Life cycle assessment of powder milk production in Indonesia

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Abstract. The industry is a human activity established to process resources or materials into goods or products that humans can utilize. The dairy processing industry is one of the industries that process raw milk into various products, such as milk powder. The process of dairy processing industry activities not only produces a product but also contributes to environmental impacts. The main objective of this research determines the most potential environmental impact caused by the production process. The research will be conducted on milk powder products manufactured by PT X. The products chosen in this research are a product with a size of 40 grams per-sachet (product A) and product with a size of 200 grams per-sachet (Product B). The LCA research boundary is “gate to gate,” such as materials transportation from supplier, manufacturing process and management waste. The method used to determine the potential environmental impacts is life cycle assessment (LCA) method. Software SimaPro v.9.1 calculates the impact assessment. The calculations showed potential environmental impacts on product A and product B, such as Marine Ecotoxicity, Freshwater Ecotoxicity, and Human Toxicity. Based on the process stages of product A and product B, the potential environmental impact arises from the manufacturing process.

1. Introduction

The growth of industries always increases every year. This growth phenomenon is supported by the increasing demand for goods and services demand used by people. The industry is a human activity established to process resources or raw materials into goods or products that humans can utilize. Besides fulfilling all the needs of human life, the industry also has a negative impact on humans due to environmental pollution. The industry is one of the main sources of pollution and the overuse of natural resources. The industry is the contributor to CO2, hazardous waste, and solid as well as wastewater, which triggers environmental pollution [1]. Along with the increase of industry, not a least who began to pay attention to environmental issues. Environmental issues began to be discussed since the holding of the United Nations Conference on the Environment in Stockholm (Sweden) on June 15, 1972 [2]. The efforts to overcome environmental problems caused by industry have been developed in several countries, but the environmental problems that resolved only come from the output of the production process (waste and emission). Basically, environmental problems are not only from production waste, but in the entire industrial process chain [3]. One of the methods for assessing the environmental problem from the entire industrial process is a life cycle assessment (LCA). Based on ISO 14040, LCA is used to evaluate input, output, and environmental impact potential of the product's life cycle [4]. LCA used to analyze and calculate the total environmental impact potential of the product in every cycle [5]. LCA also use to calculate the environmental impact potential of the product on the ecosystem, which is done with a couple of steps in its cycle [2]. LCA method is used to identify
hotspots in the production stage, which can refer to an opportunity to decrease environmental impact and increase efficiency and profitability [6]. LCA method can be used as an implementation of scenario determinant, which corresponds to resolve environmental impact [7]. LCA can be used to identify opportunities in environmental improvement action with confidence that all of the products have a life cycle product [8]. LCA used to analyze the environmental impact potential of the production activity [3]. The scenario used to analyze the impact and contribute to the main problem will be used as a recommendation for resolving action [9]. LCA has been much applied to many products and services [10]. One of the products is dairy products. Finnegan (2015) said that many countries, as a main manufacturer of the dairy product have evaluated the environmental impacts of the products [11]. Based on the Environment Impact Production (EIPRO), the dairy industry is one of the food industries that make a major contribution to the environment. In 2006, it was stated that the dairy industry contributed for eutrophication (10%), global warming (5%), and potential for photochemical ozone formation (4%). The dairy industry is one of the top 10 providers of total impacts on all environmental aspects except ozone depletion [12]. Several studies related to LCA research on the process of milk production in table 1.

| Authors                  | Research Focus | System Boundary | Function Unit | Result |
|--------------------------|----------------|-----------------|---------------|--------|
| Finnegan et al., 2016    | Powder Milk & Butter | Gate to gate | Raw milk transportation (Subsystem 1), Processing and Packaging (Subsystem 2) | 1 kg | Based on result, the most contributor of potential environmental impact is processing raw milk into milk powder and butter. It caused by electricity usage. Energy usage in drying process gives the most environmental impact. Milk transportation stands in the second place [13]. |
| Allia et al., 2018       | Powder Milk    | Cradle to gate  | Material production (subsystem 1), Transportation (subsystem 2), Manufacturing (subsystem 3), Product distribution (subsystem 3) | 40 g & 220 g | Based on result shows potential environmental impact started from GWP, EP, AP and POCP. The most contributor of potential environmental impact started from production material process, transportation, milk powder production and product distribution [15]. |
| González-García et al., 2012 | Yogurt         | Cradle to grave | Dairy farm (subsystem 1), Dairy factory (subsystem 2), Transport to retail (subsystem 3), and Disposal (subsystem 4) | 1 kg | Based on the result, the most potential environmental impact caused by Subsystem 1 and is followed by Subsystem 2. Subsystem 1 caused by CH₄, NOₓ and NH₃ originated from management animal dung and enteric fermentation. Emission SO₂ and NOₓ from usage fuel to machine combustion of farming machine. Subsystem 2 caused by |
usage of material like powdered milk, concentrated milk and packaging material, and then followed by energy usage [14].

| Authors, Year | Product | Scope | Unit | Description |
|--------------|---------|-------|------|-------------|
| Nunes et al., 2020 | Cheese production | Cradle to gate | Milk production (dairy farm), cheese production, product distribution | 1 kg | Based on result, the most environmental impact is milk production process. Milk production process related to cow farming, dung management, and milk production processes its self. Milk production process contributes more than 90% of the whole environmental impact; it is followed by the usage of electricity used by the production process, especially GWP and AP, which is approximately 3%. The distribution of the product gives the least contribution [16]. |
| Xu et al., 2013 | Powder Milk | Cradle to gate | Farming, Manufacturing, packaging, and transportation | 400 g | Based on result, most contributors are originated from farming, which produces raw material, and the manufacturing process stands in the second place. Farming contributes 74.2%, manufacturing contributes 25%, packaging and transportation contribute 0.8%. In short, one of the footprint contributors in the whole supply chain is dominated by the farming step [17]. |
| González-García et al., 2013 | UHT milk | Cradle to grave | Dairy farm (subsystem 1), Dairy plant (subsystem 2). | 1 kg | Based on result, the most significant contributor to environmental impact is caused by Subsystem 1 and followed by a Subsystem 2. Subsystem 1 is caused by farming, which primarily causes AP, EP, GWP, and TEP; animal feed production contributes to ADP, air, and water emission (GWP). Subsystem 2, the most contributors, start from packaging material usage, electricity, transport, and fuel usage. Emission created effecting AP, EP, GWP, and POPF [18]. |
| Santos Jr, et al 2017 | Cheese | Cradle to gate | Upstream activity and cheese production process | 1 kg | Based on result, the most environmental impact doesn’t come from the cheese industry but raw material production. Cheese production contributes 29% of the whole environmental impact. Raw material production (raw milk) |
gives the most contribution, which is between 70% and 98%. Thermal energy usage has a significant effect on particulate matter formation, ozone depletion and photochemical oxidant formation, but it contributes smaller about 20% or less. Electricity usage contributes to Water Depletion, Fossil Depletion, about 10% or less [19].

Based on previous research, state that the environmental impact of product production is not only influenced by the output (emissions and waste) of the process but also influenced by the use of inputs and processes. Besides, other stages also affect, such as the farming process, to obtain raw milk used as input for making milk products. This research will conduct a LCA analysis of life cycle of dairy product similar to previous research. This research was conducted at one of the dairy product manufacturers in Indonesia. PT. X is a producer of dairy products in Indonesia. This research was conducted because of the evaluation of environmental performance in PT. X still refers to the production process's output and has not been evaluated from the product life cycle. This research aims to evaluate the environmental performance of the life cycle of dairy products PT. X with LCA, similar to previous research. This performance assessment is carried out to prevent consequences from the unsustainable use of the resources needed to produce the product [1]. It's expected by measuring the environmental impact using LCA method in the dairy product life cycle of PT. X can improve environmental performance as an effort to reduce environmental problems caused by the production process.

2. Method
Assessing the potential environmental impact in this research is using LCA method. LCA method consists of four phases, such as Goal and Scope, collecting data (LCI), calculate and evaluating the result of environmental impact (LCIA), and interpretation of evaluation result [20].

2.1. Goal and scope
The purpose of determination the unit function is making easier to compare one to another chosen product and equalize the unit used to calculate input and output. The scope is used to decide system boundary of research. An appropriate system boundary also simplifies the determination of unit process and input material included or excluded in the LCA scope.

2.2. Life Cycle Inventory (LCI)
The second stage is life cycle inventory to collecting input (material consumption, energy use, water use, etc.) and output (main products, by-products, emission, waste, etc.) data for each process unit within the system boundary that have been determined. The data will be calculated to find the environmental impact potential along the product life cycle.

2.3. Life Cycle Impact Assessment (LCIA)
The third stage is life impact assessment. Life cycle impact assessment is a step to evaluate the environmental impact potential based on the result of LCI calculation. This step is connecting inventory data to environmental impact categories that have been determined to be analyzed in order as an effort to understand these impacts. Other than that, assessing the life cycle impact gives better additional information for evaluating the result of LCI calculation to find out the most significant environmental impacts from the product life cycle. SimaPro v.9.1 can help the calculation of
environmental impact assessment. The method of assessing the potential impact in SimaPro v.9.1 is using the ReCiPe 2016 method.

2.4. Interpretation
The last stage is interpretation in life cycle assessment method. Interpretation is used to identifying data that has the most significant contribution to the environment and resolving.

3. Results and discussion
3.1. Goal and scope
This research aims to assess the environmental impact potential of products which are produced by PT. X. The products analyzed were product A and product B. Product A is a product for age in infancy or adolescence with a size of 40 grams in one sachet with chocolate flavor, and product B is a product for mothers and babies with a size of 200 grams in one sachet with vanilla flavor.

![System Boundary of LCA](image)

**Figure 1.** System Boundary of LCA.

The functional unit in environmental impact assessment is one sachet of each product. The scope of this research is a gate to gate scheme. The system boundary is divided into three subsystems. The system boundary shows in Figure 1. The first subsystem is the material transportation process from a supplier to PT.X. The second subsystem is PT. X’s manufacturing process. The manufacturing process is divided into some sub-processes. The sub-processes are started by storing materials from a supplier in a material storage warehouse, production process, packaging process until sending milk products to the product storage warehouse. The process of cleaning the production machine also part of subsystem two. The last subsystem is waste management. The waste management process that will be assessed is transportation waste to a third party because PT.X doesn't treat the waste.
3.2. Life Cycle Inventory

The inventory steps are included: collecting, managing and analyzing data to reach the determined goal. Inventory data consists of a stream of input data, process, and output. In this research, inventory data is total data of one month in June 2020 to process product A and product B. Figure 2 explains the input, output, and stage of flow for the production process according to the research scope. The data explained in Figure 2 includes data needed in the transportation process, manufacturing process, and waste management process.

![Flow Chart Legend]

**Figure 2.** The Stream of Input and Output in Process Steps.

Inventory data in transportation include the total distance and kind of vehicle which is used. Raw material and packaging material transportation process in PT.X is using land and sea transportation. Land transportation uses diesel trucks (Euro 2) with wings box or log box type with a capacity of fewer than ten tonnes and more than ten tonnes. Sea transportation is using container cargo ships with a capacity of 960 tons and 320 tons. In Raw material and packaging material transportation, the cargo is assumed filled with 80% of capacity with the same material. The distance of transportation is calculated with Google Maps, either sea or land distance. Inventory border in transportation step doesn’t calculate sending process from supply location to port of supplier country, doesn’t calculate miscellaneous usage in the port area, and doesn’t calculate tools used to transfer the container to a transportation truck. Data used in the transportation process in SimaPro 9.1 is data that has criteria and appropriate to the actual condition.

In this research, the usage of data refers to secondary data, Agri Footprint and Ecoinvent 3.0. The data scope of Ecoinvent 3.0 includes transportation distance, kind of vehicle, average of fuel use that is regulated in the whole country globally, and emission data was caused along the transportation process.

Inventory data in the manufacturing process includes raw material and packaging material used, energy consumption, and production machine cleaning process. Raw material and packaging material includes main material and supporting material. Calculation of raw material and packaging material is material needed in a one-month production process. In this research, the usage of raw material and packaging material data in SimaPro 9.1 refers to secondary data Agri Footprint and Ecoinvent 3.0.
Agri Footprint and Ecoinvent 3.0 scopes are raw and packaging material production data, representing the average production activity of one kilogram of raw and packaging materials in every country globally. Emissions caused by production process of raw and packaging materials are also calculated and to be part of the secondary data. Electricity usage is a medium voltage electricity from PT. PLN. Total electric consumption is calculated in one month in every process. In this research, electricity usage refers to secondary data of Ecoinvent 3.0. Ecoinvent 3.0 scope is electricity production data that assumed with an average of similar technology and processes are same throughout in Indonesia, and emission contribution data caused by electricity usage. The data of cleaning process of production machine is the transportation process of cleaning material data, total cleaning material usage and water usage in one month. In this research, cleaning agent material and transportation process of cleaning agent refers to secondary data of Ecoinvent 3.0. Ecoinvent 3.0 scopes same as the process of transporting materials and raw material and packaging material use.

Inventory data in waste management is a total waste and waste management process. In this research, the waste management process is the transportation of waste to a third party. Waste and hazardous waste transported to the third party by using trucks with a capacity of fewer than ten tonnes, and the wastewater pumped to the third party to be treated. In this research, data usage refers to secondary data of Ecoinvent 3.0. Ecoinvent 3.0 scope includes transportation distance, kind of vehicle and an average of fuel used for waste transportation process, electricity usage for pumping wastewater process, and emission data caused by the entire process.

### Table 2. Inventory Data on the Boundary System.

| System             | Material                          | Unit  | Product A | Product B |
|--------------------|-----------------------------------|-------|-----------|-----------|
| **Subsystem 1**    | Transport packaging material      | Truck | 2,261     | 2,122     |
|                    | Transport raw material            | Truck | 17,379    | 3,989     |
|                    |                                   | Ship  | 304,021   | 83,451    |
|                    | Raw material                      | Base powder milk | 49,200 | 11,747 |
|                    |                                   | Sugar | 24,630    | 2,571     |
|                    |                                   | Additional material | 46,180 | 7,618 |
|                    |                                   | Aluminium foil | 7,705    | 591       |
|                    | Packaging material                | Box   | 8,655     | 5,949     |
|                    |                                   | Additional material | 56    | 41       |
|                    |                                   | Warehouse Raw Material and Packaging Material | kWh | 3,673 | 1,820 |
|                    |                                   | Preparation process | kWh | 2,329 | 1,319 |
|                    |                                   | Production process | kWh | 7,188 | 2,270 |
|                    |                                   | Packaging process | kWh | 343 | 176 |
|                    |                                   | Transfer product to warehouse finish good | kWh | 670 | 372 |
| **Subsystem 2**    | Electricity                       | kWh   | 3,451     | 3,420     |
|                    |                                   | Water consumption | L | 3.9 | 3.9 |
|                    |                                   | Detergent | L | 0.8 | 0.8 |
|                    |                                   | Alcohol | L | 20 | 20 |
|                    |                                   | Tissue | kg | 2.9 | 2.9 |
|                    |                                   | Detergent transportation | km | 0.08 | 0.08 |
|                    |                                   | Alcohol transportation | km | 0.8 | 0.8 |
|                    |                                   | Tissue transportation | km | 105 | 105 |
| **Subsystem 3**    | Waste                             | Solid waste | kg | 1,4117 | 52,92 |
|                    |                                   | Waste water | L | 5 | 5 |
3.3. Life Cycle Impact Assessment

In the ReCiPe method, there were two ways to decide the potential environmental impact category. They are midpoint assessment and endpoint assessment. ReCiPe impact category assessment used in this research is a midpoint assessment impact. Environmental impact characteristics assessed in this research are acidification (AP), global warming (GWP), human toxicity (HTP), photochemical oxidant formation (POFP), marine eutrophication (MEP), freshwater eutrophication (FEP), marine ecotoxicity (MECP), freshwater ecotoxicity (FECP) and terrestrial ecotoxicity (TECP).

Table 3. Potential Environmental Impact Assessment Results of Product A and Product B.

| Impact Category | Unit          | Product A (40 g) | Product B (200 g) |
|-----------------|---------------|------------------|------------------|
| GWP             | Kg CO₂-eq     | 0.289266         | 1.69185          |
| POFP            | Kg NOx eq     | 0.000557         | 0.00358          |
| AP              | Kg SO₂-eq     | 0.004073         | 0.02347          |
| FEP             | Kg P-eq       | 0.000052         | 0.00030          |
| MEP             | Kg N-eq       | 0.000536         | 0.00307          |
| TECP            | Kg 1,4 DB-eq  | 0.042636         | 0.22239          |
| FECP            | Kg 1,4 DB-eq  | 0.000605         | 0.00346          |
| MECP            | Kg 1,4 DB-eq  | 0.000465         | 0.00267          |
| HTP             | Kg 1,4 DB-eq  | 0.351261         | 2.02566          |

Based on the impact analysis, the results obtained for product A and product B. Table 3 describes the number of pollutants caused by producing one sachet of product A with a size 40 g and one sachet of product B with a size 200 g, so created an environmental impact potential that stated on each environmental impact characteristic.

Figure 3. Contribution of the Subsystem for the Environmental Impact Potential of Product A and B.

This characteristic is presented in Figure 3 to understand which step has the most contribution to every environmental impact potential. Figure 3 explain that the most potential environmental impact is
caused by the manufacturing process (Subsystem two), followed by transportation process of raw and packaging material (Subsystem one) and then waste transportation to the third party. Manufacturing process of product A and product B contributes 98.8% and 98.3% environmental impact potential, raw and packaging material transportation contributes 1.1% and 1.6% environmental impact potential, and waste transportation contributes 0.1% environmental impact potential for both products.

The next step is doing the normalization process, grouping and weighting to understand the whole process is the most environmental impact. Figure 4 explains the result of normalization, grouping, and weighting impact characteristics to determine the most significant environmental impact. Product A dan B shows same significant environmental impact but in different weights. Product A has Human Toxicity 64.1%, Freshwater Ecotoxicity 13.2%, and Marine Ecotoxicity 12%. Product B has Human Toxicity 64.2%, Freshwater Ecotoxicity 13.1%, and Marine Ecotoxicity 22.1%.

![Figure 4. Environmental Impact Potential Percentage on Product A and Product B.](image)

3.4. Interpretation

The result will become the base to determine the conclusion, recommendation, and decisions that conform to the definition of goal and scope. The results obtained from the gate to gate life cycle: manufacturing process has the most significant effect for the entire of environmental impact potential, material transportation process contributed second but not as significant as the manufacturing process, and waste transportation to the third party contributes very least. The impact result is identified in detail about its contribution to every subsystem process by the input allocation approach. Figure 5 shows in detail the contributors to the environmental impact of product A and product B. Inputs in the manufacturing process are raw material, packaging material, electricity, and cleaning machine process (usage of cleaning material, water, and transportation of cleaning material). Input in the transportation of raw and packaging material uses fuel calculated in SimaPro 9.1 based on distance. Input in waste management is used fuel for transportation waste and electricity consumption for pumping wastewater. Based on the result (Figure 5) can be described that usage of raw material gives the largest contribution for all potential environmental impact category (60-80% in every category), usage of packaging material gives the second largest contribution 5-10% for every environmental impact except POFP and usage of electricity to be the third place of contribution less than 3% for every environmental impact except POFP environmental impact. Transportation raw and packaging material gives very little contribution (less than 2%) except in POFP (less than 30%), and waste transportation to the third party gives the least contribution (less than 1%) for every potential environmental impact.
Figure 5. Impact Category of Each Process Involved Considering the Input Allocation Approach.

3.4.1. Raw Material and Packaging Material. The raw material is the most contributor to environmental impact potential, approximately 60-80% in every impact category of product A and product B. The packaging material usage stands in the second contributor, about 5-10% except for POFP. Potential environmental impact from raw and packaging material is caused from the production process to manufacture these materials or other processes to produce materials. During the process of material production by suppliers causes pollutants that cannot be controlled by PT. X. These pollutants indirectly will accumulate and to be part in the environmental impact potential caused by PT. X, because PT. X use this material as input for its production process. Allia's research stated that the most contributor to environmental impacts potential is production process of materials used as input for product production [15].

In packaging materials usage, González-García’s research stated that the production of yogurt containers and other packaging materials made an outstanding contribution to AP (41%) and CED (43%). Plastic materials have a big environmental impact because, in addition to using non-renewable materials (plastics), it also requires a large amount of energy for the material extraction process [18]. In raw material usage, half-finished milk powder input gives the most contributor to the entire environmental impact potential. It is supported by the usage amount of half-finished milk powder in product A production, and product B is more than 50% of the whole raw materials. Milk material used in product A and product B is originated from dairy cow's farm. Half-finished milk powder's production process consists of the raw milk's evaporating process until its dry by drying the fresh milk's water content until a specific concentration. The drying process requires a lot of energy. The use of energy creates pollutants that cause potential environmental impacts. Similar to González-García's research states, milk-based-inputs which are milk powder and concentrated milk is the most contributor of environmental impact for the process of manufacture with a contribution of AP 86%, EP 89%, GWP 50%, LC (land competition) 84% and POFP 58% [14].

Environmental impact contribution of milk powder usage as raw material not only occurs from the production process of material but also from the material's farming process. The farming process creates pollutants that can be analyzed. De Bruyn stated photochemical oxidant formation from CH4 emission, especially that is originated from farming; acidification caused by NH3 emission from the usage of ammonia in farming; and eutrophication occurred by the emission of farming activity like usage of fertilizer and animal dung, human toxicity and ecotoxicity [21]. Based on research by Djekic state that the farming process is the most contributor to the environmental impact potential of milk powder production with cradle to grave/gate scheme [22]. González-García and Djekic explained that...
one of the reasons farming gives environmental impact is an emission of CH4, NO3, and NH3 originated from the management of animal dung and also emission of SO2 and NOx from the usage of fuel for farming machine [18], [22].

3.4.2. Electricity. The usage of electricity becomes the third contributor (less than 5%) of the environmental impact except for the impact of the POFP. Electricity usage is similar to raw and packaging material usage, which gives a contribution to emission indirectly. Contribution originates from the usage of fossil fuel to produce electricity by PT. PLN. The environmental impact occurs from heavy metal, which is released as a footprint element in fossil fuel usage [20]. Most State Electric Enterprise in Indonesia is still using fossil fuel (more than 45% based on electricity reports in 2019) in their production, so it creates emissions like SOX, NOX and CO2, which result in potential environmental impacts. Other than that, the fossil fuel mining process also contributes to several impacts: human toxicity and ecotoxicity [20]. Emission created is directly proportional to the usage of energy, so it makes an environmental impact. In Product A, the production process (7188 Kwh) and material storage (3673 Kwh) are the largest contributors to electricity usage's environmental impact. In Product B, material storage (3420 Kwh) and production process (2270 Kwh) are the largest contributors to electricity usage's environmental impact.

3.4.3. Transportation. Raw and packaging material transportation contributes a tiny part (less than 2%) of the whole environmental impact except POFP impact (less than 30%). Figure 5 explains that raw material transportation gives the largest contribution to the environmental impact between raw and packaging material transportation. Raw material transportation of Product A and B creates approximately 30% POFP environmental impact and less than 5% for other categories. In transportation activity of raw and packaging material, transportation of the main raw material for semi-finished powdered milk has 82% contribution besides other raw material and packaging material transportation, especially on the impact of POFP. The POFP environmental impact is caused by emission (NOx) created by the usage of fuel. The main source of NOx emission to created POFP impact is originated from a high-temperature combustion engine [20]. Emission is created directly proportional to the distance of transportation, so it makes an environmental impact. Raw material transportation of milk powder has a significant contribution because the material is occupied outside Indonesia (21.079 km and 10.915 km).

Based on the whole explanation shows that raw and packaging materials are more responsive to the environmental profile of product A and product B’s life cycle. An alternative suggested to PT.X to minimize raw and packaging material used is efficiency raw and packaging material usage. Table 2 shows that the total solid waste of production and packaging process is 1,411.7 kg for Product A and 52.92 kg for Product B. Another alternative is choosing another supplier who has a friendly environmental process and products. Minimizing electricity usage can be done by creating more efficient electricity regulation. This is caused by electricity is supplied from a third party (State Electric Enterprise), not from its production. An example of electric efficiency is to minimize the usage of lights. Minimizing Photochemical Oxidant Formation (POFP) environmental impact in the transportation process can be done with milk transportation efficiency, which is the main cause of POFP. Increasing efficiency can be done by using another supplier originated inside Indonesia, which has fulfilled the industry criteria, so fuel consumption for transportation can be minimized.

4. Conclusion
The results showed a total of pollutants assessed from the life cycle of product A and product B that had a potential environmental impact. Pollutants produced as a cause of potential environmental impacts not only influenced by the output of manufacturing process but also influenced by using the inputs. Besides the manufacturing process, other processes such as material transportation also contribute to the impact of producing products A and B. The result of this research also provide information to the management of PT. X, that is important to assess the environmental performance of
the product life cycle in order to solve all environmental problems caused by the manufacturing process of the product. The result of this research also serves as a benchmark for PT. X to do innovates its environmental performance. This innovation is carried out to improve environmental performance of the company and provide motivational benefits for the company to reduce pollution due to the production process to make a healthier environment and produce eco-friendly products.

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References
[1] Herva M, Franco A, Carrasco E F, and Roca E 2011 Review of Corporate Environmental Indicators Journal of Cleaner Production 19 1687-1699
[2] Kautzar G Z, Sumantri Y, and Yuniarti R 2013 Analysis of the Environmental Impact on Leather Product Supply Chain Activities Using the LCA and ANP Methods Jurnal Rekayasa dan Manajemen Sistem Industri 3 200-211
[3] Palupi A H, Tama P I, and Sari R A 2014 Evaluation of the Environmental Impact of Paper Products Using a Life Cycle Assessment (LCA) and Analytic Network Process (ANP) Jurnal Rekayasa dan Manajemen Sistem Industri, 2 1136-1147
[4] ISO 14040 2016 Environmental Management — Life Cycle Assessment — Principles and Framework. (Jakarta: Badan Standarisasi Nasional)
[5] Honsono N 2012 Analysis of the Bioethanol Life Cycle Based on cassava and oil palm empty bunches in Indonesia (Jakarta: Universitas Indonesia)
[6] Eide M H 2002 Life cycle assessment (LCA) of industrial milk production International Journal of Life Cycle Assessment 7 115-126
[7] Bingxiong L, Xiangyuan D, and Simin H 2016 The economic and environmental implications of wastewater management policy in China: From the LCA perspective Journal of cleaner production 142 3544-3557
[8] Sopha B M, Setiwati, and Ma’mun S 2017 Environmental assessment of motorcycle using a life-cycle perspective Jurnal IIOLCAS 1 22-28
[9] Harjanto T R, Fahrurrozi, and M. Bendiyasa M I 2012 Life cycle assessment of PT Holcim Indonesia Tbk cement factory. cilacap plant: comparison between coal fuel and biomass Jurnal Rekayasa Proses 6 51-58
[10] Finnveden G, Hauschild M Z, Ekvall T, Guinee J, Heijungs R, Hellweg S, Koehler A, Pennington D, and Suh S 2009 Recent developments in Life Cycle Assessment,” J. Environ. Manage. 91 1–21
[11] Finnegan W, Goggins J, Clifford E, and Zhan X 2015 Global warming potential associated with dairy products in the Republic of Ireland Journal of cleaner production 163 262-273
[12] Putri R P, Tama I P, and Yuniarti R 2014 Environmental Impacts Evaluation in Supply Chain Activity of Kud Batu’s Dairy Product Using Life Cycle Assessment (LCA) Implementation and Analytic Network Process (ANP) Approach Jurnal Rekayasa dan Manajemen Sistem Industri 2
[13] Finnegan W, Goggins J, Clifford E, and Zhan X 2016 Environmental impacts of milk powder and butter manufactured in the Republic of Ireland Sci. Total Environ. 579 159–168
[14] González-García S, Castanheira E, Dias A, and Arroja L 2012 Environmental life cycle assessment of a dairy product: the yoghurt International Journal of Life Cycle Assessment volume 18 796–811
[15] Allia V, Chaerul M, and Rahardyan B 2018 Life Cycle Assessment (LCA) Study of a Milk Powder Product in Aluminium Foil Packaging Indonesian Journal of Life Cycle Assessment and Sustainability 2

[16] Nunes O S, Gaspar P D, Nunes J, Quinteiro P, Dias A C, and Godina R 2020 Life-Cycle Assessment of Dairy Products—Case Study of Regional Cheese Produced in Portugal MPDI Journal, 8 1182

[17] Xu C, Huang J, and Chen F 2013 The Application of Carbon Footprint in Agri-Food Supply Chain Management: Case Study on Milk Products Advanced Materials Research 807-809 1988-1991

[18] González-García S, Castanheira E G, Dias A C, and Arroja L 2013 Using life cycle assessment methodology to assess UHT milk production in Portugal Sci. Total Environ. 442 225-234,

[19] Santos Jr H S, Maranduba H L, Neto J A A, and Rodrigues L B 2017 Life cycle assessment of cheese production process in a small-sized dairy industry in Brazil Environmental Science and Pollution Research 24 3470–3482

[20] ISO 14044 2017 Environmental Management – Life Cycle Assessment – Requirements and Guidelines (Jakarta: Badan Standardisasi Nasional (BSN))

[21] De Bruyn S, Bijleveld M, De Graaff L, Schep E, Schoten A, Vergeer R, and Ahdour S 2018 Environmental Prices Handbook- EU28 version (Delft University of Technology)

[22] Djekic I, Miocinovic J, Tomasevic I, Smigic N, and Tomic N 2014 Environmental Life-Cycle Assessment of Various Dairy Products Journal of Cleaner Production, 68 64-72