of simulation steps along the time axis [11]. The method consists of the development of causal loop diagram, the flow diagram, and design improvement.

3.2.1. Causal loop diagram

It is a diagram to present relations among variables, cause and effect relation. CLD is one of the steps in creating conceptual model before developing system behavior model. Fig. 2 explains the relation of cause and effect from the variable used to model the real system.

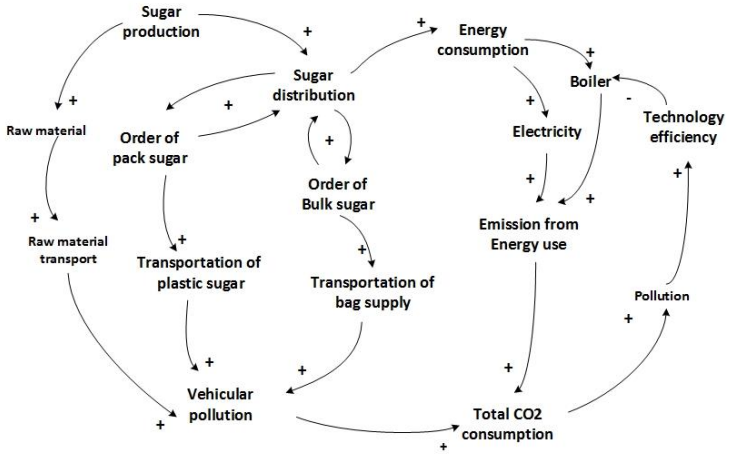

Fig. 2. Causal loop diagram of system dynamics model for sugar factory.

3.2.2. Flow diagram

Flow diagram (FD) is a diagram which represents a flow or relation among variables in a system. FD modeling cannot be separated from the CLD modeling as conceptualization stage. It causes from the CLD, the variables and relation can be known. So, modeler can develop FD model based on CLD model. Fig. 3 shows the FD integrated model to assess the CO2 emission.

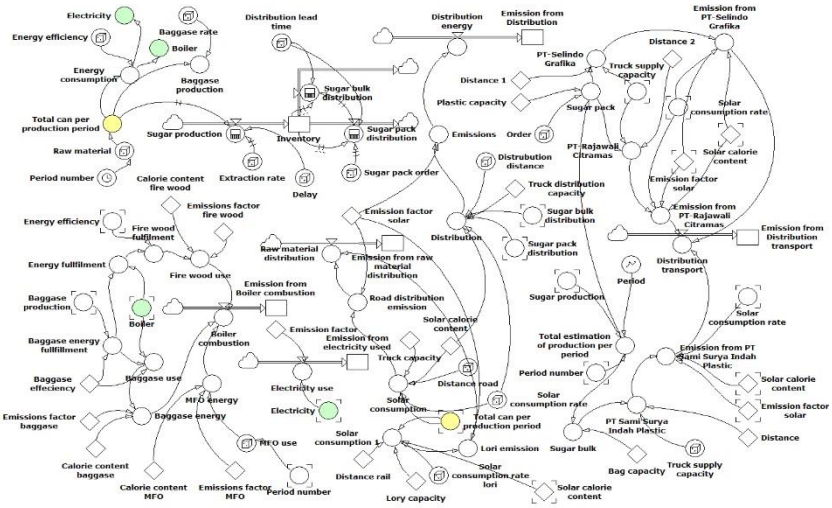

Fig. 3. Flow diagram of system dynamics model for sugar factory.

3.2.3. Validation

Validation is used to test the model building confidence. Where confidence in system dynamics model is accumulated gradually as the model that passes more tests and as new points of correspondence between the model and empirical realities that are identified. There are many methods to validate a model in system dynamic. In this research, structure method is employed as the selected method.

Verifying structure means directly comparing structure of a model with structure of the real system that has represented by the model. Structure verification may include review of model assumptions by highly knowledgeable person that well aware about corresponding parts of the real system.

3.2.4. Design improvement

The objective of improvement decision is to find alternative model for better condition which is the reduction of CO2 emission. There are two scenarios are taken as improvement decision. The first scenario is to replace the old type boiler machine with the new type. While the second is to eliminate the use of lorry (flatcar use to transport sugarcane).

The first scenario is by changing the old type boiler machine which have energy efficiency of 25.5 kg bagasse to generate 1 kilowatt per hour (kWh) with the new type boiler machine which have 10 kg bagasse to generate 1 kWh. With this condition, the reduction of CO2 was achieved. The old type boiler machine produced CO2 emissions around 178,058,688 kg. However, the use of new type boiler of machine produces CO2 emissions around 98,800,400 kg. This scenario is proved to reduce the CO2 emission up to 44% from the initial condition. The second scenario is to eliminate the use of Lorry. This

scenario is also proved to by reduce the CO2 emission for 387,600 kg. It has reduce around 0.2% of CO2 emission from the initial condition.

4. Result and Discussion

The development of system dynamic model to assess CO2 emission based on supply chain activity in sugar industry (PT. Madubaru) has resulted 174,246,500 kg in 171 days or during 2014 production period. It means that the amount of CO2 emission in a day is around 1,018,985 kg. The result of CO2 emissions is based on the energy consumption such as electricity, bagasse, firewood, MFO, and solar. The electricity is obtained from three generators powered by steam which generated from boiler. In order to power the boiler, it needs around 3,500,000 kg bagasse per day. Bagasse conversion shows that 25.5 kg bagasse resulting 1 kWh electricity. So, it takes 612 kg bagasse to generate 24 kWh electricity in a day. Based on standard conversion in normal condition, boiler needs 10 kg bagasse to generate 1 kWh. It means that boiler only need 240 kg bagasse to generate 24 kWh electricity in a day. This condition is raise a scenario to change the boiler machine since the boiler efficiency between normal boiler condition and installed boiler is 155%. However, to replace the boiler requires a huge investment, which the company cannot afford at this moment. Thus, the contribution of CO2 will increase the global warming and the environment would be unhealthy.

The use of Lorry for carrying sugarcane from warehouse to production point also contributed to CO2 emission. Besides, the use of Lorry often disrupts traffic and community activities around the industry. This condition emerges the idea on eliminating the use of Lorry which is issued to be the second scenario. In order to replace the function of Lorry, the truck lowered sugarcane is positioned in production point. However, using truck instead of Lorry gives significant result because there is no additional CO2 emission.

The result of CO2 assessment shows that there are 174,246,500 kg in one year of production period. If only Indonesian government could apply restriction on carbon emission policy, then the company has exceeded the limitation of 8,000 kg in a year should pay for compensation and social cost to the communities around $ 34,857 or Rp. 453,018,800.

5. Conclusion

Based on the results of the analysis in accordance with research's objectives, the conclusions from this research are explained as follows: System dynamic model is good to be used in assessment and provide significant result. Then, it proposes some scenarios that can be applied to reduce the CO2 emissions. The policies that should be taken is to replace the old type of boiler with the efficiency of 25.5 kg bagasse to generate 1 kWh electricity with the new type of boiler which has efficiency of 10 kg bagasse to generate 1 kWh electricity.

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