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The implementation of life cycle assessment (LCA) in the processing industry Tofu: A case study of Konawe Selatan district, Indonesia

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Abstract

This study aims to determine the impact on the environment caused by the production of tofu using the Life Cycle Assessment (LCA) method in the tofu processing industry in the South Konawe Regency, Indonesia. The research location was determined purposively. The research subjects were the parties involved in the research, namely processing industry voters, while the object in this study was tofu processing using the Life Cycle Assessment (LCA) method. Data collection was carried out by interview and documentation methods. The results showed that the total greenhouse gases (GHG) emissions from the life cycle of 1 kg of tofu products were 1.4343 kg CO_2-eq. The emission value is due to the input inventory at the transportation stage, the extraction of soybean raw materials, which is the main cause for tofu products producing high emissions compared to other inventory results. The scenario for improvement at the transportation stage is to substitute fuel oil (BBM) with gas fuel (BBG) for truck, pick-up, and motorbike transportation. Improvement scenarios at the tofu processing stage, including the utilization of tofu liquid waste biogas, replacing the furnace with a boiler, and reducing electricity consumption for washing soybeans. Through the application of these alternatives will have the potential to reduce greenhouse gases (GHG).

Keywords: Tofu, Tofu industry, Environmental impact, LCA

1. Introduction

Soybean is one of the important food crops in Indonesia after rice and maize. This commodity is getting more attention from the government in national food policy. Soybeans also contain 30-50% protein, and 15-25% fat, as well as several other important nutrients. Soybean plants can also be used as raw material for various industries for food, beverage, green fertilizer, animal feed, and for their oil extraction [1]. Based on data. The increase in soybean production is due to the increasing area of soybean harvested and the development of soybean production in Indonesia which is still low when compared to the main soybean producing countries in the world. One of the foods made from processed soybeans is tofu, which continues to innovate, from fried tofu which is sold on the side of the road to now and is also available on food menus in large restaurants. Indonesian people are less interested in consuming soybeans directly without being processed first, they prefer processed products, one of which is tofu. In Indonesia, the production of tofu in 2013 was higher than the production of tempe and there were more types [2]. Food supply chains use large amounts of fossil fuels and other non-renewable resources, as well as water and land, which have a profound impact on our environment. The food supply chain is also a complex system, and the evaluation needs to study the entire system, from primary production to end-of-life food waste solutions [3]

Fulfilling the demand for products every day makes the production process pay less attention to the impact of the production process on the environment. If the production process in the tofu processing industry is not properly monitored, it can produce a very large amount of environmental impact. The results of this environmental impact can cause harm to human health, natural sustainability, and reduced natural resources. In the case of the tofu processing industry, the production process is carried out every day so that the resulting environmental impact will appear every day. Another problem arises in the tofu processing industry related to environmental issues regarding the results of the tofu production activities itself. Tofu producers, which are generally classified as home industries or UMKM, have not been able to make improvements, starting from the collection of raw materials using transportation, the production process to handling the resulting waste. This has the potential to contribute to the increase in greenhouse gases (GHG) each year. GHG is a gas that can lead to increased heat on the earth's surface (global warming) [4]. GHGs in the tofu industry that has the potential for global warming is carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The tofu production process has its own impact on the environment, which is why the production residue (waste). Waste is the remainder of a business and/or activity [5]. Solid waste from the tofu industry in Indonesia is known as tofu dregs. Tofu dregs are leftover from soybean pulp and still have a relatively high nutritional content [6]. 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 [7].

Tofu waste is the waste produced in the process of making tofu. The waste produced is in the form of solid and liquid waste and gas. The impact of solid waste on the environment has not yet been felt because it can be used for livestock feed, but the liquid waste will cause a bad smell and if it is disposed of directly into the river it will pollute the river. Water pollution is caused by the entry of pollutants in the form of waste gas and dissolved materials. Pollution enters water bodies in various ways, for example through the atmosphere, soil, agricultural runoff, domestic and urban wastes, and industrial waste disposal [8]. The method of treating tofu liquid waste is classified into 3, namely (1) physically; a method of separating a portion of the pollution load, in particular, suspended solids or colloids from wastewater by utilizing physical forces; (2) chemical: methods of removing or converting pollutant compounds in liquid waste by adding chemical substances or other chemical reactions; and (3) biologically: reducing levels of dissolved organic substances by utilizing microorganisms or water plants [9]

Continuous production processes that do not see the effect on the surrounding environment, there will be an imbalance between nature and the ecosystem. Pollution on land, air, sea or river, or other natural disasters [10]. The advantage of LCA is comprehensive because it can analyze the potential environmental impact of the processes involved in the life cycle of a product produced. With LCA, it is hoped that it can be seen that the resources used (input) of a process are carried out and the material produced (output) from a production process [11]. Currently, various environmental impact assessment methods can be used for a food product produced by an industry. One of them is the Life Cycle Assessment (LCA) method which is increasingly being used in assessing the environmental sustainability of various products. LCA is a mechanism for analyzing or evaluating and calculating the total environmental impact of a product at every stage of its life cycle, starting from raw material preparation, production process, sales and transportation, and product disposal (ISO14040: 2006). The results of the LCA can be used as a basis for decision-making by policymakers, producers, and consumers in choosing products and production processes that are environmentally sustainable.

According to [12] life cycle assessment (LCA) is a method that can be used to evaluate the environmental impact caused by a product during the production process or product life cycle activities and the flow of materials that occur in the production process. The data needed in conducting LCA consists of environmental impacts, by-products, energy consumption, and materials used at each stage of the process. Using the life cycle assessment (LCA) method is expected to assist the industry in implementing an environmentally friendly industry. Several studies conducted using LCA have been conducted, both focused on principles, challenges. and opportunities for LCA applications [13,14,15-26] or include life cycle assessment (LCA) applications for existing materials [27,28], building and construction [29-34], food [35], transportation [36,37], energy sources among others: bioenergy energy [38-45], solar energy [46-49], wind energy [50-53], and geothermal energy [54], and electricity generation [55-57]. The advantage of implementing life cycle assessment (LCA) is that it is comprehensive because it can analyze the potential environmental impact on the processes involved in the product life cycle. With the application of life cycle assessment (LCA), it can be seen that the resources used (input) of a process and materials produced (output) of a process [58]. The focus of life cycle assessment (LCA) is usually on contributions to regional and global scale impacts, including the consumption of resources [59]. This fact is what encourages researchers to research the Application of Life Cycle Assessment (LCA) in the Tofu Processing Industry in Konawe Selatan Regency, Indonesia.

2. Materials and methods

2.1 Subject and object

The subjects in this study were the owners of the tofu processing industry in Konda District, South Konawe Regency. Research subjects are the parties involved in the research. In this case, they are those who act as providers of information related to the research conducted [60]. The object in this research is tofu processing using the Life Cycle Assessment (LCA) method in the tofu processing industry in Konda District, South Konawe Regency, Indonesia. (c) documentation. The research approach uses quantitative and qualitative methods.

2.2 Analysis of tofu processing industry using the LCA method (life cycle assessment)

The International Organization for Standardization (ISO) introduced principles, frameworks, and basic requirements addressing each phase of life cycle assessment (LCA) adoption in 1997 [61,62]. It was extended in the late 90s onwards to four phases of life cycle assessment (LCA) application, including objectives and scope definition and life cycle inventory analysis (LCI) [63], life cycle impact assessment (LCIA) and interpretation [64], which was later revised and replaced by two shorter but more concise documents, ISO 14040 and ISO 14044 [65,66]. An elaboration of the History of Standard development can be found in [67,68], in addition to a summary of changes reported by [69]. Life Cycle Analysis (LCA) or often referred to as Life Cycle Assessment is a cradle to the 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 taking raw materials to finished products used by consumers. Each step of the life cycle assessment (LCA) is described in international standards (ISO 14040, ISO 14041). These steps are (1) setting goals and scope; (2) inventory analysis; (3) determination of impact, and (4) determination of improvement (ISO 14040, 2006) [70].

2.2.1 Goal and scope determination

Setting goals and scope is the first step in an Life Cycle Assessment (LCA) method in setting clear references and boundaries in its implementation so that it can answer the problems to be resolved. The goals of this LCA study include sections of the research objectives previously mentioned. The scope or scope of the product life cycle chosen includes the collection of raw materials using transportation (soybeans) and supporting materials (vinegar and firewood), processing soybeans into tofu products, and handling production waste.

2.2.2 Inventory analysis

The purpose of the inventory is to show the environmental effect per part of the life cycle of tofu products. Inventory Analysis is also carried out by taking an inventory of all input and output flows involved in units and energy in tofu products. Inventory Analysis is good for finding areas that have a great opportunity to improve environmental quality through the conservation of resources and reducing emissions. This stage is the most intensive and requires more time due to data collection. Data collection can take a little time if the existing database is well available and clear.

2.2.3 Impact assessment

At this stage, grouping and assessing the effects on the environment are carried out based on the data obtained at the Inventory Analysis stage. This stage consists of three main steps, namely characterization, normalization, weighting. Characterization provides a way to directly compare the LCI results in each category. The characterization factor is often referred to as the equality factor. Normalization aims to provide relative magnitudes of potential impacts and resource consumption/use, as well as to present results in a form suitable for final weighing and decision making. The normalization stage can be calculated by dividing the characterization result by the normalization value. To compare various potential environmental impacts, judgments must be made by categories relative to one another. This can be done by weighting. Weighting can be done by multiplying the results of normalization or the impact of normalization of the potential value by the weight factor. After the weighting step, all potential environmental impacts are converted to a single score.

2.2.4 Determination of repair

Determination of improvement is the interpretation stage of all the previous stages. This interpretation will later lead to improvements to reduce the environmental impact of the product being observed. At this stage, the results from the previous Life Cycle Assessment (LCA) phase are compared with the research objectives stated in the definition of objectives and scope.

3. Results and discussion

3.1 Goal and scope determination

The application of this Life Cycle Assessment (LCA) is carried out in the tofu processing industry which produces 2 types of products, namely tempeh, and tofu. Both products are made from soybeans. This study only focused on tofu products for the application of Life Cycle Assessment (LCA). The scheme of applying Life Cycle Assessment (LCA) to the tofu processing industry can be seen in Figure 1.

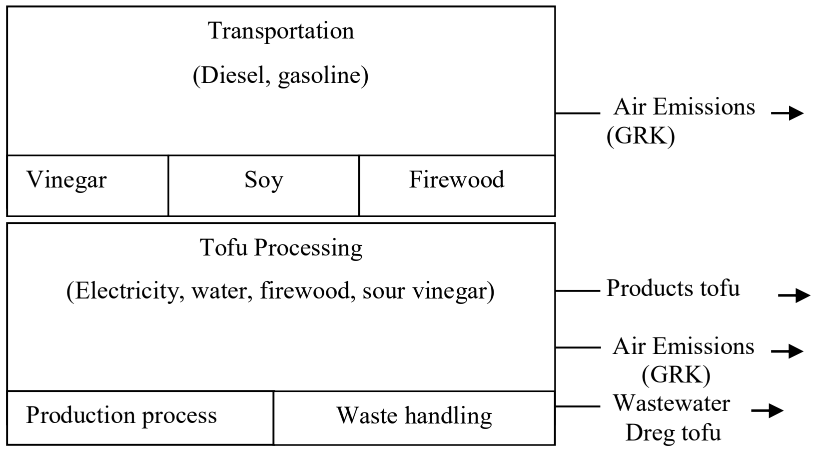

Figure 1 Product life cycle scheme know.

The life cycle of tofu products shown in Figure 1 shows the limitations of this Life Cycle Assessment (LCA) study, starting from the transportation of soybean raw materials to making tofu products, such as vinegar and firewood to the end of the tofu production process.

3.2 Inventory analysis

Analysis of the life cycle inventory of tofu products begins with the raw materials for soybeans. The soybeans used by the tofu processing industry originate from the Baruga market in Kendari City. The soybeans are distributed to the tofu processing industry using trucks heading to Konda District where the tofu processing industry is located. Apart from the transportation of soybeans, there is also transportation of supporting materials in the form of acids and firewood which will be needed in making tofu. Tamarind is transported using a motorbike with sour gasoline purchased from a traditional market located in Baruga, while firewood is transported using a gasoline-fueled pick-up car located in Cialam Jaya Village, Konda District. The tofu processing industry does not collect data related to fuel consumption for transportation and some transportation involves outsiders, so it is assumed that the amount of fuel use is calculated based on the fuel consumption of each km distance traveled using this mode of transportation in a period of one month or 30 days. Maps (google maps) can be used to estimate the distance that will be traveled in the transportation of these materials. The following inventory analysis is the tofu production process. The tofu production process in the tofu processing industry is similar to the tofu making process in general, it's just that the hygienic and environmental aspects are things that must be considered in every production process.

The hygienic aspect of making tofu can be seen from the use of its tools, which almost all use simple equipment, for example, in the cooking process, soybeans still use used barrels that are modified again so that they are easy to use, wherein terms of health it is still less good than if the equipment is made from stainless steel. it is still very rarely used by conventional tofu factories, even though the material is of course no doubt its cleanliness. Making tofu in the tofu processing industry has several stages, starting from soaking, the soybean is muted for about 3 hours, then the soybeans are milled, then boiled, when boiling the additional ingredients of tofu are added, namely acid, when it is boiling then separated the dregs with the juice, the juice is then which is printed into tofu products. The materials that enter (input) in the production system are soybean raw materials, vinegar, firewood, water for production, and electricity, while the materials that come out (output) from the system are in the form of tofu and solid and liquid waste products. Inventory of the production process stage that can have an impact on the environment is each consumption of electricity and firewood. Firewood is used in the process of boiling soybeans and boiling water and pumping machines to supply production water. Firewood can have a direct impact during its use, while the electricity that is calculated as an impact comes from the provision of the power source used (IPCC 2014). The results of the tofu processing industry inventory analysis can be seen in Table 1.

Table 1 Analysis of tofu product life cycle Inventory.

Inventory	Unit	Amount per kg tofu
Solar	Liter	0,0046
Firewood	Kg	0,0007
Acid	Kg	0,0075
Solid Waste (Dregs)	m^3	0,3850
Liquid Waste	m^3	0,0005
Electricity	KWh	0,3600

The life cycle inventory analysis of tofu products in Table 1 shows that each tofu production requires a large amount of water which can be seen from the amount of electricity consumption because water is obtained from suctioning well water using a pump machine. the amount of use of electricity, firewood, vinegar, and water causes the number of soybeans produced to consume a lot of energy. The use of these ingredients is directly proportional to the number of soybeans used. In addition, there is an additional use of fuel for the transportation of solid waste in the form of soybean dregs. Transportation using a gasoline-fueled pick-up car is carried by a second party, namely goat and cattle breeders located in the Cialam Jaya area.

3.3 Impact asessment

Impact assessment is the next stage to determine the magnitude of the impact generated by the product. The impact assessment is carried out on tofu products, the magnitude of the impact on these products is analyzed through greenhouse gases (GHG) calculations and the level of energy efficiency. Carbon dioxide (CO_2) emissions, each greenhouse gases (GHG) emission such as CO_2, CH_4, and N_2O will be converted into CO_2 equivalent (CO_2-eq). CO_2-eq can be interpreted as the description of several greenhouse gases in a common unit. The amount of CO_2-eq shows the total CO_2 emissions resulting from the amount or combination of greenhouse gases (GHG) added by the degree of equivalent impact on global warming [71]. The calculation of the impact of global warming uses a global warming potential (GWP) of 100. The following is the equivalence of greenhouse gases at GWP of 100 according to IPCC (2007) which is presented in Table 2.

Table 2 Equivalence of greenhouse gases in GWP 100 Global Greenhouse Gas.

Greenhouse Gas	Global Warming Potential 100
CO_2	1
CH_4	25
N_2O	298

In this study, greenhouse gas emissions are expressed in terms of kilograms CO_2-eq / kg of tofu products. The level of CO_2-eq emission produced is influenced by several uses in the tofu product life cycle. In Table 2. The equivalence of greenhouse gases in global warming potential (GWP) 100, Greenhouse Gas CO_2 with a value of 1, CH_4 with a value of 25, and N_2O with a value of 298, this value has become a stipulation in global warming potential (GWP). The results of the total calculation of CO_2 emissions from the life cycle of tofu products are summarized in Table 3.

Table 3 Total life cycle emissions of tofu products.

Inventory	Emisi CO_2-eq/kg Tofu	Prensentase
Transportation	0,0144	1,00%
Solar	0,0144	1,00%
Tofu Processing	1,4199	99,00%
Firewood	0,0019	0,13%
Acid	0,0202	1,41%
Solid	0,7219	50,33%
Liquid waste	0,0010	0,07%
Electricity	0,6750	47,06%
Total	1,4343	100,00%

Table 3. shows that the value of kg CO_2-eq / kg of tofu product is 1.4343, this number shows a fairly low number compared to previous research conducted by [72], which is 1,849 kg $C0_2$-eq of tofu products. The table above shows that the processing stages of soybean raw materials lead to high fuel consumption, this can be seen

from the emissions produced at the soybean processing stage, which is 1.4199. The amount of emission from soybean processing is due to the high contribution of electricity use in soybean processing, namely 47.06%. Then the emission that is being produced in the transportation stage of soybean raw materials reaches 1.00%. from the use of firewood for the process of making tofu that is equal to 0.13% and the additive material is acid by 1.41%. Physically, burning firewood produces more smoke and soot than if using LPG gas in the tofu-making process, but the tofu processing industry still uses firewood for the tofu cooking process.

Emissions can also be generated from liquid waste and solid waste from production. Liquid waste emission comes from the remaining wastewater from the tofu production, which can produce high enough methane gas. Methane gas is one of the harmful greenhouse gases, while solid waste comes from the remaining starch of tofu products which is no longer used so that it is solid, solid waste also produces methane gas. Energy efficiency in this Life Cycle Assessment (LCA) study can be determined by measuring the net energy from the tofu product life cycle. Net energy is defined as the amount of energy required and generated from a product life cycle in units of product MJ / Kg. In the tofu product cycle, energy input is needed such as transportation fuel (diesel, gasoline, and firewood for the boiling process, as well as the use of electricity and production equipment. The output produced is in the form of tofu which of course has its own caloric value. The resulting output will be calculated as the amount of calorific energy (MJ) from the respective inventory data. The results of the energy calculation of the tofu product life cycle can be seen in Table 4.

Table 4 Energy product life cycle tofu.

Energy Input	Energy Tofu (MJ/kg tofu)	Persentase (%)
Transportation	0,1646	9,52%
Solar	0,1646	9,52%
Tofu Processing	1,5650	90,48%
Firewood	0,0226	1,31%
Acid	0,2464	14,25%
Electricity	1,2960	74,93%
Total Energy Input	1,7296	100%
Total Energy Output	2,8072	

Table 4 shows the energy value of the tofu product life cycle of 1.7296 MJ / Kg. Tofu, the value of the energy input produced is quite large, which can be seen in the total energy input value in the tofu processing process of 1.5650 MJ / Kg tofu, then in the transportation of collection. raw material of 0.1646 MJ / Kg Tofu (9,52%). Almost not much different from research [72] which was carried out to produce 1 kg of fresh tofu 1.5269 MJ / kg and 9% from transportation [73]. Total energy intake and energy out of tofu products can be seen in Table 5.

Table 5 Total energy intake and energy out of tofu products.

Energy	Tofu
Energy Input (MJ/Kg Tofu)	1,7296
Energy Output (MJ/Kg Tofu)	2,8072
Net Energy Ratio	1,6230
Net Energy Value (MJ/Kg Tofu)	1,0776

Table 5 shows that the input energy is 1.7296 MJ / Kg tofu and the output energy is 2.8072 MJ / Kg tofu and the net energy value is 1.0776 MJ / Kg tofu. The amount of efficiency of the tofu product can be seen from the NER and NEV values. Tofu product has a fairly large energy input value, which is caused by the processing of raw materials which requires a fairly large fuel input. This can be seen from the tofu processing sector, which is 1.5650 MJ / Kg. Meanwhile, the output value is generated from the calorific value of soybean raw material which is converted to MJ / kg. The NEV and NER values produced from tofu products in the tofu processing industry have shown good results. Energy efficiency in the life cycle of this tofu product is said to be good if it has a positive NEV value and a NER value of more than 1 (one). In addition to tofu processing, the transportation process also consumes a large amount of energy, namely the use of vehicle fuel for raw material extraction.

3.4 Determination of repair

The tofu processing industry, which is a cottage industry located in Konda District, Konawe Selatan Regency, Indonesia, has yet to find any opportunities for improvement. There are potential improvements that can be made based on the findings during the observation and the magnitude of the impact calculation. The following are some alternative improvements that can be selected as scenarios for developing the life cycle of tofu products which are viewed better from an environmental perspective. The improvement scenarios can be seen in Table 6.

Table 6 Scenarios for tofu product improvement to tofu processing industry.

No	Improvement scenario	Potential RK reduction (CO_2-eq)	Other benefits	Constraints/Weaknesses
1	Utilization of biogas wastewater from tofu production	Reduces GHG emissions by 3.45% - 5.73%	Replacing the use of firewood with LPG to make it more environmentally friendly	Requires additional costs to use LPG
2	Replacement of fuel stove with boiler cooking system	Reduces GHG emissions by 11.49% to 19.03% (consumption)	Saves 2.82 kg of LPG or the equivalent of 3 kg of LPG per day.	Requires a high investment in the purchase and installation of tools
3	Substitution of gasoline and diesel with CNG and LNG	Reducing GHG emissions by 5% of total soybean tofu emissions	The cost of purchasing fuel is cheaper	There are not many SPBGs available in some places needed to purchase CNG converter kits LNG products have not been produced in Indonesia for domestic consumption. Country
4	Savings in electricity use	Reduce GHG by 0.79% of total tofu product emissions	Save on electricity supply	There are no obstacles

Table 6 shows that if these improvement scenarios are realized, the greenhouse gases (GHG) generated from the life cycle of tofu products made from soybean will be reduced, among other things:

Scenario I: It is hoped that there will be the utilization of biogas from liquid waste from tofu production. The tofu processing industry does not yet have a biogas installation which is usually used as additional fuel for the soybean boiling process. Biogas is usually obtained from the fermentation of tofu liquid waste mixed with cow dung in the biogas plant. Biogas mostly contains methane gas (CH_4), carbon dioxide ($C0_2$), and several other compounds in small amounts including hydrogen sulfide (H_2S), ammonia (NH_3), hydrogen (H_2), and oxygen (O_2). The quality of biogas is determined by the amount of methane gas (CH_4) content, the greater the methane gas in the biogas, the greater the energy produced by the biogas. Biogas is the end product of digestion or anaerobic degradation of organic materials by anaerobic bacteria in oxygen or air-free environment. The largest components of biogas are methane (CH_4, 54 - 80% by volume) and carbon dioxide (CO_2, 20 - 45% by volume) as well as small amounts of H_2, N_2, and H_2S. The density of methane gas is 0.554, its solubility in water is low, at a temperature of 20 °C and a pressure of 1 atm. Methane gas is a stable gas. The process of extraction by microorganisms to decompose organic materials occurs anaerobically. In principle, the anaerobic process is a biological process that takes place in conditions without oxygen by certain microorganisms that can convert organic compounds into methane (biogas). In general, the anaerobic process consists of four steps, namely: hydrolysis, acid formation, acetate formation, and methane formation. Anaerobic processes are controlled by two groups of microorganisms (hydrolytic and methanogens) [74]. Utilization of liquid waste biogas from tofu production can: (a) reduce greenhouse gases (GHG) emissions by 3.45% -5.73%, and (b) replace the use of firewood with LPG to make it more environmentally friendly,

Scenario II: replacement of the fuel stove with a boiler cooking system. A boiler (boiler) is a vessel for producing hot water (steam) that has been used by several tofu and tempe industries for the soybean cooking process. Boilers are considered to have a higher efficiency than using a furnace in the cooking process in various food processed products by 33% and save cooking time by up to 50% [75]. In boiler design, several important factors must be considered so that the planned boiler can work properly as needed. The factors that underlie the selection of the type of boiler are as follows: the capacity used, the required steam conditions, the fuel needed, and the simple construction. The process of boiling soybeans can also be done by using a steam heating system.

This boiling process is carried out in a round tub made of cement or metal, which has a steam heater at the bottom. Hot steam comes from a steam boiler or boiler which is flowed through an iron pipe. The purpose of boiling is to denature the protein from soybeans so that the protein is easily coagulated when the seasoning is added. The endpoint of boiling is marked by the appearance of hot bubbles and the thickening of the soybean solution/slurry. The advantages of boiling using hot steam produced by a steam boiler include: increasing energy efficiency, increasing production capacity, avoiding the scale that occurs in the cooking tub, and avoiding the stink smell of tofu [76]. Replacing a fuel stove with a boiler cooking system can (a) reduce greenhouse gases (GHG) emissions by 11.49% to 19.03% (consumption), and (b) saving 2.82 kg of LPG or the equivalent of 3 kg of LPG per day.

Scenario III: replacement of natural gas (BBG) in the transportation system. The use of natural gas (BBG) for motorized vehicles is one of the scenarios for the government's efforts to reduce emissions from the transportation sector. The advantage of gas fuel (BBG) is that it has a higher combustion efficiency and is more environmentally friendly than using fuel oil so far. In Indonesia, the use of gas fuel (BBG) in the transportation sector is still limited to trans Jakarta buses, reconditioned bajaj, and several other public vehicles. This gas fuel (BBG) conversion policy can be implemented properly through: (a) gas supply; (b) procurement of a conversion kit; (c) infrastructure: SPBG and gas supply system (pipeline and mother-daughter system); and (d) socialization regarding safety aspects. Procurement of conversion kits and SPBG components should be on a domestic basis by encouraging the domestic manufacturing industry. Substitution of gasoline and diesel with CNG and LNG could: (a) reduce greenhouse gases (GHG) emissions by 5% of total emissions of soybean tofu; and (b) the cost of purchasing fuel is cheaper. The gas emission is very small compared to gasoline, the use of gas fuel (BBG) can reduce CO emissions by 95%, CO_2 emissions by 25%, HC emissions by 80%, and NOx emissions by 30%. This will have a positive impact on the environment because it takes part in reducing global warming. Natural gas vehicles (NGV) will save on fuel purchases because CNG prices are much cheaper than fuel prices. NGV users also save on vehicle maintenance because gas fuel (BBG) does not produce crust on the engine and spark plugs are cleaner and more durable, and the exhaust and sound absorbers have a longer life [77].

Scenario IV: saving electricity. Electricity savings contributed to generating greenhouse gases (GHG) 4.64% of the total greenhouse gases (GHG) emissions of tofu products. GHG emissions from electricity use are in the form of indirect emissions, but it is necessary to reduce them to save energy in electricity consumption. One of the facilities that contribute greatly to electricity use is the washing process of soybeans because it uses water that is channeled using electricity [78]. Savings in electricity use in the tofu processing industry can: (a) reduce GHG by 0.79% of the total emission of tofu products; and (b) saving on the cost of providing electricity.

4. Conclusion

Based on the results of research that has been carried out to determine the impact on the environment of the tofu industrial processing process by applying the Life Cycle Assessment (LCA): The total greenhouse gases (GHG) emissions from the life cycle of 1 kg of tofu product are 1.3434 kg CO_2-eq. The emission value is due to the input inventory at the processing stage of soybean raw materials, which is the main reason for tofu products producing high emissions compared to other inventory results, the NER and NEV values for 1 kg of tofu product are 2,7006. Through the value of NER and NEV, if the value is more than one and positive, it shows that the production efficiency is good because of the occurrence of greenhouse gases (GHG) and the highest energy use in the transportation and tofu processing stages so that an improvement scenario is needed. Improvement scenarios at the tofu processing stage, including utilization of tofu liquid waste biogas, replacing tunggku bakar with a boiler, and reducing electricity consumption for washing soybeans. Through the application of these alternatives will have the potential to reduce greenhouse gases (GHG).

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