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Green Logistics Approach in Bioethanol Conversion from Potato Starch in Central Java

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Abstract. The demand for alternative sources of fossil fuel energy in Indonesia is increasing. One alternative to fossil fuels is bioethanol. Potato skin starch can be a raw material for making bioethanol. Potato skin contains starch, cellulose, hemicellulose, lignin and sugar. Bioethanol can be used must go through several stages, including the logistics system. Logistics activities require transportation, material handling equipment, and warehouses. In Indonesia, transportation sector which is the biggest user of fuel actually receives fuel subsidies. Bioethanol is the most appropriate alternative solution to replace gasoline. In processing, bioethanol through five stages, namely, potato skin starch, raw material logistics, processing bioethanol, delivery process and customer. This study presents green logistics model of potato transportation with a cost model and GWP. The results of the study show that the green logistics model by looking at the total costs and environmental impacts can be used as a reference in developing environmentally friendly bioethanol production in the future.

1. Introduction

The demand for alternative sources of fossil fuel energy in the world is increasing. In the past decade, fossil fuels including coal, natural gas and petroleum have become the main energy sources. However, based on research, about 40-50 years into the future this fuel source will run out. Environmental problems such as global warming cause adverse effects of 80% of carbon emissions [1]. Energy evolution occurs because of the limitations of fossil fuels. Some of the factors that affect the evolution of energy is a global focus to help reduce greenhouse gases (GHGs) emissions and control climate change; traditional fuel sources are becoming increasingly expensive to extract and purify; and instability in regions that currently supply world oil. An important part of a country's energy strategy that successfully incorporates biofuels is to reduce the risk of energy shortages and reduce environmental impacts [2]. Biofuel is an alternative fuel that is liquid or gas for transportation and other needs derived from biomass processing. In this case, biofuels can be produced directly by processing raw materials from plants or processing indirectly from industrial waste. As a result of this problem, the biofuel industry has made significant steps that have shown biofuels can be a viable alternative to fossil fuels as a way to reduce the environmental impact of CO₂ production and GHGs. In this era of low carbon emissions, biofuels are a renewable alternative energy which was discussed



predominantly in several previous studies. In the world of industry and transportation today, the most popular biofuels are bioethanol, biogas and biodiesel. Based on research, bioethanol in the world produced nearly 100 billion liters in the 2009-2010 periods. Where consumption needs for fuel (68%), industry and transportation (21%) and other needs (11%). Bioethanol is used as a substitute for gasoline and a mixture of E15 gasoline-bioethanol where bioethanol (15%) and gasoline (85%). The combustion process that occurs using bioethanol fuel is cleaner, because bioethanol contains oxygen. Therefore, bioethanol can be an alternative source of potential biofuel that is environmentally friendly as a substitute for fossil fuels [1]. Bioethanol is produced by fermentation or biosynthetic processes [3]. Ethanol is a transparent colorless liquid that has a specific taste, can be degraded naturally, harmless because it does not pollute the environment and has less toxicity. In the process, bioethanol burns so that it produces carbon dioxide elements and still contains elements of water. Bioethanol in this case has a high octane that can replace the function of lead (Pb). Mixing bioethanol with gasoline, oxidizes the fuel mixture so that it burns perfectly so as to reduce environmental pollution and emissions. The most common ethanol fuel mixtures are 10% ethanol and 90% gasoline (E10).

2. Bioethanol Production

In this study, the main focus is the use of bioethanol as an alternative fuel that is environmentally friendly. Bioethanol is ethyl alcohol (ethanol) which is produced from a biological activity process that is able to convert biomass into bioethanol. This process is carried out through biochemical reactions to microbiologists including hydrolysis and fermentation. Bioethanol is liquid so it can be used as a liquid biofuel that can be produced from several different biomass raw materials [1]. Bioethanol is a type of alcohol that can be produced from several agricultural biomass products, such as potatoes, sugar cane, corn, sorghum, and wheat. These agricultural products contain sugar, cellulose and starch. Bioethanol is able to capture the potential of GHGs and air pollution so it is very relevant to the current low carbon transition period [4]. Starch derived from potato skin can be used as raw material for making bioethanol. Besides the starch contains potato starch also contains lignin, cellulose, hemicellulose, sugar. The process of processing potato skin starch into industrial scale bioethanol in this study consisted of 3 stages, in Figure 1: (1) the process of starch melts using the enzyme endoamylase, in this case used α -amylase; (2) the next process, to produce sugar, the saccharification stage is carried out using enzymatic; and (3) the last process is fermentation which converts glucose into bioethanol.

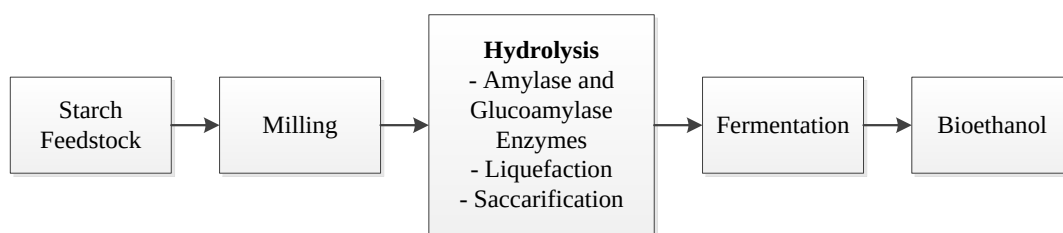


Figure 1. Bioethanol production [5]

Bioethanol is produced from the biomass of agricultural products through several stages, including the process of hydrolysis and sugar fermentation. In order not to have problems with increasing food needs, the use of raw materials derived from agricultural waste becomes more important, agricultural waste (biomass) generally contains relatively complex carbohydrate polymers. These polymers usually originate from cell walls, referred to as lignin, cellulose and hemicellulose. In order to produce sugar, the biomass is processed using acids or enzymes [3]. There are two alternatives for processing starch from potato skin into bioethanol, using a dry or wet grinding process. In Figure 2, it can be seen that production with a wet grinding process, the process starting from the kernel in potato skin flour is soaked in warm water; this is intended to release starch and break down existing proteins, in addition

to softening the kernel in the grinding process. In the dry process cleaning and splitting of the kernel into fine particles is carried out in the hammer mill process.

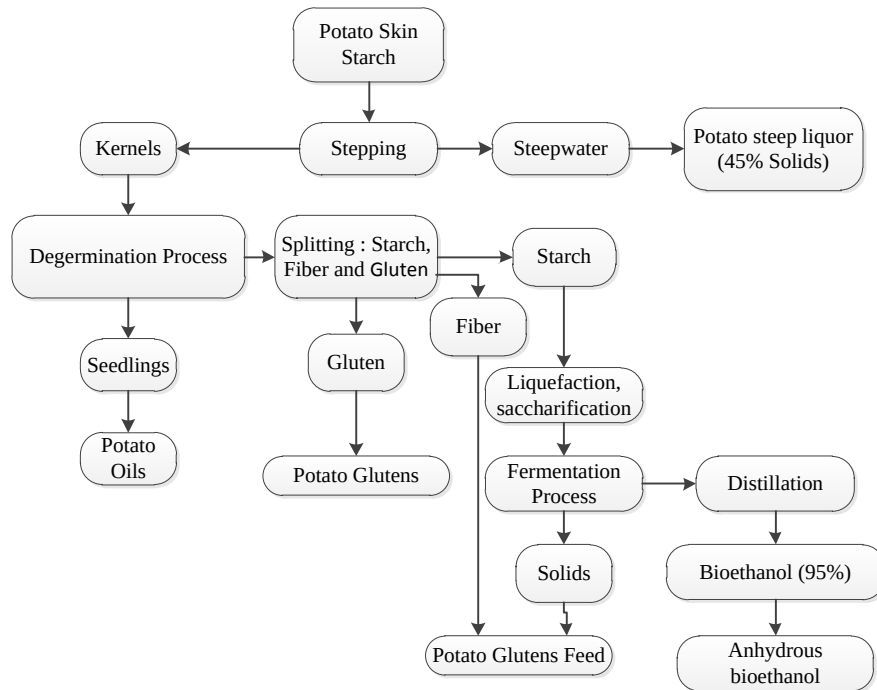


Figure 2. Potato skin starch wet milling process flow diagram [1]

3. Prospective for Bioethanol in Indonesia

Indonesia has a variety of potential energy resources, including the dominant use of fossil fuels including coal, natural gas and petroleum. In addition, Indonesia has also used renewable energy sources such as hydro, geothermal, solar, wind and biomass. Petroleum resources are now in desperate need of attention, because the oil reserves continue to decline, while consumption continues to increase imports of crude oil and fuel continues to rise. The transportation sector which is the biggest user of fuel oil actually receives fuel subsidies, while the industry and electricity generation do not receive subsidies. On the other hand increasing the flow of goods transportation, and people who are less supported by the availability of adequate mass transportation. Steps to reduce energy subsidies and dependence on fossil fuels, namely by reducing or revoking subsidies, utilizing alternative energy and technology more efficiently, and changing energy use habits. Ethanol needs in Indonesia are still very high at 3 million kilolitres per year. While Ethanol production in Indonesia is still as much as 535 thousand kilolitres per year. This means that at present, Indonesia still lacks an ethanol supply of 2.465 million kilolitres. Therefore, the more parties involved in ethanol production can have a very good impact on Indonesian growth itself. Another reason for the lack of ethanol supply in Indonesia is because of low prices for the local market. Increased growth in the transportation sector has led to increased gasoline consumption every year with growth reaching 9% per year. From the gasoline consumption during the period 2006-2012 around 96% - 97% is premium which has octane 88, around 3% - 4% pertamax and around 0.1% bio premium also bio pertamax [6].

Potatoes (*Solanum tuberosum L.*) are the fourth most popular horticulture in the world. Planted in almost 150 countries [7] from the Yunnan highlands of China and the subtropical lowlands of India to the equatorial plateau in Java Indonesia, potatoes are produced around 310 million tons in the world every year. More than one billion people consume it all over the world and become the consumption of half a billion people in developing countries. In Indonesia, potatoes are one commodity that is the focus of increasing national agroindustry. Technology bioethanol production process is very simple and has been controlled by the people since ancient times, among other things, the production of

alcohol made from juice and sugar. Considering that the need for fuel oil continues to increase every year due to the growth in the number and mileage of vehicles while oil reserves continue to decline, the import of fuel is carried out; the volume continues to increase as well.

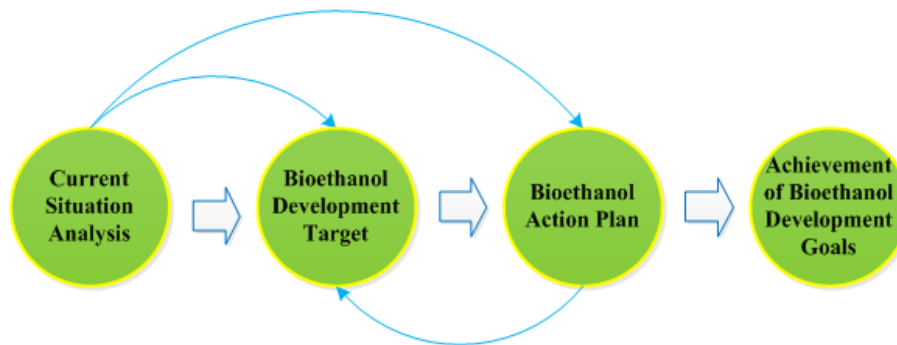


Figure 3. Study analysis the use of bioethanol in Indonesia [6]

The problem is that fuel oil receives subsidies which are increasingly burdening the state budget. To reduce this subsidy the Indonesian Government is trying to reduce fuel consumption by using biofuel. Where this policy is contained in the Presidential Instruction (Inpres) Number 1 of 2006 and is supported by ESDM Ministerial (Kementerian ESDM) Regulation Number 32 of 2008. For the reduction of gasoline (Premium and Pertamina) it is regulated by mandatory utilization of bioethanol for gasoline substitution in the industrial and transportation sectors both public and non-public transport, while the household and power generation sectors have not yet been determined. The mandatory target of bioethanol is quite large, but the implementation is still constrained, the target is lowered even though for 2025 the target is raised to 20% from 15%. An overview of the mandatory implementation of bioethanol can be seen in Table 1.

Table 1. Mandatory implementation of bioethanol and its realization in Indonesia [6]

Type	Year ^a			
	2011	2012	2013	2014
Subsidized gasoline	25,530	28,340	29,260	32,320
Bioethanol	694	968	1,167	1,334
Public transport	230	244	146	165

^athousand KL.

4. Logistic Structural Model of Bioethanol

Bioethanol cannot be used directly, but must go through several stages throughout the logistics system so that it can be used as fuel. The core of logistics activities is moving material from suppliers to producers for the production process, and moving goods from producers to consumers. Logistics activities require transportation, material handling equipment, and warehouses. In addition, to support transportation activities, fuel and infrastructure are needed in the form of highways, railroads, terminals, depots, stations, docks, ports, and airports. More than 70% of logistics activities come from transportation. The main processes are raw material production, raw material preparation, raw material logistics, bioethanol production and bioethanol distribution. The potential for renewable energy is in the current increase in energy demand and is accompanied by a decline in energy sources made from fossil fuels. A good combination of renewable energy production made from bioethanol with logistic systems is expected to provide good service to customers, so the end result is customer satisfaction. Good logistics in this study, must meet six criteria, namely: 1) certainty the type of goods needed is the right item; 2) the right amount of goods; 3) exact conditions needed; 4) the right place of delivery or distribution; 5) on time; and 6) the right shipping costs. In this study, bioethanol is the right

alternative solution by considering the availability of raw materials. Therefore, in this study we will present a green logistics model of potato transportation (postharvest activity), conversion from potato skins to bioethanol and its distribution process. The distribution and transportation process considers the distance of one point to another and the travel time of transportation. This model is also expected to contribute to research related to bioethanol production, distribution and logistics processes. In this study bioethanol processing involves five stages: 1) processing potato skin starch at both the distribution center and farmer level; 2) logistics activities and transportation of raw material logistics; 3) processing raw materials into bioethanol; 4) shipping bioethanol to the fuel distribution center; and 5) downstream activities at the customer level.

Potato producing areas in Central Java are Banjarnegara, Wonosobo, Batang, Tegal, Pekalongan, Purbalingga, Magelang, Temanggung, Semarang, Boyolali, and Karanganyar. Feedstock logistics is mainly related to the storage and transportation of feedstock. Bioethanol plants in Central Java located at Kebakkramat Karanganyar with capacity of 50 million litres and uses sugarcane and potatoes as feedstock. This is related to distribution mode, location, number and their capacity. Central Java potato distribution center in: Wonosobo and Boyolali. In this study, the customers who become bioethanol users at the final level of production are customers. In this case, they are users of transportation facilities such as motorbikes, cars, trucks and buses; and industry, especially food and beverage processing. The logistics potential associated with customers can be described in the quadrant. The use of exploratory logistics can help penetrate new markets or create new types of demand. Technology does not play the role of 'support', but is in the seat of a driving seat. In Figure 4, the bioethanol logistic model can be seen as follows:

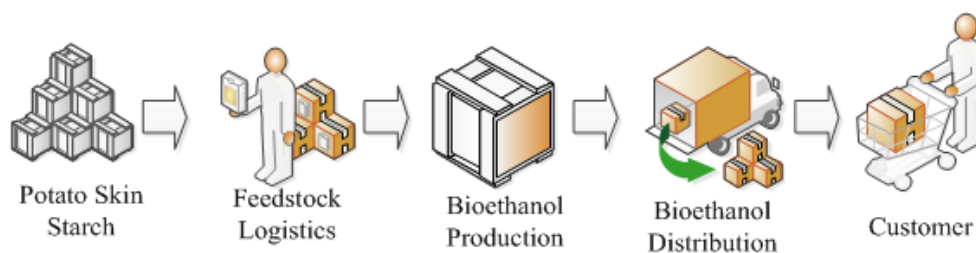


Figure 4. Logistic structural model of bioethanol

The increase in the price of the main raw material for bioethanol occurred in 2016. The impact of climate change resulted in an increase in the price of horticultural products, and this affected the increase in the price of bioethanol raw materials which directly affected the price of bioethanol. Following economic law, automatic price increases followed a decrease in demand for bioethanol, alternatives that can be done by conducting distribution arrangements, including management of raw material inventories. Projection of Kebakkramat Karanganyar Production Plants is shown in table 2.

Table 2. Projection of Kebakkramat Karanganyar Production Plants [8]

	2016		2017
	Projection ^a	Realization ^{a, b}	Projection ^a
Sales	510,975	500,540	583,994
Cost of goods sold ^a	416,484	410,836	477,464
Gross profit	94,491	89,704	106,529
Income before income tax	20,285	169	22,731

^ain billion rupiah.

^b Product wise sales contribution for 2016 was 80.98% from Ethanol, 8.54% from Acetic Acid and 3.97 % from Ethyl Acetate, and the balance from other products

5. Green Logistics Approach

Potato plantations in Central Java are Banjarnegara, Wonosobo, Batang, Tegal, Pekalongan, Purbalingga, Magelang, Temanggung, Semarang, Boyolali, and Karanganyar. Bioethanol plants in Central Java located at Kebakkramat Karanganyar. In this study, the distance and time variables are the focus of the discussion. So that logistics activities in transporting raw materials from agricultural land or distribution centers to bioethanol refineries at Kebakkramat, up to the distribution process to the final level are considered and become an important component of the cost of producing bioethanol. In terms of transportation, the potential of global warming and emissions pollution is also considered. The model developed has attempted to identify the total production costs (from raw materials to industrial-scale bioethanol), minimized distribution and transportation [9]. Development of this green logistics model by connecting the total costs of production, transportation and distribution; and the effect of greenhouse gas emissions based on consideration of shipping distance and travel time. The measurement parameters in this study show that the logistics cost function developed can be a more cost effective and environmentally friendly model.

The activities of shipment planning, routing and scheduling, and shipment execution allow us to choose the most optimal route at a low cost and a relatively short distance. We also add infrastructure variables, which can help speed up time and shorten distance. Logistics is very dependent on road infrastructure, the travel speed of trucks when transporting is also affected by this condition. Here software can also help, but often a router needs to find a solution without the help of management software, once the problem is identified. Bioethanol Distribution Centers mainly deals with the distribution, location, quantity and capacity. Central Java potato distribution center is located in Pasar Induk Wringinanom Wonosobo and Pasar Induk Cepogo Boyolali. The green logistic approach in this study uses traceability methods including tracking and tracing routes. Mileage, road density conditions, amount of fuel needed and total transportation costs can be easily planned. So that time and costs can be minimized while environmental factors can be improved. The traceability method that we developed makes tracking and tracing easier, and able to provide the most optimal route alternative. To support visualization, this model is combined with GIS-based spatial data. Model testing in all production areas in 11 potato plantations, distribution centers (DC) and bioethanol plants at Kebakkramat Karanganyar.

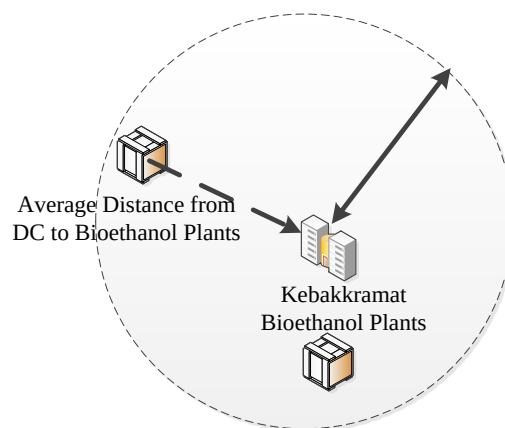


Figure 5. Average distance from DC to Bioethanol Plants

Logistics costs of potato skin starch are the amount of raw potato transportation costs, production costs and operating the plant [10]. After going through the processing process, from the Kebakkramat factory, pure bioethanol is then put into a tanker truck. The process of transporting from the factory to the distributor (fuel base) is done by considering traceability so that the environmental impact can be minimized. After arriving at the distributor, according to E15 policy, pure bioethanol (15%) is mixed with gasoline (85%). Then from this fuel base the fuel is sent to the consumer/retail service station. The mode of transportation used in Central Java is a tank truck. The type of mode is not included in

the variables in this study. However, this model was developed in general, allowing the use of other modes of transportation in accordance with the characteristics of different road infrastructure. In this study, the green logistics model included the amount of raw materials, production costs, transportation of raw materials from DC to the Kebakkramat plant, the capacity of bioethanol produced and the distance from the plant to the fuel base and from the fuel base to the end consumer/retail station. In general, the green transportation and logistics distribution system approach is illustrated in Figure 6. From Figure 6 it can be seen that the selected DC namely DC Wonosobo and DC Boyolali will send bioethanol raw materials continuously. In the Kebakkramat factory the raw materials are processed into pure bioethanol. After that, pure bioethanol will be put into a tank truck to be sent to the fuel base. Logistics and distribution from DC to fuel base based on traceability methods that are environmentally friendly.

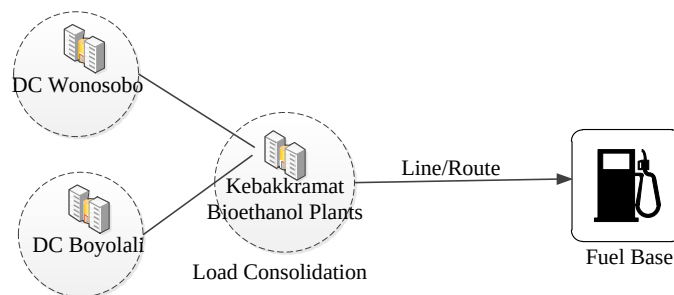


Figure 6. The general structure of the system to transport bioethanol.

Of the 11 plantations in Central Java there is no need to process potato skin into potato skin starch, but send it to DC in Boyolali or Wonosobo. DC Boyolali and Wonosobo, potato skin is processed into potato skin starch as a bioethanol feedstock to be sent to the factory at Kebakkramat Karanganyar. Potato skin is processed into potato skin starch as a bioethanol feedstock. Feedstock is sent to the Kebakkramat factory to be converted into bioethanol. After the process is complete, the Kebakkramat Factory distributes bioethanol to the fuel base. Fuel bases can redistribute bioethanol to consumers by truck. This is expected to reduce GWP emissions. The green logistics approach in Central Java can be seen in Table 3.

Table 3. Cost and Global Warming Potential Model for Production in Central Java

Parameter	Unit	Value
Potato Feedstock field coverage	%	0.25
Cane Truck Capacity	Ton cane/truck	38
Potato yield per area	ton cane/km ²	8200 ^a
Ethanol yield of Potato Starch	L ethanol/ton cane	86
Cost of goods sold	IDR/yr	410,836
Gross profit of plants	IDR/yr	89,704
Cane truck operating cost	IDR/truck-km	1.40
Radius of production region to minimize cost	km	64.4
Cost of cost-minimizing radius	IDR/L	49.920
GWP of cost-minimizing radius	g CO ₂ eq/L	36.5
Fixed GWP per vehicle distance	g CO ₂ eq/truck-km	780
Marginal GWP per unit ethanol	g CO ₂ eq/L-km	0.42
Marginal GWP per unit ethanol	g CO ₂ eq/L	21
Radius of production region to minimize GWP	km	16
Cost of GWP-minimizing radius,	IDR/L	0.041
GWP of GWP-minimizing radius,	g CO ₂ eq/L	35.4

^a[8]

The green logistics approach for the conversion of bioethanol from potato skin starch is expected to have broad implications, allowing for the replacement of alternative raw materials, especially for abundant horticultural commodities that have enough lignin, cellulose and hemicellulose. So problems like raw materials are rare, high raw material prices, environmentally unfriendly distribution processes and GWP effects can be minimized.

6. Conclusions

Potato skin starch can be used as a source of the main raw material in the process of making bioethanol. This potato skin contains starch, cellulose, hemicellulose, lignin and sugar. To use bioethanol as a final product there are stages along the logistics system. The main subject of logistics activities is moving material from suppliers to producers for the production process, and moving goods from producers to consumers. Logistics activities require transportation, material handling equipment, and warehouses. More than 70% of logistics activities come from transportation. In Indonesia, transportation sector which is the biggest user of fuel actually receives fuel subsidies. The use of biodiesel to replace some of its use of diesel as mandated in the Minister of ESDM (Kementerian ESDM) No. 25 year 2013 has already been implemented, but the use of bioethanol has not been as expected. Bioethanol is the most appropriate alternative solution to replace gasoline. In processing, bioethanol through five stages, namely, potato skin starch, raw material logistics, processing bioethanol, delivery process and customer. Potato producing areas in Central Java are Banjarnegara, Wonosobo, Batang, Tegal, Pekalongan, Purbalingga, Magelang, Temanggung, Semarang, Boyolali, and Karanganyar. Bioethanol plants in Central Java located at Kebakkramat Karanganyar with installed production capacity of 50 million litres. The results of the study show that the green logistics model by looking at the total costs and environmental impacts can be used as a reference in developing environmentally friendly bioethanol production in the future.

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