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Regional Case Study

Assessment of the Environmental Impact of Drug Products Using Life Cycle Assessment: A Case Study in a Pharmaceutical Company, Semarang

Sri Hartini[1], Diana Puspita Sari[1]*, Dian Tri Kusuma Ningrum[1]
[1] Department of Industrial Engineering, Faculty of Engineering, Universitas Diponegoro, Jalan Prof. Soedarto, SH, Kampus Undip Tembalang, Semarang, Indonesia 50275
*Corresponding Author, email: dianapuspitasari@lecturer.undip.ac.id

Abstract

The pharmaceutical production process produces 55% greater emission intensity than the automotive industry. Along with increasing attention to the environmental impact of pharmaceutical drugs, pharmaceutical companies need to know the impact resulting from their production processes. This study analyzes the environmental impact of the anti-hangover drug production process using a Life Cycle Assessment. The analysis was carried out on 1 batch which produced 1,000,000 drugs. The scope of the gate to gate study from the initial process to the end of production. The research objective was to determine the potential impact resulting from the drug production process on the environment. The indicator measured is eco-cost, which is the cost of environmental impact calculated using the SimaPro software. This study found that the eco cost was IDR 3,931,237.65 with the largest environmental costs in the packaging process and the largest impact indicator on climate change. The biggest source of impact comes from the consumption of electrical energy. This study recommends the use of solar panels. For the energy conversion process, 80 KWp is needed with 288 solar panels and a land requirement of 0.564 Ha. This recommendation is estimated to reduce 22% percent of environmental costs.

Keywords: Pharmaceutical industry; life cycle assessment; eco-cost; energy convention

1. Introduction

Climate change and the threat of environmental damage have become a significant focus in recent years. Environmental considerations must be integrated into business decision-making, individuals, public administration, and policymakers. Sustainability is what can be maintained for a long time. Sustainability is a sustainable property such as regulation, situation, product, process, and technology (Heijungs et al., 2010). Sustainability research can be classified into environmental sustainability, social sustainability, ecological sustainability, corporate sustainability, human sustainability, triple bottom line, and some sustainability combinations (Shankar et al., 2017).

Many environmental problems began emerging from various reports and conferences on the development of sustainability; many environmental problems began to emerge. Sustainable development requires a balance in implementing policies, strategies, and projects that treat the environment and development as one issue; in other words, environmental issues are essential in sustainable development (ADP, 2012). One of the reports developed by the Brundtland commission entitled "Our Common Future" describes resource scarcity, increasing population, environmental impacts, and unequal economic well-being and development are driving future imbalances on earth (Wenzel et al., 1997).

The aspects that have the most potential to impact the environment are resources and population. The environment is crucial, and climate change will cause an imbalance in the world. ISO has developed a quality management system for both products and the environment. Currently, the company focuses on reducing the environmental impact that occurs (Paul et al., 2014). Tools and indicators to assess the environmental impact of various systems have been developed, such as life cycle assessment, environmental risk assessment, ecological footprint, strategic environmental assessment, environmental impact assessment, material flow analysis, and cost benefit analysis.

Life cycle assessment (LCA) as a tool for measuring environmental impact has been carried out by many previous researchers. Hellweg and Milà i Canals (2014) reviews recent developments in LCA, including existing and developing applications aimed at supporting environmentally sound decisions, and Guinee et al. (2011) examines the development of LCA over time. The use of LCA to measure the environmental impact of construction has been widely carried out, such as Chau et al. (2015) evaluating the environmental impact of building construction using three methods, one of which is LCA; Sharma et al. (2011) reviewed various buildings in different places using LCA, then looked at which building life cycle phase and type of building consumes more energy and has more greenhouse gas emissions. Abd Rashid and Yusoff (2015) reviews the LCA method to distinguish phases and materials that significantly impact the environment in the construction process to manufacture building materials. Buyle at al. (2013) provides an overview of the current LCA situation in the construction industry from regulatory developments and academic case studies. Bahramian and Yetilmezsoy (2020) conducted a narrative literature review to provide an overview of the environmental evaluation of high-rise and low-rise buildings. Islam et al (2015) also reports a comprehensive review of life LCA and life cycle cost (LCC) implications on residential buildings.

In other research objects, studies on the ongoing evolution of LCA and its use in bioenergy applications have been carried out by Mattila et al. (2012) and McManus and Taylor (2015). Corominas et al. (2013) carried out a comprehensive review of wastewater treatment and LCA. Kirchain Jr et al. (2017) uses LCA to sustainably identify material pathways, considering material costs both during production and as a product. LCA has also been used to compare the environmental impact of conventional vehicles with electric vehicles (Hawkins et al., 2013) and the environmental effects of conventional and organic agricultural products (Van der Werf at al., 2020). Several studies have found that environmental impact measurement in pharmaceutical industry has yet to be carried out much. So this research tries to measure the environmental impact of pharmaceutical industry.

The life cycle of the pharmaceutical industry has been a concern for many environmental scientists (Wernet et al., 2010), the sustainability of the pharmaceutical industry has also stimulated the interest of chemical, engineering, and environmental scientists (Milanesi et al. 2020). The carbon footprint of the pharmaceutical industry, in terms of emission intensity, is 55% larger than that of the automotive industry (Bartolo et al., 2021). The pharmaceutical industry influences people's health and quality of life (EFPIA, 2019).

The pharmaceutical industry has become a topic of various literature related to its impact on rivers and lakes, mainly due to product emissions after use. There needs to be more analysis regarding the production of active pharmaceutical ingredients (API) on environmental impacts (Wernet et al., 2010). Components of pharmaceutical products pass through humans and animals to a large extent, and substances in products are often encountered in the environment where they may have harmful effects. Consumption of components of pharmaceutical products that are known to help determine the effects of use and their final disposal can be carried out through an environmental impact assessment of the production process (Wernet et al., 2010). The application of green engineering in the perspective of the pharmaceutical and chemical industries can be carried out by reducing inventory, reducing carbon footprint, reducing waste and emissions, reducing energy consumption, reducing rework products, reducing resource use, reducing potential exposure to chemical hazard risks (Jiménez-González et al., 2011).

LCA method can measure the environmental impact of pharmaceutical products. Life Cycle Assessment is a tool for assessing potential environmental impacts and resources used throughout the product life cycle, from acquiring raw materials, the production process, and the use of finished products to waste treatment (ISO 14044, 2006). The advantage of the LCA method is its focus on products from a life cycle perspective. The comprehensive coverage of LCA methods helps avoid transferring one problem to another, for example, from one life cycle phase to another, from one region to another, or from one environmental problem to another (Finnveden et al., 2009). LCA is a technique that has been standardized by ISO 14040-44. Life Cycle Assessment is defined as a procedure for addressing environmental aspects and potential environmental impacts throughout the product life cycle from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal (ISO 14044, 2006). There are five main stages in the product or service life cycle: finding the raw materials needed for products or services, processing raw materials and assembling products, and sending products to consumers. And then usage by consumers in the final stage of the product or service life cycle when consumers have stopped using a product or service (Lehtinen et al., 2011). There are several system boundaries for LCA, namely from raw material processing to manufacturing production (cradle-to-gate), from raw material processing, product use to disposal (cradle-to-grave), and from a defined point in the entire life cycle gate-to-gate) (Guinée et al., 2002). There is another limitation of the cradle-to-cradle system developed by McDonough & Braungart. Cradle-to-cradle is a more specific type of cradle-to-grave where the product's final disposal is recycling. In the recycling process, new identical or different products will be born.

PT. X is a state-owned pharmaceutical holding company that contributes to the supply of essential medicines for the people of Indonesia. This company has produced more than 284 drugs which can be grouped into ethical, generic, Over-the-Counter, and Agromed products. This company has submitted sustainability in the form of reports since 2016 with the GRI Core option standard. Currently, the company assesses limited sustainability with various indicator criteria based on GRI standards in general and selected through group discussion (FGD) forums. In support of the Regulation of the Minister of Environment and Forestry No. 1 of 2021 concerning the Company Performance Rating Rating Program in Environmental Management (PROPER) developed one assessment criterion, namely the application of LCA with a minimum rating of 10% of the company's total product. PROPER assesses companies using color values from the highest to the lowest, namely gold, green, blue, red, and black. A company is said to be "compliant" with regulations if it gets a blue rating; if the company wants to increase its rating to "beyond compliance," it must get a minimum of green or gold. A company that succeeds in getting a gold rating means that the company has implemented comprehensive environmental management has exceeded what is required by the relevant laws and regulations, and is carrying out continuous management.

If the company achieves a gold, green, or blue PROPER score, it can increase the company's prestige in the eyes of the public and increase the company's sales value. However, if a company gets black color twice in a row, the company will be prosecuted, or worse, the company's business license will be revoked until 2020 PT. X has received green PROPER 8 times successively. PROPER in 2021 needs additional parameters are needed, namely, LCA calculations. Thus, this becomes the basis that companies need sustainability assessments, especially on environmental aspects, using the LCA method. The application of LCA aims to identify the sustainable use of natural resources and evaluate and implement possible environmental improvements.

This study aims to measure the environmental impact of the pharmaceutical product production process using the Life Cycle Assessment method assisted by SimaPro software on drug X tablet preparations which are pareto products from this company and provide suggestions for improvement.

2. Materials and Methods

2.1. Location and Time of Research

Research conducted at PT. X, which is located in the city of Semarang. This company is a pharmaceutical company that produces drugs with active pharmaceutical ingredients. Since 2021 the company has been interested in fulfilling PROPER with additional parameters, namely the calculation of the life cycle assessment. This research focuses on the production waste generated by one of the drugs in the form of tablet preparations. The research was conducted from September 2021 to December 2021.

2.2. Research Variables

This study used variables obtained from direct and secondary observations from the company. The research variable of this study is material data. Table 1 presents the research variables used.

Table 1. The research variables

Data input	Data Collection Technique	Output
Type and quantity of medicinal raw materials (kg), water (liters) Type and amount of electrical energy (kWh) Type and amount of material waste (kg)	Secondary data collection, interviews, and observations	The magnitude of the impact generated by the production process using the LCA method

2.3. Data Processing and Analysis

The data collected before is then processed in the following steps. The first is the determination of goals and scope. Goals and scope are subjective stages that are tailored to decision-makers (Miettinen and Hämäläinen, 1997). Goal and scope LCA describes the product system within system boundaries and functional units. At this stage, determine and describe the objectives, the scope to be studied. The LCA method's purpose in this study was to identify and measure the environmental impact caused by the production of drug X in tablet preparations. The scope of this study is gate-to-gate, namely production process. The research scope is described in Figure 1.

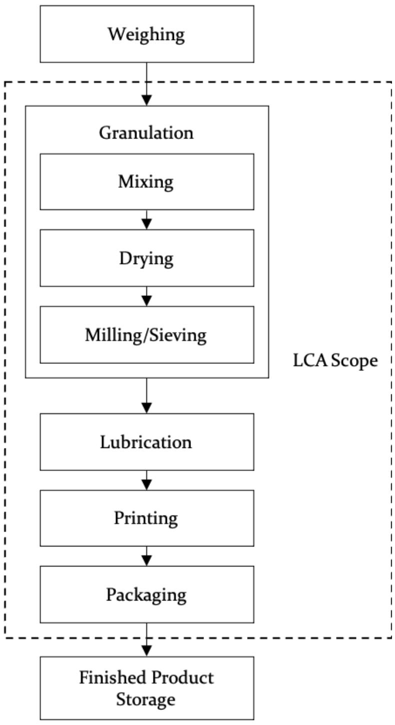

Figure 1. Research scope

The second stage is the Life Cycle Inventory (LCI) which identifies the input and output requirements of each product production process within the scope of LCA. LCI is a methodology for estimating resource consumption and the number of waste streams and emissions generated by the product life cycle (Rebitzer et al., 2004). The purpose of LCI is to measure the number of resources needed and emotions and waste per unit of functional unit (Rebitzer et al., 2004). The inputs from the research are various types of chemicals and water, as well as the energy used during the production process. At the same time, the output of this research is the emission that comes from the production process. Input and output obtained from company observation data. The data inventory process is carried out for 1 batch or 1,000,000 items of drug product X in tablet preparations.

The third stage is the Life Cycle Impact Assessment, which is the stage to analyze the type and amount of value generated by each category. LCIA is changing emissions generated by production processes or products into impacts on humans and the environment (AIA Guide to Building LCA in Practice, 2010). LCIA aims to significantly evaluate potential environmental impacts based on LCI (Vinodh et al., 2016). According to ISO 14044 (2006), essential components in LCIA include the selection of impact categories, category indicators, and characterization models; assignment of LCI results to selected impact categories (classification); and the results of the calculation of category indicators (characterization). In addition to these three elements, optional elements can be used depending on the LCA goals and scope, namely calculating the size of the category indicator results relative to reference information (normalization), grouping, and ranking of impact categories (grouping), converting and aggregating the results of indicators across impact categories using numerical factors based on the choice of values (weighting) and a better understanding of the reliability of the collection of indicator results (data quality analysis). At this stage, it produces data from processing the output of the production process in the form of the magnitude of the potential impact on environmental aspects. Data processing was carried out with the help of SimaPro software and impact measurement using the eco-cost method through several phases, namely characterization, normalization, weighting, and a single score. Eco-cost is a measure that states the total environmental burden of a product based on preventing that burden. Eco-cost is also the cost that must be incurred to reduce environmental pollution and depletion of natural resources on earth. Eco-cost is a virtual cost because it has not been integrated into the real-life costs of the current production chain (life cycle cost). Environmental costs should be considered as hidden obligations or can be called external costs. These prevention costs still need to be integrated into fixed costs in the production chain or life cycle costs, such as negligible green costs. The calculation model for this eco-cost includes direct and indirect environmental impacts (Vogtländer et al., 2010).

SimaPro are that it can implement various LCA applications, such as reporting sustainability, carbon and water footprint analysis, designing process products, manufacturing environmentally friendly products, and determining key performance indicators (Goedkoop et al., 2016). SimaPro able to systematically and transparently model and analyze the life cycle of complex products; measure the environmental impact of products and services at all product life cycle stages; and identify important information linked in the supply chain, starting from extraction of raw materials to the end of product life. SimaPro has various supporting LCA analysis methods, including Impact 2002+, Eco-cost, TRACI 2.1, ReCiPe 2016, Ecosystem Damage Potential, Greenhouse Gas Protocol, and Cumulative Energy Demand (Goedkoop et al., 2016b).

The fourth or final stage of the LCA is the interpretation stage, where we identify, measure, and evaluate the results of the LCIA (Vinodh et al., 2016). At the interpretation stage, the data that has been collected and calculated will be interpreted to become the required information; then, we can conclude further development and provide recommendations for improvements to the company.

3. Result and Discussion

3.1 Data Collection

Raw material consumption data for environmental impact measurement in this study was obtained from the company's historical data for September 2021. The functional unit used in the study was 240 kg of drug or 1,000,000 drugs. Consumption data is shown in Table 2. Electrical energy consumption is calculated using equation 1 for 3 phases, while for 1 phase using equation 2, where V is voltage and I is current. Electrical energy consumption (W) at PT.X is measured by multiplying the machine usage time (t) for 1 batch of drug X tablets with the machine power used (P), as shown in equation 3. The company has determined the time to use the production machine. Moreover, Cos phi was measured from PT. X is known to be 0.99.

$$P = V \times I \times Cos\ \varphi \times \sqrt{3} \quad (1)$$

$$P = V \times I \quad (2)$$

$$W = P \times t \quad (3)$$

Table 2. Raw material consumption

Process	Material	Mass
Granulation	A	52.5 kg
	B	94.08 kg
	C	2.4 kg
	D	0.303 kg
	E	0.307 kg
	F	4.8 kg
	G	77.502 kg
	H	3 kg
	I	60 lt
Lubrication	Granule ex sieved dry	230 kg
	J	5 kg
	K	1 kg
Printing	Granule ex lubrication	234.3 kg
Packaging	The bulk tablet product	232.686 kg
	Big box	33.529 kg
	CC. Product	240 kg
	Ds. Product	53.2 kg
	Adhesive seal	0.069 kg
	Pack tapes	0.439 kg
	Product plo	0.051 kg
	Transparent plo	0.05 kg

3.2. Goals and Scopes

At this stage, the goals and limitations of the research will be determined so that it is more directed. The LCA goal is to identify the environmental impacts arising from the production of X-tablet drugs. Furthermore, the scope includes: The X tablet drug production system evaluated in the Life Cycle Assessment; Inputs to the Life Cycle Assessment analysis are Active Pharmaceutical Ingredient (API) raw materials in units of mass (kg), water in liters (lt), and electrical energy used to operate the machine in power units (kWh), and Calculations were performed using SimaPro V 9.1.1.7 software and the eco-cost 2017 version 1.5 method. The output of the SimaPro software is the impact resulting from the X tablet drug production system.

3.3. Life Cycle Inventory

LCI shows the inputs and outputs associated with a product throughout a defined production cycle. Various API products and other supporting components are needed in the production process. At the same time, the output in the production process is the product, and the resulting emissions are shown in Table 3.

3.4. Life Cycle Impact Assessment

The Life Cycle Impact Assessment stage has several stages: characterization, normalization, weighting, and a single score. Table 4 shows the use of machine power to produce drug X. The characterization stage is the stage for identifying and classifying factors that have the potential to cause environmental impacts into several categories based on the method used. This impact category was calculated using the SimaPro software. There are 12 impact categories in the eco-cost method. The twelve impact categories include climate change (CC), acidification (AC), eutrophication (EU), photochemical oxidant formation (PO), fine dust (FD), human toxicity (HT), ecotoxicity (freshwater) (EC), metals depletion (MD), oil & gas depletion exd energy (OG), waste (WA), land-use (LU), and water stress indicators (WS). The results of the characterization are shown in Table 5.

Table 3. Input output production process

Process	Input	Quantity	Output	Quantity
Granulation	A	52.5 kg	Granule ex sieved dry	230 kg
	B	94.08 kg	NPO	4.602 kg
	C	2.4 kg		
	D	0.303 kg		
	E	0.307 kg		
	F	4.8 kg		
	G	77.502 kg		
	H	3 kg		
	I	60 lt		
	Granulation	25.030 kWh		
	Granulation	88.104 kWh		
	Granulation	3.304 kWh		
Lubrication	J	4.8 kg	Granule ex lubrication	234.300 kg
	K	0.6 kg	NPO*	1.100 kg
	Lubrication	1.214 kWh		
Printing	Printing	68.831 kWh	The bulk tablet product	232.300 kg
			NPO	1.614 kg
Packaging	Big box	33.529 kg	Packaged finished	559.408 kg
	CC. Product	240 kg	NPO	0.616 kg
	Ds. Product	53.2 kg		
	Adhesive	0.069 kg		
	Pack tapes	0.439 kg		
	Product plo	0.051 kg		
	Transparent	0.05 kg		
	Stripping	189.975 kg		
	Coding	1.176 kg		
	Conveyors	58.048 kg		

*NPO=Non product output

Table 4. Engine power usage

No	Engine	Watt	Run Time (H)	Engine Power
1	Granulation machine 1	50,000	0.5	25.030
2	Granulation machine 2	40,000	2.2	88.104
3	Granulation machine 3	6,600	0.5	3.304
4	Lubrication machines	4,850	0.25	1.214
5	Printing machines	5,500	12.5	68.831
6	Stripping machines	11,500	16.5	189.975
7	Coding machines	150	13.423	1.176
8	Conveyors	400	145.12	58.048

The normalization value results from multiplying the characterization value by the normalization factor so that all impact categories can be compared with the same unit. Weighting is the stage of giving weight to each category of environmental impact. The weighting factors have various values depending on the method used and the level of importance of an impact category. The weighting factor used in this study is 1. The results of the weighting are shown in Table 6.

From the value of the single score, it can be seen that activities contribute to environmental impacts and the impact of the damage. The single score calculation value is obtained from the weighting of each process. The results of a single score in IDR based on the Euro – IDR exchange rate on March 16, 2022, amounting to IDR 15,694.19, are shown in Table 7.

Table 5. Characterization of impact categories

Category Impact	Unit	Total	Granulation	Lubrication	Printing	Packaging
CC	kg CO2 eq	1080	409	3.062	49.2	618.738
AC	kg SO2 eq	5.28	2.39	0.022	0.191	2.677
UE	kg PO4-- eq	1.99	1.68	0.003	0.01	0.298
PO	kg C2H4 eq	0.124	0.054	0	0.001	0.068
FD	kg PM2,5 eq	0.456	0.11	0.001	0.015	0.33
HT	cases	0	0	0	0	0
EC	PAF.M_3.day	355,000	92,800	1.024	12,200	248,976
MD	Euro	16.8	9.29	0.115	0.115	7.28
OG	kg Oil equ	12.5	4.22	0.032	0.769	7.479
WA	MJ	-	-	-	-	-
LU	Euro	-	-	-	-	-
WS	WSI Factor	15.5	1.31	0.032	0.085	14.073

Table 6. Production process weighting results (euro)

Category Impact	Granulation	Lubrication	Printing	Packaging
Total	99.287	0.811	9.099	143.043
CC	47.5	0.355	5.71	71.435
AC	20.9	0.189	1.67	23.441
UE	7	0.011	0.041	1.228
PO	0.563	0.003	0.016	0.708
FD	3.74	0.032	0.5	11.228
HT	5.09	0.042	0.28	6.288
EC	0.514	0.006	0.068	1.383
MD	9.29	0.115	0.115	7.28
OG	3.38	0.025	0.615	5.98
WA	-	-	-	-
LU	-	-	-	-
WS	1.31	0.032	0.085	14.073

Table 7. Single score results (in IDR)

Category Impact	Granulation	Lubrication	Printing	Packaging
CC	745,474.03	5,571.44	89,613.82	1,121,114.46
AC	328,008.57	2,964.63	26,209.30	367,889.08
UE	109,859.33	176.10	641.89	19,270.57
PO	8,835.83	47.13	243.26	11,119.29
FD	58,696.27	509.75	7,847.10	176,206.83
HT	79,883.43	664.49	4,394.37	98,679.73

Category Impact	Granulation	Lubrication	Printing	Packaging
EC	8,066.81	89.02	1,060.93	21,700.80
MD	145,799.03	1,805.15	1,804.83	114,253.39
OG	53,046.36	399.26	9,651.93	93,844.35
WA	-	-	-	-
LU	-	-	-	-
WS	20,559.39	500.64	1,337.14	220,862.77

The single score stage is the final stage in a series of LCA calculations using the 2017 eco-cost method. The single score represents the value of all impact categories in each production process. This stage is used to classify the value of the impact category based on the process. At this stage, all impacts are calculated in the same unit so that a comparison of the magnitude of the impact generated for each process can be carried out. The unit used for this research is Euro.

The total value of the single score from the entire production process is 252.24 Euros or IDR 3,958,702.49 for one production. With one production of 1,000,000 eggs or 100,000 strips, each item has an eco-cost value of IDR 3,958. The process with the most significant value is packaging, with a total of 143,043 Euros or IDR 2,244,941.26 for each batch. The packaging process has the most outstanding value, especially in the climate change category, because this process requires a large amount of electrical energy and takes a long time to use are shown in Figure 2 and 3.

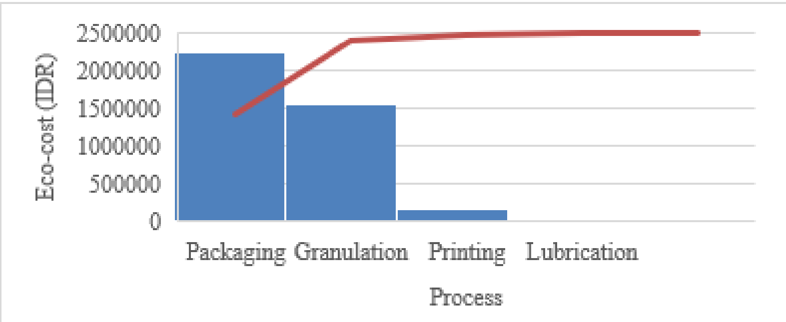

Figure 2. Eco-cost value of each process

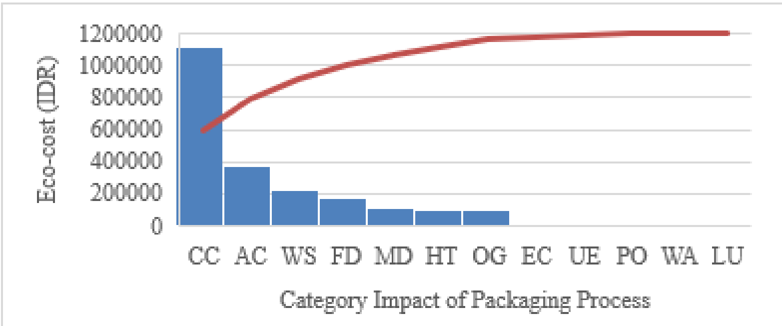

Figure 3. Eco-cost value of category impact in packaging process

Based on the annual report data, the company's selling price is IDR 3,168, while the production cost is IDR 1,017. The difference between production costs and the company's selling price generates a net value of IDR 2,151. The value of environmental indicators can be seen from the eco-efficiency index of a product. The eco-efficiency index shows whether the product is affordable and sustainable. The EEI value is 54.34. The EEI value is above 1, which means the product is included in the affordable and sustainable category. Affordable means that the product is economically efficient and able to provide benefits for the company, as seen from the value of the eco-cost or the cost of dealing with waste which is smaller than the net value. Meanwhile, sustainability means that the production process of anti-motion sickness drugs does not harm the environment.

Eco-cost value ratio (EVR) is an indicator that compares the ecological aspects with the economic aspects of the product. The economic aspect is seen from the net value, and the ecological aspect is seen from the eco-cost value. The resulting EVR is 0.018. The smaller the EVR, the better the anti-motion sickness drugs will be produced. The eco-efficiency ratio rate (EER) determines the efficiency of hanger products in terms of ecology and economy. The ERR Rate for anti-motion sickness drugs is 98.15%.

3.5. Recommendations for Improvement

Based on the results of the single score, the results obtained a significant impact on the packaging process. Improvement recommendations are used to determine the correct production process improvements. The packaging process has a high impact due to the effective use of electrical energy from burning fossils. Therefore, recommendations for improvement are focused on reducing electrical energy. Due to the higher energy consumption due to population growth, more and more fossil fuels are being burned to produce electricity. The results of this calculation encourage research from (Wernet et al., 2010) on the impact produced by APIs related to energy. The impact this energy has a significant role in the impact on human health due to greenhouse gas emissions and respiratory problems.

This condition encourages the substitution of conventional for renewable electrical energy. Solar panels are a way to reduce our dependence on fossil fuels, and is a good way to reduce global warming by reducing greenhouse gas emissions (Masson et al., 2014). The advantages of selecting solar panels are the significant potential, affordable, and environmentally friendly (*BP Statistical Review of World Energy*, 2019); the potential of solar panels is more than 13,368 exaJoules per hour (Smill, 2006). Solar panels are an efficient, endless, and clean technology development for using solar energy that will have long-term benefits (Gulaliyev et al,, 2020). Some researchers say that the environmental impact of using solar panels on biodiversity and the direct impact is so weak that it can be ignored (Dale et al., 2011; McCrary et al., 1986). Solar energy could become the main source of energy in the future. Table 8. shows the potential environmental impacts of using conventional electricity and solar panels. The results show that solar panels are more environmentally friendly than conventional electricity. A comparison of the potential environmental impacts between conventional electricity and solar panels in IDR is shown in Table 8. Based on Table 8, conventional electricity has an eco-cost value of IDR 3,958,702.49, while solar panels have an eco-cost value of IDR 3,079,043.14.

Table 8. Comparison of potential impacts (in IDR)

Impact Category	Conventional Electricity	Solar Panels
Climate Change	1,961,773.75	1,403,060.59
Acidification	725,071.58	564,990.84
Eutrophication	129,947.89	126,024.35
Photochemical Oxidant Formation	20,245.51	18,833.03
Fine Dust	243,259.95	194,607.96
Human Toxicity	183,622.02	156,941.90
Ecotoxicity (Freshwater)	30,917.55	24,482.94
Metals Depletion	263,662.39	257,384.72
Oil & Gas Depletion exd Energy	156,941.90	97,303.98
Waste	-	-
Land-Use	-	-
Water Stress Indicator	243,259.95	235,412.85
Total	**3,958,702.49**	**3,079,043.14**

The capacity required to produce 1 batch of drug X is 412,462 KWh. The average production of drug X per month is 36.5 batches. The solar panel product has specifications of 288 solar panels with a capacity of 80 kWp, with an inverter, and including On-Grid, the required investment cost is IDR 989,100,000. Table 9 shows the power required for production.

Table 9. Required power

Period	Required Power (kWh)
1 batch	435.682
Production 1 month = 36.5 batches	16,120.2
Production 1 year	193,443

The intensity of sunlight received by Indonesia's earth's surface averages 5.1 kWh/m²/day, so the power generated by solar panels is 408 kWh/day or 12,240 kWh/month or 146,880/year. With the total area required for a solar panel size of approximately 0.0564 Ha, the savings that the company can make are shown in Table 10.

Table 10. Saving

Period	Electric Power (kWh)	Panel Power (kWh)	Saving (IDR)
1 month	3,880.226	12,240	13,644,417.60
1 year	46,562.717	146,880	163,733,011.20

The payback period (PP) is one indicator to assess economic feasibility. The payback period is the time needed to recoup investment expenditures or the period needed so that the investment funds that go into investment activities can be fully recovered. Equation 4 is a formulation to calculate the payback period for the proposed use of solar panels

$$PP = \frac{total\ amount\ of\ initial\ investment}{amount\ of\ cash\ flow} x \text{ 1 year} \quad (4)$$

$$PP = \frac{989{,}100{,}000}{163{,}733{,}011.20} x \text{ 1 year}$$

$$PP = 6.04 \text{ year}$$

Solar panels with specifications of 80 kWp and a total of 288 solar panels cost IDR 989,100,000. Table 9 shows that the power required for producing anti-motion sickness drugs in a year is 193,443 kWh. With a significant intensity of sunlight received by the earth's surface, Indonesia averages 5.1 kWh/m²/day, and the solar panel power that can be produced is 146,880 kWh. Using these solar panels requires a total area of around 0.0564 Ha and can help the company save IDR 163,733,011.20 for one year of production, as shown in Table 10. Based on the payback period calculation, it takes 6.04 years to return the company's investment funds for the procurement of solar panel packages.

4. Conclusions

Based on an analysis using SimaPro v V 9.1.1.7 software using the eco-cost method, the production process for drug has a total environmental impact of IDR 3,958,702.49 where the company has to pay the prevention costs for one batch of units. The result of the calculation of the LCA process that has the most significant impact on the environment is the packaging process, with an eco-cost value of IDR 2,244,941.27. The use of electricity generation from fossil fuels causes this value. Of the 12 impact categories, climate change has the highest eco-cost value of IDR 1,121,114.46. This value is caused by the use of electricity for a long time. Recommendations for improvement to reduce the potential impact of production process is to use renewable power generation energy as energy to drive the machine. The SimaPro software calculation results show that replacing conventional power plants with renewable power plants can reduce the eco-cost value by 22%. Future research can be developed for a wider scope, not only in drugs production but up to the product's end of life. Regarding the proposed improvements, it can be continued with an analysis of the feasibility of using solar panels.

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