Advance Sustainable Science, Engineering and Technology (ASSET)

Vol. 7, No.1, January 2025, pp. 0250106-01 ~ 0250106-08

ISSN: 2715-4211 DOI: https://doi.org/10.26877/asset.v7i1.747

Environmental Impact Analysis on Furniture Industry by Implementing Life Cycle Assessment (LCA) Method

Aulia Dita Ananda Lestari*, Farida Pulansari

Departemen of Industrial Engineering, Faculty of Engineering, Universitas Pembangunan Nasional "Veteran"Jawa Timur, Jl. Rungkut Madya No.1, Gn. Anyar, Kec. Gn. Anyar, Surabaya, Central Java60294, Indonesia

*farida.ti@upnjatim.ac.id

Abstract. Currently the industry is experiencing an increase every year. One of them is the furniture production industry. In East Java there is a furniture industry which experiences an increase in production demand every year. This does not only apply to local consumers but also foreign consumers. PT XYZ implements a make to order system, namely products are made when consumers order them. The amount of production demand is directly proportional to the amount of industrial waste produced, but the company has never carried out an analysis of the impacts. Therefore, this research will discuss environmental impact analysis using life cycle assessment to calculate the life cycle value of the production of a furniture product with cradle to gate limitations. This research was assisted by OpenLCA 2.1.0 software using the Agribalyse_301 database and then for impact assessment using the EDIP 2003 method. After calculating, recommendations for improvement were looked for to reduce the resulting environmental impact. The results of this research for 1 unit of table product production are 3.51166 Pt. The highest impact was produced by the production process, namely Ozone depletion of 0.58215 Pt. This impact can pollute the environment due to the large use of electricity. It is best for companies to use electricity from renewable sources.

Keywords: Environmental Assessment Environmental Impact, Furniture Industry, Life Cycle Assessment, Sustainability Metrics, Sustainable Supply Chain Management, OpenLCA

(Received 2024-06-29, Accepted 2024-07-02, Available Online by 2024-11-30)

1. Introduction

Competition between manufacturing and service industries is increasingly fierce, this is helped by advances in science and technology [1]. This has a good impact on the Indonesian economy. However, on the other hand, it also causes environmental impacts due to the increasingly intensive disposal of industrial waste. According to Wihardjo and Rahmayanti (2021), based on the form of waste produced, waste is divided into three groups, namely, solid waste, liquid waste and gas waste [2]. Nowadays, furniture is a fairly important societal need [3]. The furniture industry generates the largest amount of solid waste, mainly wood, which can be recycled or used for energy. Its disposal is costly and potentially hazardous [4]. This manufacturing industry produces large amounts of wood waste in the cutting and sanding process. The main raw materials are solid wood and wood panels. [5]. The amount of wood waste from furniture production is increasing [6]. This sector has a major negative impact on the environment, contributing around 8–10% of global greenhouse gas emissions [7]. In the process of producing wood into furniture, pollution will be produced, namely particles of wood dust[8]. These wastes cause serious environmental problems in both their production and disposal. Apart from that, the continuous use of wood as raw material for furniture also has a negative impact on the environment, namely causing the loss of forests and other resources. Therefore, productive and environmentally friendly processing of industrial waste is very important for a sustainable environmental ecosystem and clean production [9].

PT XYZ is one of the largest furniture manufacturing and exporting companies in Indonesia, with a product line specializing in wooden and wicker indoor furniture. This company's production system uses a make to order system, namely according to orders from customers. The main market of PT. XYZ is the United States at 60%, Europe 20%, and Asia 20%. PT XYZ produces many products, one of which is a table called NS RIDGE BLEDGE OAK DESK. This product is one of the most ordered products, which can be seen in the table below.

Table 1. Production Quantity Requests for NS RIDGE BLEDGE OAK DESK

Kode Item	Production Quantity					Total
	2019	2020	2021	2022	2023	
CNB02183-40A	355	625	1956	1050	2453	6439
CNB02183-40B	355	625	1950	1025	2388	6343
Total	710	1250	3906	2075	4841	

Sources : Company Data processed

It can be seen in table 1, production of the NS RIDGE BLEDGE OAK DESK table has increased from 2019 to 2023, namely an increase of 5.81%. The large demand for furniture production at PT. XYZ is directly proportional to the increase in production waste as well. However, this company has never measured the environmental impact of materials in its production process.Greenhouse gases, harmful emissions produced by material processing and waste disposal are an important part of creating environmental pollution that can lead to dangerous consequences for the future [10]. The production waste produced can be seen in the table below:

Table 2. Output Production

Output Production					Total
2019	2020	2021	2022	2023	
710	1250	3906	2075	4841	12.782 Kg

Sources : Company Data processed

In the sustainable management of production waste and clean production, it is stated in Law Number 32 of 2009 Article 3 Paragraph 1 concerning Environmental Protection and Management, Sustainable development is a fundamental and planned approach that combines environmental, social and economic aspects in a development strategy to guarantee the integrity and security, capacity, environmental welfare and quality of life of present and future generations. To support this program, there is a tool that is used as a measuring tool for evaluate the environmental effect caused by a product, process or activity is called Life Cycle Assessment (LCA). A process called life cycle analysis (LCA) is used to examine the environmental impact of a product at every stage of its existence, from extraction of raw materials to production, distribution, consumption, repair, maintenance, disposal and recycling. [11]. With the Life Cycle Assessment (LCA), it is possible for evaluate a company's environmental performance regarding products or processes and makes it easier to make environmental improvements [12].

Based on previous research conducted by Arieyanti et al (2019) it only discusses the classification stage [13]. Meanwhile, research conducted by Pinkan et al (2019) discusses the normalization stage [14]. This research aims for assess the potency for environmental impacts during the life cycle of table products. This research is an implementation of a Life Cycle Assessment with a Cradle to Gate scope, namely from the process distribution raw materials by suppliers until the product is ready to be distributed as well as LCIA management to the impact stage to weighting. Life Cycle Assessment calculations using OpenLCA 2.1.0 software using the Agribalyse_301 database and then for impact assessment using the EDIP 2003 method. The emission factors for all the operations in the background and foreground system were extracted from AGRIBALYSE v3.0.1 database perform with openLCA Software [15]. EDIP 2003 is a continuation of EDIP 1997 [16].

Once the impact of the production process is known, alternative improvements will be sought through literature searches and brainstorming. This alternative is expected to reduce energy use and waste produced. Therefore, the application of life cycle assessment needs to be applied to the production industry, especially in the PT XYZ furniture industry, so that it can help companies assess and minimize the impact of the table production process to determine strategies. Strategies for cleaner production guarantee sustainable development [17]. The novelty of this research is calculating the utilization of production results which are reused by the Company as boiler raw materials. Previous similar research did not take into account the reuse of production output. It is hoped that the results of this research can be used as a basis for implementing a life cycle assessment to develop a mitigation strategy for environmental pollution resulting from furniture production activities at PT XYZ. It is hoped that from this research companies can reduce their impact on the environment, energy sources and achieve economic health.

2. Methods

This research uses the life cycle assessment method to assess the product's impact on the environment. Everything from the input to the output of material flows is calculated to analyze how these flows affect the environment [18]. The four phases carried out in a life cycle assessment are first defining the objectives and scope, second is collecting a life cycle inventory (LCI), third is calculating a life cycle impact assessment (LCIA), and fourth is interpretation. [19]. Determining goals and scope is the first step in the Life Cycle Assessment (LCA) method so that it can answer the problems you want to solve [20]. The aim of the research is to identify the potential environmental impact of each life cycle of the NS RIDGE BLEDGE OAK DESK product and determine the best mitigation alternative that can reduce the environmental impact caused in the production process. The boundary that will be examined in this research is Cradle to Gate. The functional unit used in this research is 1 product unit. So the resulting environmental impact is the impact of every 1 unit of product produced. The second stage is inventory analysis starting from identifying processes relevant in the product system, then collect data from input and output in each process for each functional unit that has been determined. Collection adjusted data [21]. LCI is referred to as the second stage in LCA, namely measuring pollution emissions to water, air and land and then calculating the extraction of environmental raw materials during all processes in the manufacturing system life cycle [22]. The aim of the impact assessment stage is to use the LCI results to assess the potential magnitude of the environmental impact produced by the product system being analyzed [23]. Assessment process impacts must reflect ecological impacts and human health impacts, must also explain the impact of resource use natural power [24]. Interpretation is the final step in the LCA stage. Action plans will be made based on the results of the interpretation [25].

3. Results and Discussion

At this chapter, the input and output produced during the production of the NS RIDGE BLEDGE OAK DESK table will be calculated by carrying out four phases in the life cycle assessment.

3.1. Life Cycle Inventory

At this stage, the number of inputs and outputs from each process is calculated. Input consists of all materials and energy used in a process, while output consists of all the results of a process, both in the form of products and emissions or waste. Input and output data can be obtained from observations in the field, historical data or from previous research references. Then the data is entered into OpenLCA software. Existing data must be adjusted to the database in the OpenLCA software.

Table 3. Table of input output production

Activity Unit	Input-Output	Inventory Data	Unit	Total
Delivery of raw materials	Input	Transportation	t*Km	2292,1
	Output	CO2	Kg	216,124393
		CH4	Kg	0,09734
		SO2	Kg	0,5616
		CO	Kg	0,1872
		PM10	Kg	0,03744
		NOx	Kg	1,3104
Kiln Dry	Input	piece of wood	Kg	2,37
		Water	M3	6,2
		Mindi Wood	M3	0,0614
	Output	Mindi Wood	M3	0,0614
		Wood ashes	Kg	0,9

Production	Input	Mindi Wood	M3	0,0614
		Sengon Wood	M3	0,003
		Plywood & MDF	M3	0,445457
		Veneer	M3	0,0108
		Electricity	kWh	3685,5
		Water	Ml	1055,7
		Toluene	Kg	0,49450
		Coating &Sealer	Kg	0,30426
		Ferrous Metals	Kg	1,66195
		Glue Laminated	M3	0,49200
		Polyster Resin	Kg	0,058
	Output	1 Unit Table	Item	1
		Sawdust	Kg	1
		Sludge	Kg	0,39
		CO2	Kg	3,2
Packaging	Input	Corrugated Board box	Kg	5,5
	Output	Product ready to send	Item	1

Sources : Data processed

3.2. Life Cycle Impact Assessment

The next stage in the life cycle impact assessment is assessing impacts based on EDIP 2003. Life Cycle Impact Assessment aims to identify how much an activity contributes to the NS RIDGE BLEDGE OAK DESK production process to the environment. This impact assessment is carried out by directly comparing the results of the Life Cycle Inventory in each category.

a. Characterization

Characterization is the stage of assessing the amount of substances that contribute to the impact category of the NS RIDGE BLEDGE OAK DESK production process based on characterization factors so that it can show the relative contribution of various compounds. The following is a comparison of the overall process characterization results.

Table 4. Table Comparison from the characterization results of the entire process.

Impact categories	Distribution of Raw Material	Kiln Dry	Table Production	Product Ready to Ship	Unit
Acidification	1,47E-01	9,00E-01	66	3,12E-01	m2

Aquatic eutrophication EP(N)	1,02E-03	1,11E-02	0,4625	3,83E-03	kg N
Aquatic eutrophication EP(P)	1,00E-04	1,42E-03	0,15954	2,24E-03	kg P
Bulk waste	1,69E+00	9,64E+01	88	9,84E-01	kg
Ecotoxicity soil chronic	4,97E-01	6,09E-01	7.322	3,31E+01	m3
Ecotoxicity water acute	8,15E+01	2,20E+03	3,19E-05	1,20E+03	m3
Ecotoxicity water chronic	6,14E+02	1,87E+00	1,90E-06	7,65E+03	m3
Global warming 100a	1,88E+00	2,20E+00	3.190	5,58E+00	kg CO2 eq
Hazardous waste	1,36E-05	6,53E-05	0,06814	9,91E-05	kg
Human toxicity air	3,07E-04	2,78E+00	4,26E+00	1,67E-05	person
Human toxicity soil	8,82E-01	3,19E+00	274	1,82E+00	m3
Human toxicity water	1,55E+01	1,16E+03	1,93E-04	1,75E+02	m3
Ozone depletion	2,77E-07	2,62E-07	0,00019	4,68E-07	kg CFC11 eq
Ozone formation (Human)	9,10E-04	1,24E-02	0,76376	2,35E-03	person,ppm,h
Ozone formation (Vegetation)	1,33E+01	1,82E+02	1,08E-04	3,30E+01	m2,ppm,h
Radioactive waste	1,60E-04	7,31E-05	0,02685	1,60E-04	kg
Resources (all)	1,70E-04	5,40E-04	0,14887	4,90E-04	PR2004
Slags/ashes	7,20E-04	1,05E+00	2	1,50E-02	kg

Source : Data processes

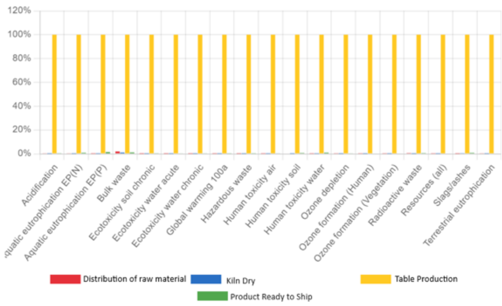

Figure 1. Comparison from the characterization results the entire process.

Sources : Output Software

Based on Figure 1, it can be concluded that the process that produces the most 100% is the table production process, which occurs in all impacts.

b. Normalization

Stages to show the relative contribution of all impact categorieson all environmental issues to create a uniform unit, for all impact categories by multiplying the characterization value by normal value [26]. Normalization stage identifies hotspot points/activity process units with the highest environmental impact. Units are standardized using the Pt unit for comparison.

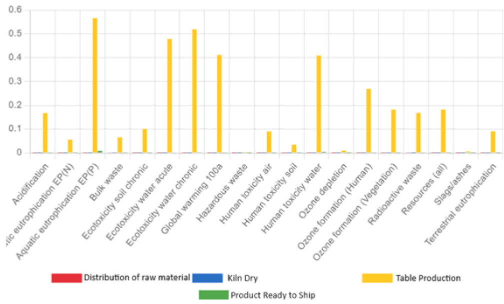

Figure 2. Comparison from the Normalization results the entire process.

Sources : Output Software

Based on Figure 2, it can be concluded that the process that produces the highest impact is the table production process. This occurred in 19 impacts with the highest value compared to other processes.

c. Weighting

Weighting places emphasis on the most important potential impacts. Comparison values based on weighting between categories are obtained by multiplying the impact value by the weighting factor. The following are the weighting values in each process. The following is a comparison from the weighting results of the entire process.

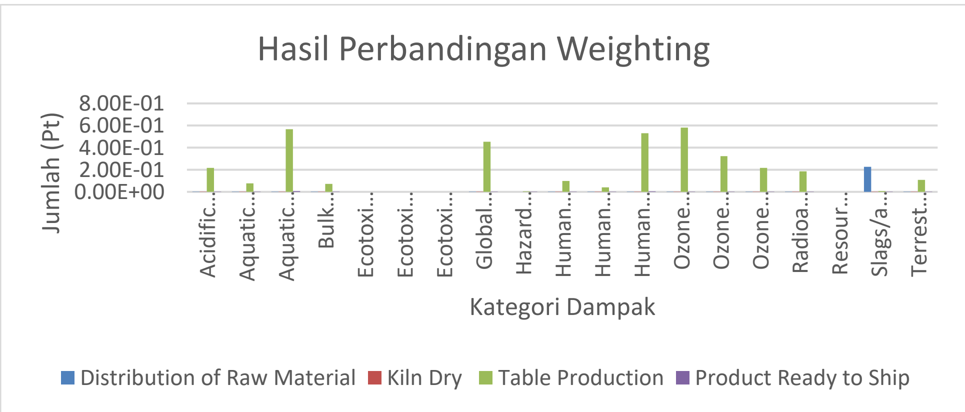

Figure 3. comparison from the weighting results the entire process.

Sources : Output Software

At the interpretation Based on Figure 3, it can be concluded that of all the processes that occur, the biggest impact category that occurs is Ozone Depletion caused by the table production process. This happens because of the use of electricity.

d. Single Score

Single scoring is a method used to combine several impact categories into a single value to make assessment easier. The following are the results of the single scoring from each stage. The following are the results of a single score comparison from the raw material delivery process, wood drying/kiln drying, table production, and packaging.

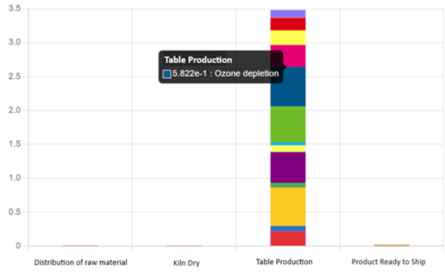

Figure 4. comparison from the single score results the entire process.

Sources : Output Software

Based on figure 4.38 is the single score result of the entire process. It can be seen in the figure that the process that has the biggest impact is the table making process, namely 3.48215 Pt. This was followed by packaging at 0.0213 Pt, delivery of raw materials at 0.00609 Pt and kiln dry at 0.00131 Pt.

3.3. Life Cycle Interpretation

In the interpretation stage, LCI and LCIA are identified and evaluated. The results will be analyzed and recommendations for improvements provided based on cleaner production strategies to reduce environmental impact. By measuring the environmental impact of a process, researchers can find out which processes have the greatest impact and can take action to optimize the process to increase efficiency and reduce negative impacts. The processes of making finished products, kiln drying, and packaging have the greatest environmental impact. In the process of sending raw materials from suppliers, the highest impact produced was in the bulk waste impact category of 0.00138 Pt. The use of medium and large trucks that use diesel fuel causes high exhaust emissions, such as CO2, CH4, SO2, CO, PM10 and NOx. These emissions can worsen air quality and cause respiratory and cardiovascular problems, respiratory irritation and lung disease, damage to the nervous system and be fatal, increasing the risk of lung infections. In the packaging process the highest impact produced is the impact of Aquatic Eutrophication EP(P) of 0.00796 Pt. The use of cardboard in product packaging can cause the release of phosphorus and nitrogen which can cause eutrophication and disrupt aquatic ecosystems. In the process of making finished products, the highest impact produced was ozone depletion of 0.89879 Pt. The use of electricity from power plants that use fossil fuels can contribute to pollution that has an impact on climate change and the ozone layer.

Recommendations for improvements to overcome B3 waste in the delivery of raw materials are improving fuel efficiency and vehicle technology, using cleaner alternative fuels, better management and recycling of vehicle waste, strict policies and regulations regarding vehicle emissions, and choosing appropriate transportation. appropriate. meets EURO 5 standards. To overcome B3 waste in the packaging process, good cardboard waste management can be carried out, increasing public awareness about recycling, and using recycled cardboard. In the finished product production process, mitigation that can be done is to increase energy efficiency, adopt renewable energy sources, implement strict regulations, and invest in the development of new energy technology that is more environmentally friendly. Apart from that, the process of producing and using electricity also has a significant impact on water quality and the balance of aquatic ecosystems. With LCA calculations to evaluate the environmental impact of the entire supply chain, companies can optimize the supply chain by choosing more sustainable suppliers and reducing the carbon footprint in transportation and distribution.

4. Conclusion

Life cycle assessment calculations are very helpful for calculating the environmental impact assessment of the table production process. After carrying out calculations using OpenLCA 2.1.0, we obtained the environmental impact caused by the life cycle of the NS RIDGE BLEDGE OAK DESK. That in making 1 unit of product, from sending raw materials to packaging, it has a value of 3.51166 Pt. The highest impact is produced by the production process, namely ozone depletion of 0.58215 Pt. The highest impact that occurred was eutrophication of EP waters (P) amounting to 0.00796 Pt. For the raw material delivery process, the biggest impact is bulk waste of 0.00131 Pt. Suggestions for further research focus more on the highest waste by using other methods or comparing two methods with different impact categories.

References

[1] Z. N. Firdantara and D. Setiawan, "Supplier Selection Modeling and Analysis in the Metal Casting Industry Using Analytical Hierarchy Process," *Adv. Sustain. Sci. Eng. Technol.*, vol. 6, no. 2, pp. 1–8, 2024.

[2] R. S. D. Wihardjo and H. Rahmayanti, *PENDIDIKAN LINGKUNGAN HIDUP*. Penerbit NEM, 2021.

[3] N. Harahap, Ramadhani S. Zahara, Elvia A. Martaliah, "Analisis Perilaku Konsumen Dalam Pengambilan Keputusan Pembelian Pada Usaha Mandiri Furnichia Furniture Di Kecamatan Sungai Gelam Menurut Perspektif Islam," *Jkpim J. Kaji. dan Penal. Ilmu Manaj.*, vol. 1, no. 4, pp. 157–171, 2023.

[4] A. Szczurek, M. Maciejewska, and K. Mo, "Detection of emissions from the combustion of wood-based materials being furniture industry waste," no. November, 2020.

[5] G. Costa, D. S. Pinho, D. L. Medeiros, and D. Vieira, "Wood Waste Management from the Furniture Industry : The Environmental Performances of Recycling , Energy Recovery , and Landfill Treatments," *Sustainability*, vol. 5, 2023.

[6] W. Setiawan, Deni. Hidayat, Arif. Supriyadi. Lestari, "Environmental Ethics Policy in Jepara : Optimization of Handicraft Designs from Wood Waste in the Furniture Industry," *J. Korean Wood Sci. Technol.*, vol. 51, no. 5, pp. 392–409, 2023.

[7] M. N. Sakib, G. Kabir, and S. M. Ali, "A life cycle analysis approach to evaluate sustainable strategies in the furniture manufacturing industry," *Sci. Total Environ.*, vol. 907, p. 167611, 2024, doi: https://doi.org/10.1016/j.scitotenv.2023.167611.

[8] V. P. Bratandhary and R. Azizah, “LITERATURE REVIEW : FAKTOR YANG BERHUBUNGAN DENGAN GANGGUAN FUNGSI PARU PEKERJA INDUSTRI MEBEL LITERATURE REVIEW : FACTORS RELATED TO LUNG FUNCTION,” *kesma J. Ilmu Kesehat. Masy.*, vol. 18, no. 1, 2022, doi: 10.19184/ikesma.v18i1.25100.

[9] N. Ijaz and F. Dai, “Paper and wood industry waste as a sustainable solution for environmental vulnerabilities of expansive soil : A novel approach,” vol. 262, no. January, 2020.

[10] J. K. Runtuk and A. L. Maukar, “Pemilihan Pemasok Dengan Mempertimbangkan Produksi Bersih / Green Manufacturing Pada Industri Otomotif,” *J. Rekayasa Sist. Ind.*, vol. 9, no. 1, pp. 33–44, 2020.

[11] V. Thiruvengadam, N. Huda, B. Baharuddin, and L. J. Shiun, “Implementation of life cycle analysis on green tea process,” *Heliyon*, vol. 9, no. 5, p. e15450, 2023, doi: 10.1016/j.heliyon.2023.e15450.

[12] F. Pulansari and I. Nugraha, “Analysis of the Implementation Life Cycle Assessment (LCA) Method for Identification of Environmental Assessment in Liquid Waste Production Tofu at PT . XYZ,” vol. 2022, 2022.

[13] D. A. Astuti, “Potential Analysis Of Environmental Impact Of Sugarcane Plantation Using Life Cycle Assessment (LCA) Approach,” *J. Litbang*, vol. 15, no. 1, p. 14, 2019.

[14] P. P. Parameswari, M. Yani, and A. Ismayana, “Penilaian Daur Hidup (Life Cycle Assesment) Produk Kina Di PT Sinkona Indonesia Lestari,” *J. Ilmu Lingkung.*, vol. 17, no. 2, pp. 351–358, 2019, doi: 10.14710/jil.17.2.351-358.

[15] O. Pringga *et al.*, “Heliyon Evaluation of comparative scenarios from different sites of chestnut production using life cycle assessment (LCA): Case study in the Beira Interior region of Portugal,” *Heliyon*, vol. 9, no. 1, p. e12847, 2023, doi: 10.1016/j.heliyon.2023.e12847.

[16] M. Hauschild and J. Potting, *Spatial Differentiation in Life Cycle Impact Assessment – The EDIP 2003 Methodology*, vol. 80. 2005.

[17] M. Ikram, M. Ferasso, R. Sroufe, and Q. Zhang, “Assessing green technology indicators for cleaner production and sustainable investments in a developing country context,” *J. Clean. Prod.*, vol. 322, p. 129090, 2021, doi: https://doi.org/10.1016/j.jclepro.2021.129090.

[18] N. Kazemi, M. Gholami, and A. Mohammadi, “Results in Engineering Environmental life cycle assessment and energy-economic analysis in different cultivation of microalgae-based optimization method,” *Results Eng.*, vol. 19, no. June, 2023.

[19] M. A. Curran, *LIFE CYCLE ASSESSMENT: PRINCIPLES AND PRACTICE*, no. May. 2006.

[20] D. Herdhiansyah, S. A. Sari, S. Tenggara, and S. Tenggara, “Asia - Pacific Journal of Science and Technology case study of Konawe Selatan district , Indonesia,” vol. 27, no. 4, pp. 1–11, 2021.

[21] G. Finnveden and K. T. H. Royal, *Life Cycle Assessment*, Third Edition., vol. 2. Elsevier, 2014.

[22] A. Gac, J. Aubin, and S. Espagnol, “Allocation in the LCA of meat products : is agreement possible ? Aur,” vol. 2, no. July 2020, 2021.

[23] J. Letamendi, E. Sevigne-itoiz, and O. Mwabonje, “Jurnal Produksi Bersih Analisis dampak lingkungan dari anggur organik Chili melalui penilaian siklus hidup,” *Clean. Prod.*, vol. 371, 2022.

[24] M. Sirait, “Studi Life Cycle Assessment Produksi Gula Tebu : Studi Kasus di Jawa Timur,” vol. 13, no. 2, pp. 197–204, 2020.

[25] E. U. Lolo, R. I. Gunawan, and A. Y. Krismani, “Penilaian Dampak Lingkungan Industri Tahu Menggunakan Life Cycle Assessment (Studi Kasus : Pabrik Tahu Sari Murni Kampung Krajan , Surakarta),” vol. VI, no. 4, pp. 2337–2347, 2021.

[26] Klopffer and Wagner, *4 Life Cycle Impact Assessment*. 2014.