Analysis Of Environmental Impact With The *Life Cycle Assessment* (LCA) Method On Tofu Production

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Abstract

Tofu is a typical Indonesian food. The tofu production process has its own impact on the environment because the rest of the production results in solid and liquid waste. If the processing or utilization of the waste products is not carried out, it will pollute the surrounding environment. The aim of this research is to identify the environmental impact of the tofu production process. The method used in this research is the method of mixed method simapro program assisted 7. From the results showed that the production process knows it can cause environmental pollution, it is seen from the damage category. Score a single score of 4076,345 Pt, with an environmental impact of Human Health of 1701.54 (41.7%), Ecosystem Quality of 1409.057 (34.6%), and Resources of 965.7484 (23.7%). Based on research results of several categories of the study, obtained on alternative improvements to reduce environmental impact by replacing firewood with biogas as fuel.

Keywords : Biogas, *Life Cycle Assessment* , *Environmental Pollution, Production Know, SimaPro*

I. INTRODUCTION

The role of small industries in several areas of Semarang Regency is very important in supporting the economy, especially around these industrial locations. One small industry that has the potential to develop is the tofu industry [1]. Tofu is a typical Indonesian food. The production of tofu is occupied by most of the Indonesian people, because it can be produced without the need for large and complicated tools.

On the other hand, the tofu production process has its own impact on the environment, because it is the residue of the production (waste). Waste is the remainder of a business and / or activity[2]. Solid waste from the tofu industry in Indonesia is known as tofu dregs. Tofu dregs are the residual juice of soybean pulp and still have a relatively high nutritional content [3]. Tofu liquid waste contains high levels of organic compounds and will pollute the environment and endanger human health if discharged into rivers without undergoing a waste treatment process [4].

From the explanation above, if the waste produced from the tofu production process is not processed or reused, it will pollute the surrounding environment, living things, plants, animals, soil and air. Continuous production process which does not see its effect on the surrounding environment, it will be an imbalance of nature and ecosystems. Pollution on land, air, sea or river, or other natural disasters [5]. The advantage of LCA is that it is comprehensive because it is able to analyze the potential environmental impacts on processes involved in the life cycle of a product [6]. With LCA, it can be seen that the resources used (input) of a process and the materials produced (output) of a process [6].

Life Cycle Assessment (LCA) is a tool or method for identifying environmental impacts with several stages of analysis. *Life cycle assessment* (LCA) is a method or tool used to analyze the environmental impacts that occur as a result of the manufacturing process of a product. The advantage of LCA is that it is comprehensive because it is able to analyze the potential environmental impacts on processes involved in the life cycle of a product. With LCA, it can be seen that the resources used (input) of a process and the materials produced (output) of a process [7]. The focus of LCA is usually on contributions to regional and global scale impacts, including resource consumption [8]. Life Cycle Analysis (LCA) or often called Life Cycle Assessment is a cradle to grave based method (analysis of the entire cycle from the production process to waste treatment) which is used to determine the amount of energy, costs, and environmental impacts caused by the product life cycle stages. starting from the time of taking raw materials until the product is finished being used by consumers. Every step of the LCA is described in international standards (ISO 14040, ISO 14041). This step is always repeated, with the level of detail and effort depending on the research objectives (World Business Council for Sustainable Development, 2002). These steps are: (1) defining objectives and scope, (2) inventory analysis, (3) impact analysis / assessment, (4) interpretation (ISO 14040, 2006) [9].

The purpose of this study is m enganalisa the environmental impact of the production process knows, m engidentifikasi factors that influence the environmental impact, and m emberikan recommendations for improvement to reduce the negative environmental impact.

II. METHODS

The research took place from March to July 2020. The research was conducted in one of the tofu production process in the Veteran Jaya Village, Martapura District, East OKU. Data collected from primary data derived from interviews and observations. The research approach used both quantitative and qualitative *methods* (*mixed method*). Mixed Methods Research (MMR) is a research method that is applied when the researcher has questions that need to be tested in terms of *outcomes* and processes, and involves a combination of quantitative and qualitative methods in one study. Because it focuses on outcomes and processes, MMR design is commonly used in program evaluation research [10]. The stages of the LCA method used are the LCA procedure according to ISO 14040 which consists of four stages, namely *goal and scope definition*, *life cycle inventory*, *life cycle impact assessmen* , and *interpretation* , assisted by the Simapro program.

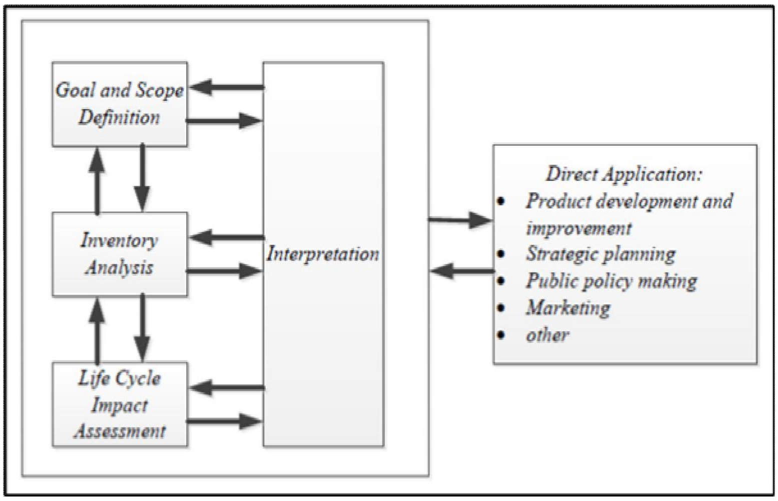

Fig. 1. Phase *Life Cycle Assesment*

III. RESULT

Tofu Production Process

Fig 2 communicating groove production processes that occur in the industry know. The tofu production process begins with soaking and washing the soybeans for 2–3 hours, followed by milling using a diesel-powered mill, so that it will produce pulp. The next process of cooking aims to improve taste and aroma, kill bacteria, and facilitate protein coagulation. After becoming slurry, it is filtered. Filtering aims to separate the soybean juice from the pulp, to produce an extract. The result of the extract was added with vinegar so that it would clot, and the tofu was ready to be printed.

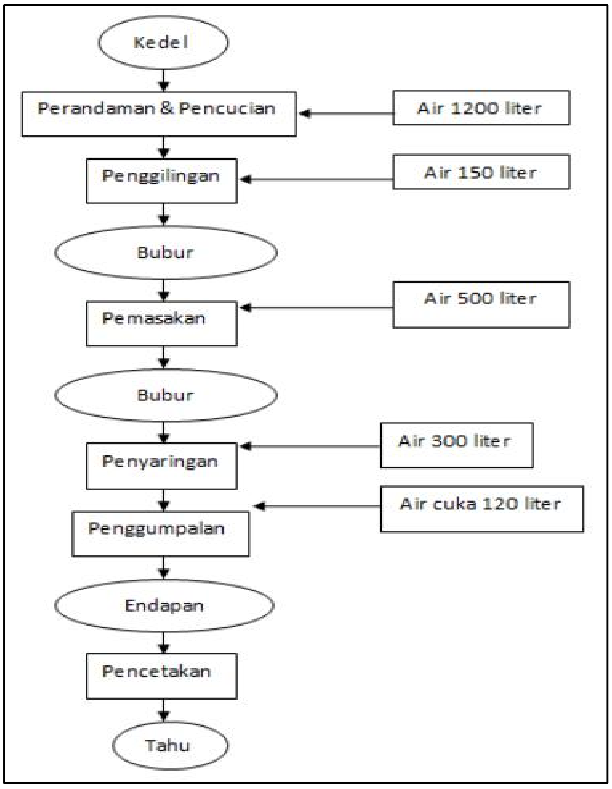

Fig. 2. Tofu Production Process Flow

IV. *LIFE CYCLE ASSESSMENT* DATA PROCESSING

In processing the *Life Cycle Assessment* data, this stage is assisted by using the SimaPro 7 *Software*. The following is a table of *Input Output* in the production process.

Table 1 . *Input Output*

	Input	*Output*
Data Material Proses Produksi	Kedelai	4,200 Kg
	Air	64,500 Liter
	Asam Cuka	3,600 Liter
Konsumsi Energi Solar	Energi Solar	2,150.1 MJ
Konsumsi Energi Kayu Bakar	Energi Kayu Bakar	441,000 MJ
Energi Listrik	Natural Gas (listrik)	18.019 kWh

V. RESULTS OF DATA PROCESSING

Several stages are carried out in the impact assessment, among others, namely *characterization*, *normalization*, and *Single Score.* From the results of table 2 above, then *characterization is* carried out , and results in the value in table 2 .

Table 2 . Table of *Characterization* Value

Impact Cateegory	Total	Material	EnergiListrik	EnergiBiomassa	EnergiSolar
Carcinogens	100 %	22.10144	0.0000012324166	77.85999	0.038575
Resp. organics	100 %	48.23993	0.004501	50.9011	0.854473
Resp. inorganics	100 %	7.544798	0.012637	91.5312	0.911366
Climate change	100 %	41.18592	0.158435	56.394	2.261646
Radiation	100 %	35.65536	0	64.28713	0.05751
Ozone layer	100 %	71.7393	0	26.66805	1.592651
Ecotoxicity	100 %	21.50833	0.0000012138127	78.44397	0.047707
Acidification/ Eutrophication	100 %	10.17899	0.024015	88.19351	1.603485

Land use	100 %	65.28123	0	34.71093	0.007836
Minerals	100 %	44.4057	0	55.50908	0.085201

Table 2 above explains the percentage results of material and energy use against 10 categories of environmental damage impacts. The use of biomass energy has the highest impact on damage in 8 impact categories including *carcinogens, respiratory organic, respiratory inorganic, climate change, radiation, ecotoxicity, acidification / eutrophication, Minerals*, while the use of manufactured materials has an impact on environmental damage in the *Ozone layer* and *Land* Use categories. The consumption of electricity and solar energy has a low percentage which does not really have an impact on environmental damage around the tofu production process. The table above can also be illustrated in Figure 3.

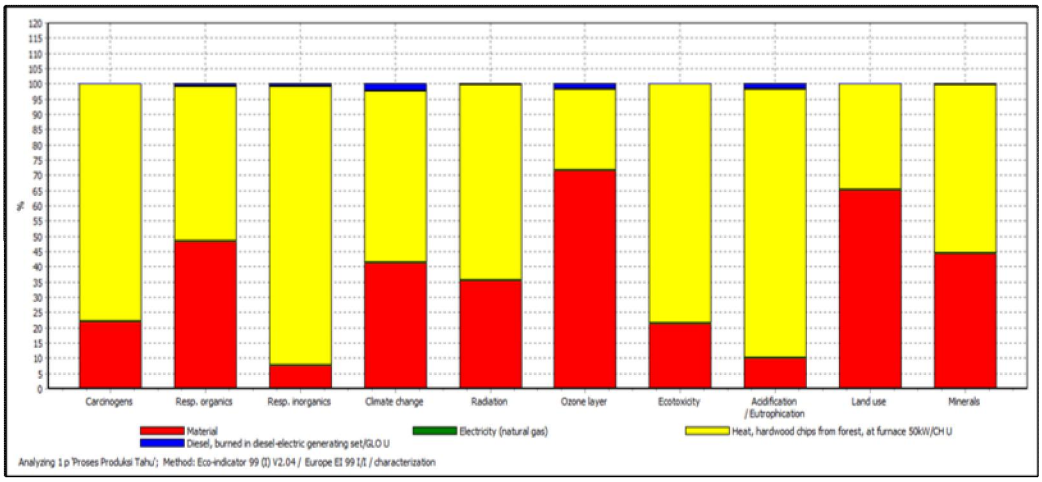

Fig. 3. *Characterization* diagram

Normalization value is obtained by dividing the *characterization* value by the *reference* value (normal). The result of the division is the value *impact category* in which the value of having a uniform unit, so that the value of *impact category* can be compared with one another in table 3 and drawing four.

Table 3. Table of *Normalization* Values

Impact Cateegory	**Total**	**Material**	**Energi Listrik**	**Energi Biomasa**	**Energi Solar**
Carcinogens	0.109013	0.024094	0.000134350	0.084878	0.0000420518
Resp. organics	0.004572	0.002206	0.000205794	0.002327	0.0000390662
Resp. inorganics	2.776564	0.209486	0.000351	2.541422	0.025305
Climate change	0.202778	0.083516	0.000321	0.114354	0.004586
Radiation	0.000632	0.000225	0	0.000407	0.0000363687
Ozone layer	0.000151	0.000108	0	0.0004019677	0.0000240060
Ecotoxicity	0.069987	0.015053	0.000849506	0.0549	0.0000333888
Acidification/ Eutrophication	0.246984	0.02514	0.000593130	0.217824	0.00396
Land use	5.319256	3.472476	0	1.846363	0.000417
Minerals	4.828742	2.144237	0	2.680391	0.004114

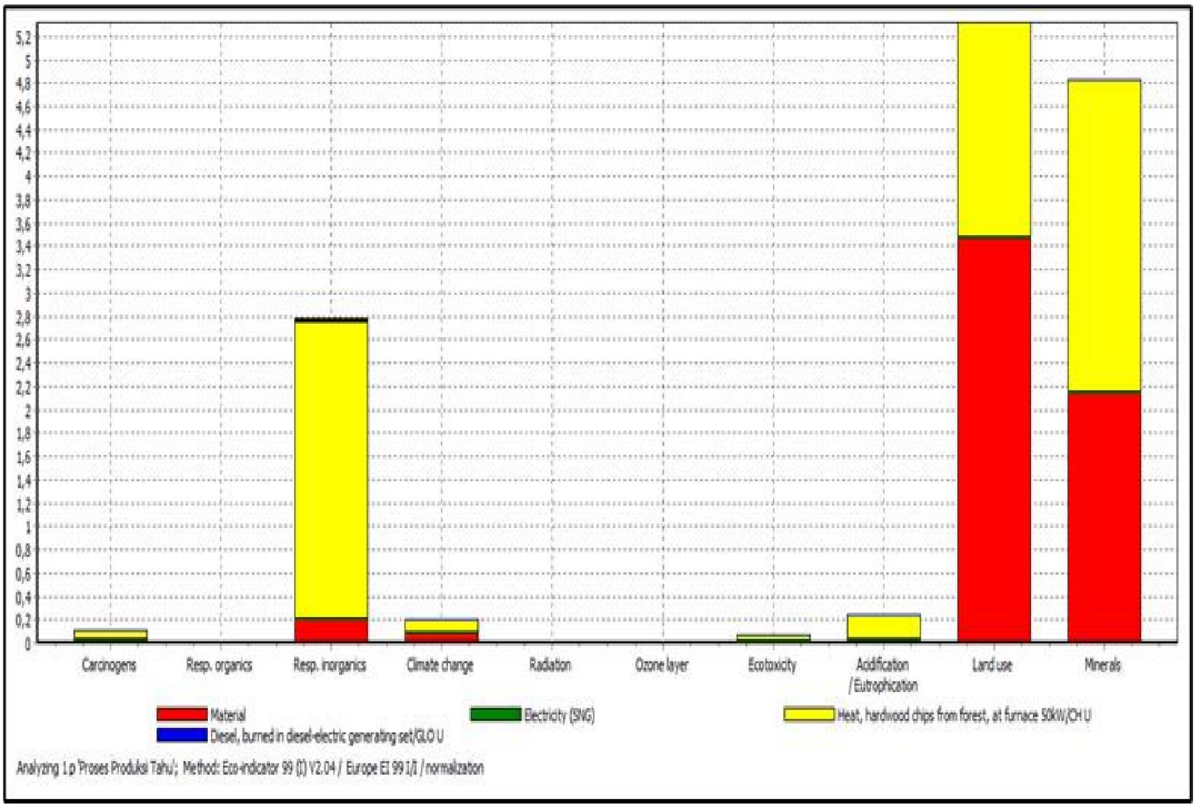

Fig. 4. *Normalization* Value Diagram

From table 3, data on the contribution of each process that has an impact on the environment is obtained , the environmental impact categories are obtained from the largest to the smallest , namely *Land Use, Minerals, Resp. Inorganics, Acidification / Eutrophication, Climate change, Carcinogens, Ecotoxicity, Radiations, Resp. Organics,* and the *Ozone Layer* . On the production knows, this category is caused by use are na an firewood taken from the garden / forest and pulp from the processing of soybeans. The smallest environmental impact is the *Ozone layer*, the damage to the ozone layer occurs due to the emission of gases containing chemicals. In the production of tofu, it only uses acetic acid which has little potential to damage the ozone layer.

At the *single score* stage, there is a grouping of environmental impact categories based on the types of losses incurred. These groups include *human* losses, *ecosystem quality*, and *resources*. In *human health* consists of impact categories *carcinogens, respiratory organics, inorganics respiratory, climate change, radiation,* and *ozone layer*. Then *ecosystem quality* consists of *ecotoxicity, acidification / eutrophication,* and *land use*. Meanwhile, the *resources* consist of *minerals* and *fossil fuels*. All potential environmental impacts based on the method *of eco-indicator* 99 is converted into a *single score* or value tu provision of furniture. The *single score* for each *Damage Caegory is* shown in Table 4.

Table 4. Results of *Single Score* Based on *Damage Category*

Damage category	***Unit***	***Total***	**Material**	**Energi Listrik**	**Energi biomassa**	**Energi Solar**
Total	Pt	4076.345	1482.814	0.384622	2574.735	18.41152
Human Health	Pt	1701.54	175.799	0.369793	1508.885	16.48605
Ecosystem Quality	Pt	1409.057	878.1673	0.014828	529.7719	1.102646
Resources	Pt	965.7484	428.8474	0	536.0781	0.822825

Based on table 4, the *single score* results show *the* categories of environmental damage from the highest to the lowest, respectively *Human Health*, *Ecosystem Quality*, and *Resources,* which shows the biggest energy impact is also shown illustrated in Figure 5.

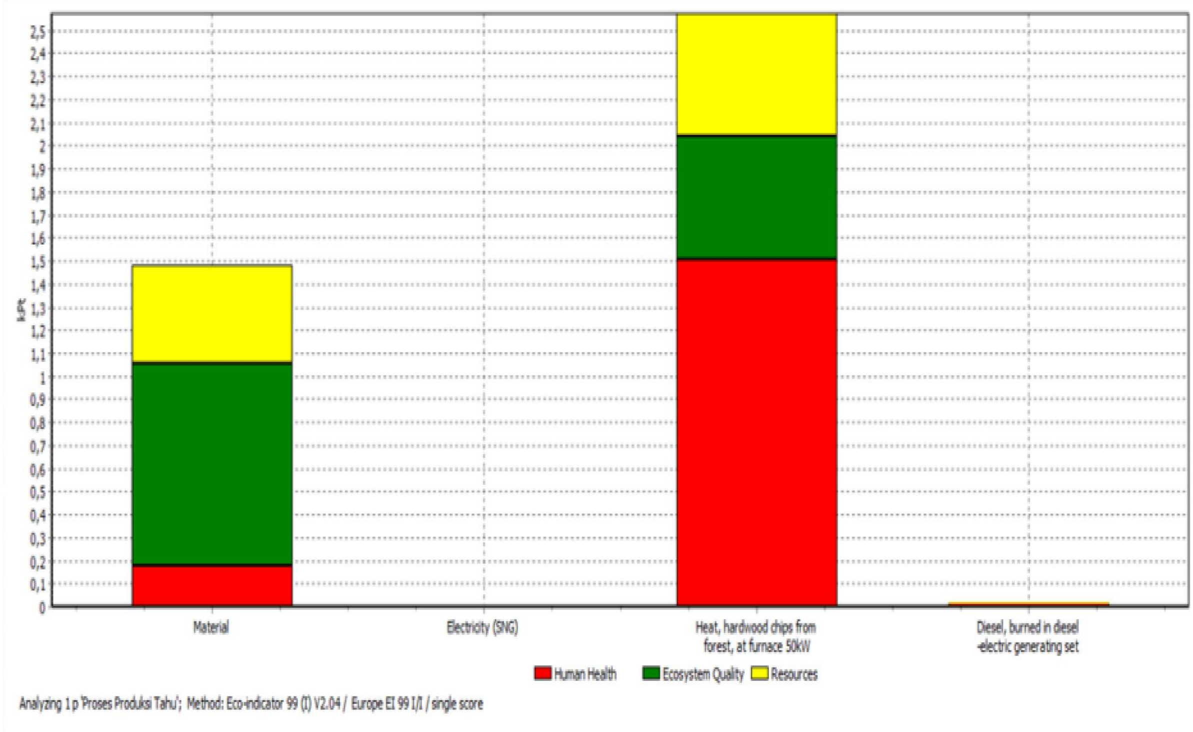

Fig. 5. *Single Score* Graph of Environmental Impact

Based on Figure 5 illustrates some of the factors that most contribute to the environmental impact of the tofu production process are:

1. The use of firewood as fuel in the soybean cooking process, where the amount of firewood used in June 2020 reached 60 m^3 or 60,000 kg with a previously calculated energy period of 882,000 MegaJoules.
2. Production waste in the form of tofu dregs up to 190 kg / day and waste water from the production process.

Impact Assessment on the environmental category of environmental damage derived from the highest to lowest as follows:

a. Environmental Impact Analysis on *Human Health*
Based on the results of the *Normalization* value in the production process, it is known that the greatest impact is influenced by fuels in the form of diesel, electricity, and firewood. The main contribution dam pa k environment h *uman health* is the use of machine katel steam that generates a huge carbon dioxide from the burning of wood, especially in the respiratory tract.

b. Environmental Impact Analysis on *Ecosystem Quality*
Based on the results of the *Normalization* value in the production process, it is known that the impact of e *cosystem quality* is most affected by the use of chemicals and waste generated from the production process , namely the waste water from mixing water and vinegar which is flowed directly into the river which results in a deterioration of water quality plants in the surrounding environment.

c. Environmental Impact Analysis on *Resources*
Based on the results of the value of *Normalization* in the production process knows that impact most on the *resources* affected by the use of resources is done repeatedly, that the use of wood fuel that reaches 2 m^3/day, and does not guarantee environmental sustainability.

VI. ALTERNATIVE REPAIR

Alternative improvements are made to reduce the *impact* of a production process on the surrounding environment. In the calculation of *the single score is* known to the highest environmental impact lies in *Human Health* (Human Health) caused by the use of firewood taken directly from the garden / forest and waste produ results k si. The use of firewood in the tofu production process in this study is not good because the impact on the surrounding environment is quite high and affects the impact of damage to the surrounding environment. An alternative improvement that can be done is to replace the fuel in the form of firewood to be replaced by biogas fuel.

Biogas is a solid, liquid or gas fuel produced from organic materials. Biogas can be produced directly from plants or indirectly from industrial, commercial, domestic, or agricultural waste. The choice of biogas as an alternative is because the tofu production process produces tofu dregs that reach 190 kg / day. The tofu waste can be used and processed into biogas. The scenario of using biogas in the tofu production process has been tested on SimaPro *Software*. The replacement of energy sources from firewood to biogas is carried out in the cooking process of soybeans. For many biogases is used, do the conversion equation of biogas with firewood, 1 m^3 of biogas is equivalent to 3.5 kg Wood (Pamilia Coniwanti and Anthon, 2009).

It can be seen that the comparison of the use of biogas and wood against its environmental impacts is seen in Figure 6 and Table 5.

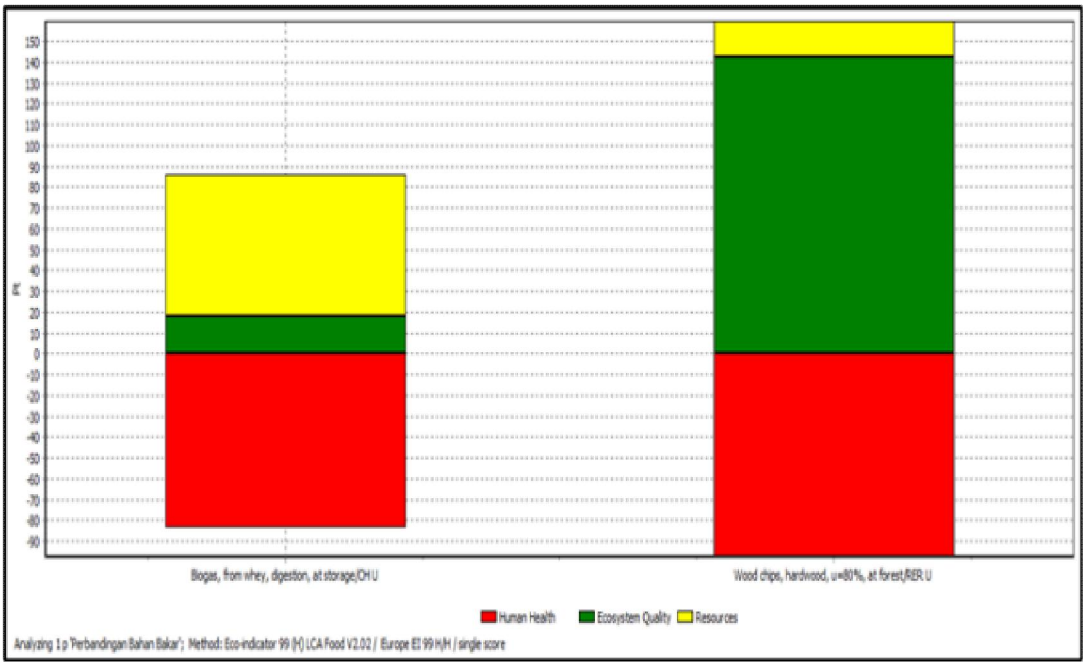

Fig. 6. Comparison Graph of Biogas and Firewood

Table 5. *Single Score* Comparison of Biogas and Firewood

Damage category	*Unit*	*Total*	Biogas	Kayu Bakar
Total	Pt	172.1927	101.5039	70.68882
Human Health	Pt	-148.32	-53.4752	-94.8447
Ecosystem Quality	Pt	181.1951	38.01397	143.1811
Resources	Pt	139.3175	116.9652	22.35239

Based on the single score, it is known the value of each damage category based on the use of biogas and firewood.

1. Human Health. In the Human Health categoryitem the use of biogas results in a low environmental impact with a value of -53.4752 compared to fuelwood with a value -94,8447.
2. Ecosystem Quality. In the Ecosystem Quality category, the use of biogas has a low environmental impact with a value of 38.013 compared to firewood with a value of 143.181.
3. Resources. In the Resources category, the use of biogas produces environmental impacts with a value of 116.9652 while firewood with a value of 22.352.

The advantages and disadvantages of using firewood are as follows:

1. Advantage
   a. Saves production costs because firewood is taken directly from one's own garden / field.

   b. Food cooked using firewood has a more delicious taste than fuel.
2. Loss
   a. If taken continuously without sustainability, it will cause natural disasters such as landslides, floods, and so on.
   b. Air pollution is very high so that replacing the g gu gas exchange, plant growth, development of animals, and the human respiratory tract.

The use of biogas also has the following advantages and disadvantages:

1. Advantage
   a. The community does not need to cut trees for firewood.
   b. The cooking process is cleaner and healthier because it doesn't emit smoke.
   c. Can reduce greenhouse gas emissions by reducing the use of wood fuel.
   d. Being one of the alternative processing a waste, because reusing the results of the production process.
2. Loss
   a. Requires more funds for applications in the form of a biogas installation.
   b. Not very well known to the public

Based on the above comparison, it is known that the use of biogas can reduce the environmental impact that was previously caused by the use of firewood.

VII. CONCLUSION

Based on the results of data processing and analysis, the following conclusions can be drawn.

1. Based on the results of the processing of *the Life Cycle Assessment* on the production process out using the *software* SimaPro 7, earned value *single score* of 4076.345 Pt, with the environmental impact *Human Health* at 1701.54 (41.7%), *Ecosystem Quality* of 1409.057 (34, 6%), and *Resources* 965.7484 (23.7%).
2. Several factors that have an impact on the environment include the use of wood fuel in the soybean cooking process and the waste from the tofu production process.
3. Based on the environmental impact, recommendations for improvement are obtained by replacing wood fuel with biogas fuel which has a low environmental impact because it is made from tofu pulp itself.

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