Global Warming Impacts Study on Tofu Products in Mampang Prapatan Small and Medium Enterprises with Life Cycle Assessment Methods

Bayu Sukmana[a], Isti Surjandari[b], Muryanto[c *], Arief Ameir Rahman Setiawan[c], Edi Iswanto Wiloso[c]

[a]Environmental Sciences School, University of Indonesia, Jakarta, 10430,
[b]Department of Industrial Engineering, Faculty of Engineering, University of Indonesia, Jakarta, 16424,
[c]Research Centre for Chemistry, Indonesian Institute of Sciences, Serpong, 15314, Indonesia.

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Abstract

Global warming issue can be caused by greenhouse gas emissions which come from human activities. Along with the increase of daily needs, humans activities on food production also increase, which include the production of tofu. Tofu is a traditional Indonesian specialty made from soybeans and served as a side dish. The purpose of this study was to determine the impact of global warming from tofu products of Mampang Prapatan's Small Tofu and Medium Enterprises. The method used in this study was the Life Cycle Assessment (LCA) method using SimaPro 8.4 software with a 1 kg tofu as functional unit. The data collected in this study was based on the average data of tofu production for 3 months, from January to March 2018. This include the process of soybean cultivation, transportation for shipping soybeans, and use of water, wood and electricity. The scope of this study is from cradle (soybean cultivation) to gate (tofu products). The results showed that SMEs Mampang Prapatan has the potential impact of global warming with a value of 3.84 kg CO_2-eq, while the value of global warming in the production process with the scenario of waste water treatment and the use of Liquefied Petroleum Gas (LPG) as fuel for boiling pulp was 4.49 kg CO_2-eq. Based on the results of this study, the intervention that can be proposed is to optimize the use of raw materials for production to reduce the impact of CO_2-eq kg global warming.

Keywords: *Greenhouse Gas Emissions, Global Warming, LCA, Tofu*

* Corresponding and main contributor author. Tel.: +6221 756 0929
E-mail address. moeryanto.mrt@gmail.com

1. INTRODUCTION

Global warming issue caused by greenhouse gas emissions from human activities around the world is the global issue that needs to have a solution to decrease the environmental impact[1], because global warming affects the environment and climate change. Greenhouse gases are a number of gases that cause a greenhouse effect and one of them the dominant gas is carbon dioxide (CO_2)[2]. Regulations related to the limits of greenhouse gas emissions originating from human activities started to be regulated by the government. The Indonesian government made a commitment to tackle climate change, among others, through a commitment to reduce greenhouse gases by 26% with its own efforts and up to 41% with international support in 2020[3]. Presidential Regulation No. 61/2011 concerning the National Action Plan (RAN) declined Greenhouse gases regulation and provided guidance to central, regional, business/private and communities in implementing various activities/programs to reduce GHG emissions on 2010-2020[3]. The regulation described the aim to reduce GRK emissions on 5 main sectors / sectors, namely: (a) forestry and peat land, (b) agriculture; (c) energy and transportation; (d) industry, and (e) waste management.

The advancement of human civilizations will influence energy utilisation, therefore effects of greenhouse gas emissions, especially CO_2, will affect global warming potential faster[4]. By 2050, it is estimated that the impact of global warming will be indicated by the food crisis caused by climate change due to greenhouse gas emissions[5]. Food industry production activities are human activities which are assisted by the use of technology managed by management systems to produce quality food products. The occurring impact of global warming makes countries in the world to commit to emphasise the industrial world, one of which is the food industry which help to prevent climate change by keeping global temperature rise below 2 °C and to reduce greenhouse gas emissions resulting from the process industry[6].

Food security is the one of the important issues for Indonesia[7]. This has become a business opportunity in the food industry. The tofu industry has a high market potential because most Indonesians consume tofu. Tofu is a traditional Indonesian specialty made from soybeans and is served as a side dish with the main food as a source of vegetable protein[8]. The level of consumption of tofu and tempeh in Indonesia reached 18.6 kg/capita/year in urban areas and 13.9 kg/capita/year in rural areas[9]. Based on the level of consumption of foods derived from soybeans, soybean needs are relatively high because it is the raw material for tofu production, therefore Indonesia is the high importer of soybeans[10].

In addition, the tofu industry is required to have a strategy in carrying out the tofu production process; this is in order to protect the environment from these production activities and to adhere with government regulations. The tofu production process has a potential of environmental impacts. The environmental impact that becomes an international issue is the impact of global warming caused by greenhouse gas emissions and resulting in climate change. Climate change is the most serious challenge faced in the 21st century[11].

In the tofu industry, energy plays an important role in several processes for making tofu, some of them are as fuel and electricity. Waste water released from tofu production activities also has the potential for environmental impacts which can pollute the rivers around the industrial area. The policy of waste water treatment is highly necessary to reduce waste water discharge to environment.

The purpose of this study is to determine the impact of global warming from tofu products in Mampang Prapatan Small and Medium Enterprises (SMEs). Modelling was carried out in two scenarios, (i) the utilisation of Liquefied Petroleum Gas (LPG) as fuel and (ii) waste water treatment. LCA method was used to assess the impact of global warming in this study to find out the greenhouse gas emissions released in the production process and the environmental impact from waste water[12].

2. MATERIAL AND METHODS

2.1. Data Source and Product Systems

The research was conducted in tofu SMEs at Mampang Prapatan and managed by Mampang Sub-District, South Jakarta, DKI Jakarta. The location was selected because it is close to the river because therefore waste dumps carried out by SMEs will easily have the potential to cause negative effects on the environment[13]. The study was conducted in January 2018-March 2018. In this study, the data collected includes: soybean raw material data, transportation of raw material, water utilisation, electricity, and firewood as fuel Figure 1).

The data collected in this study was from the average production for 3 months and the data became a sample for production[14]. The inventory data consists of primary data that was taken directly from the tofu industry and secondary data that was obtained from supporting information sources in the tofu industry. Google map website application[15] and sea distance website application[16] were used to calculate distance

between the location of raw materials, distributors, and the factory location[17]. This inventory data was used to analyse global warming effects caused by greenhouse gas emissions and to determine input sources used in the system [18]. Some inventory data was also provided by ecoinvent 3.0 database in the Life Cycle Inventory (LCI) application on SimaPro 8.4 [19] to determine inventory data that was not available in the study location. Based on the obtained data, this study discussed the impact of global warming originated from greenhouse gas emissions released during the production process to make 1 kg of tofu. The mass 1 kg of tofu is considered as a function unit of this study. The function unit is the product unit selected in the study [20].

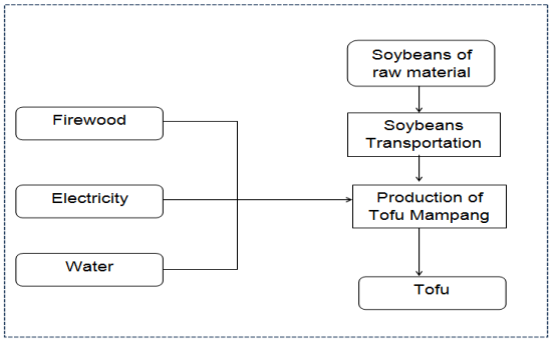

Figure 1. Flow diagram of tofu production in industry Tofu Mampang

This research has boundary system, which is data processed from cradle to gate, starting from data of soybeans raw material which comes from soybeans cultivation in Chicago, US up to the final process where the tofu product is ready for sale by tofu SMEs at Mampang Prapatan.

2.2. Method of LCA

The impact of global warming was analysed in this research using Life Cycle Assessment (LCA) method using International Standard (ISO) 14040[21]. LCA method consists of steps determine the purpose and limitation of the research, life cycle inventory, life cycle assessment, and interpretation. [21]. The input data from the tofu industry was based on the LCA method, in which the data was analysed according to the actual data on the field and inventoried to be analysed based on the research boundaries. The LCA method can also be used as a determinant of implementing appropriate scenarios to address environmental problems [22]. The system boundary on this research is illustrated in Figure 2.

The Environmental Cycle Impact Analysis (LCIA) used in this study is only the single issue impact category, which is Global Warming Potential (GWP 100). The amount of heat trapped in certain gases was compared to CO_2 with the same mass in the period of 100 years. The calculation of the amount of CO_2 –eq emissions per kg referred to the IPCC 2013 GWP 100a as shown in Equation below.

$E = AD * EF$

Where:

E = emission

AD = Activity data

EF = emission factor (kg CO_2 –eq / AD)

The value of emission factors (EF) used in this study were presented in Supplementary Materials (SM) 5 and the calculation method was done using SimaPro 8.4.

2.3. Boundary system

The LCA method was used in this study to analyse the impact of CO_2 emissions generated from the tofu production. Figure 2 shows that 1 batch of tofu production requires 10 kg of soybean raw material and 235 litres of water to produce 27 kg of tofu. There are three types of processes that occur in the production, namely background process, foreground process, and multifunctional process. Background process is a process that is out of the tofu industry's control, such as cultivating soybean on the farm and transporting soybean to the tofu industry. Furthermore, foreground process is a process that is under the control of the tofu industry such as tofu production from raw material to tofu product prior to be sold on the market. This process consists of soaking soybeans, cleaning soybeans, grinding soybeans, boiling soybeans, screening soybeans, making soybeans curd, pressing process, to it finally becomes a tofu product. Whereas the multifunctional process is a process that is capable of producing several product results, this occurs in the soybean screening process which produces co-product of soybean pulp and tofu products. The soybean pulp is classified as a co-product; this is because soybean pulp is re-used as animal feed, and does not become waste that threatens the environment.

This research used primary data based on site and secondary data which was not found in the research location that can be obtained from the ecoinvent 3.0 data which was described in SM 3. Therefore, all of the data was then processed by LCA modelling.

Tofu production produces wastewater during the production process. There are two type wastewater in this industry, namely top wastewater and bottom wastewater. Top waste water is waste water containing soybean skin. Soybean skin is the output from the soaking process of soybeans. Recently, this waste is directly discharged into the river. Furthermore, bottom waste water is waste water originating from several stages of the process in tofu product and this waste water contains chemicals that threaten the environment.

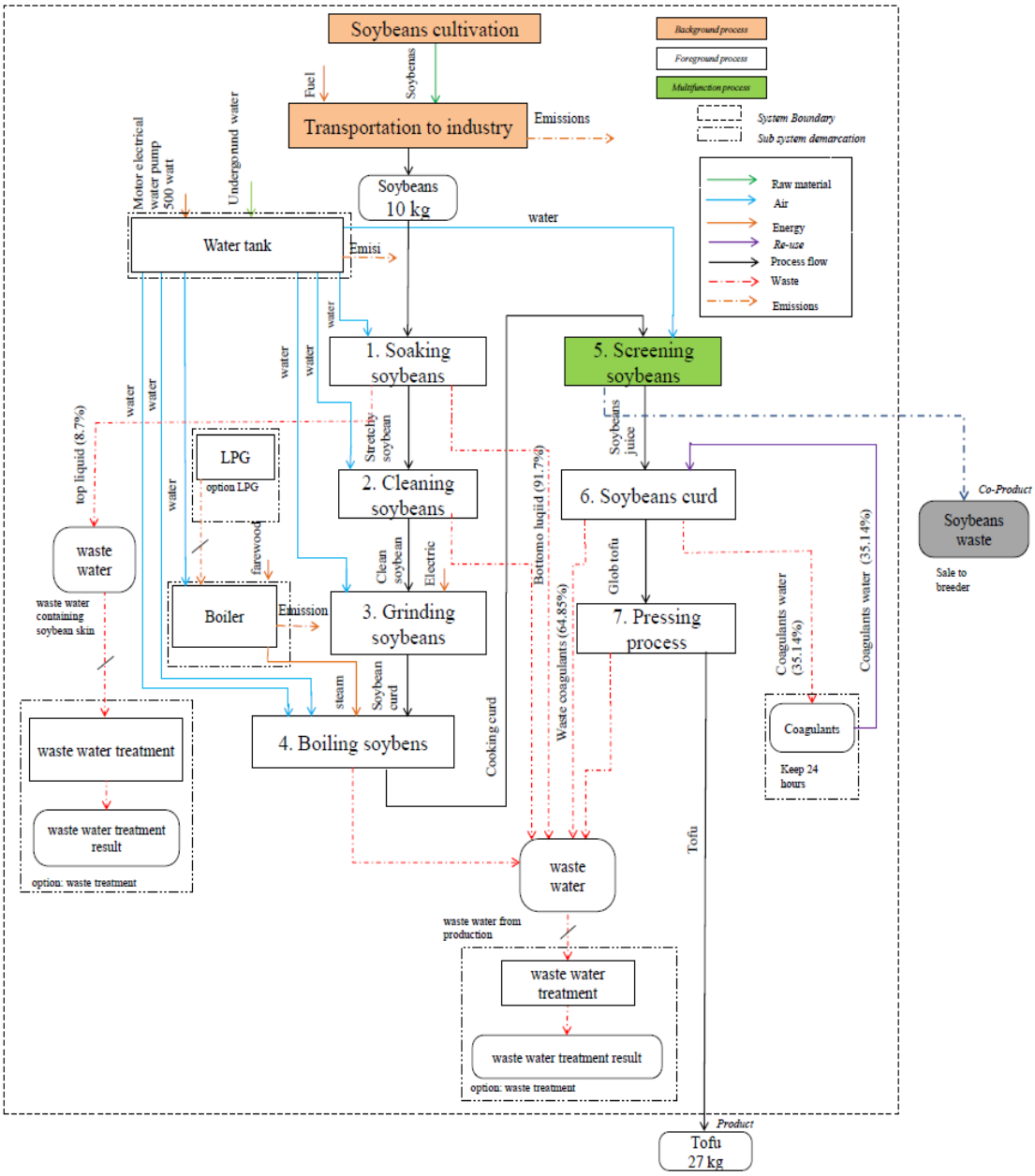

Figure 2. System boundary tofu of LCA study

The potential of river pollution caused by waste water threatens the quality of the river, therefore a scenario for waste water treatment plant (WWTP) is needed. This waste water treatment aims to treat waste water before being discharged directly into the river.

2.4. Inventory Data

Data used in this research is the average data of production tofu process from January to March and showed on Table 1. The production process for 3 months has a relatively similar production level because the level of demand for these 3 months is constant.

3. RESULTS AND DISCUSSION

3.1. Inventory Analysis

This study researched the use of energy during the process which results in greenhouse gas emissions. The impact assessment or Life Cycle Impact Analysis (LCIA) in this study was performed to analyse the impact of global warming to produce 1 kg unit of tofu. Inventories of production processes in the tofu industry are shown in Table 1.

Table 1. Inventory of data for making 1 kg tofu

Process	Input	Total	Unit
Soybeans Raw Materials (Background Process)			
Soybeans cultivation	Soy bean seeds	[a]10	kg
Soybeans Transportations (Background Process)			
Chicago to Portland Maine	Train	[b]1739.7	km
Portland Maine to Cigading	Shipping	[b] 16297.8	km
Cigading to Industry tofu Mampang Prapatan	Truck	[b] 116	km
Raw materials support (Foreground Process)			
Water used	Water	[a] 235	l
Energy used (Foreground Process)			
Electricity energy used	Electric	[a] 0.2	kWh
Wood fire energy used	Wood fire	[a] 46	kg
Transportation of Bogor fire wood to tofu industry in Mampang	Truck	[b]50	km
Production Process (Foreground Process)			
1.Soaking soybeans	Soybeans	[a] 10	kg
	water	[a] 25	l
2.Cleaning soybeans	Stretchy soybeans	[a] 12	kg
	water	[a] 20,75	l
3.Grinding soybeans	Clean soybeans	[a] 14	kg
	water	[a] 32,75	l
4. Boiling soybeans	Soybeans curd	[a] 46,75	kg
	water	[a] 50	l
5. Screening soybeans	Cooking curd	[a] 81,75	kg
	water	[a] 26,75	l
6. Soybeans curd	Soybeans juice	[a] 92.9	kg
	Coagulants	[a] 27,75	kg
7. Pressing process	Glob tofu	[a] 35,3	kg
Tofu (Foreground Process)			
Tofu ready for sale	Tofu	[a] 27	kg

[a] *Primary data*
[b] *Primary data, calculated using Google maps application and Sea Distance*

The inventory data shown in Table 1 are production average data in each batch and detailed assumptions used are presented in SM 4. All of these data have the same criteria and types of actual conditions. Every 1 batch requires 10 kg of soybean as raw material. One working day or 8 hours of work time produces 60 batches of tofu production process. The raw materials used by SMEs Tofu Mampang Prapatan were imported from America.

Based on the transportation calculation explained in Table 1, data of transportation use for the process of transporting the raw materials of soybean was calculated from the soybean cultivation location in Chicago to SMEs Tofu Mampang Prapatan. Transportation data was obtained by calculating the distance between the places and type of vehicle used. Data regarding distances was obtained with the help of Google map software and sea distance. The soybean shipping pathway used in this study is a common American soybean distribution route used to ship to various countries [23]. The type of vehicle chosen in this study was done using the secondary data from ecoinvent 3.0. In this case, there are three types of soybean shipping transportation modes, namely trains, ships, and trucks.

Tofu production used electric energy to run a water pump to provide water availability during the production process and has the role of running a grinding machine which used in the soybean grinding process. The type of electricity chosen in this study was originated from ecoinvent 3.0 data, namely electricity originating from the National Electricity Company.

Furthermore, the energy used for the tofu production process is the energy derived from burning firewood. The type of firewood found in this study was originated from data derived from ecoinvent 3.0. Firewood is the main energy for the evaporation process of water in a boiler system that used to produce steam water. This steam water is used to cook soybean curd. The firewood originates from Bogor, therefore the data for transportation of firewood used in this study was based on the distance from Bogor to the SMES Tofu Mampang Prapatan and the type of vehicle used. The distance calculation of firewood shipping was aided with Google map software. In the next stage, data inventory that has been collected was calculated and processed using SimaPro 8.4 software to evaluate the impact of global warming. The results of calculations and processed data inventory are displayed in the form of LCA diagrams.

3.2. Impact Assessment

3.2.1. Global Warming

The processes that exist in this industry that use energy that have the potential to contribute to greenhouse gas emissions are the transportation process, the tofu production process, and the electricity process. The process carried out by humans is not

analysed for its environmental impact, because energy factors that support human activities are very complex, therefore the human energy was ignored. The highest percentage of the impact value of global warming listed in Table 2 is the transportation process for the delivery of soybean raw materials from soybean cultivation to Mampang Tofu SMEs, which is 1.61 kg CO_2-eq and the second percentage is soybean cultivation, which is 1.53 kg CO_2-eq.

The transportation calculation results in the highest percentage because fuel energy is needed in transportation to energise the modes of transportation. Soybean cultivation was ranked second there is a considerable amount of energy used to cultivate soybeans into superior soybean seeds, which were electricity and fuel energy. Based on the results of inventory data collection and determining the value of impacts, these results can be used to interpret and draw conclusions regarding the goals and scope of LCA research. Furthermore, the data was calculated and processed, hence the resulting LCA diagram was produced with SimaPro 8.4 software as attached to SM 1.

3.2.2. Waste treatment

In accordance with the purpose of this study, waste water was also considered as an impact of global warming. This waste water comes from the ongoing production process and must be handled properly.

Tofu industry produces top waste water and bottom waste water. Table 3 explained the amount of waste water released from each production process. Waste water released by the tofu industry has the effect of greenhouse gas emissions and it has an impact on the environment surrounding the industry, especially the river environment. This waste water contains solids which produce toxic substances and induces the growth of germs, resulting in foul odour and causing pollution to the river [9]. One of the effects of greenhouse gas is caused by methane gas emissions, in which methane is a hydrocarbon gas that is mostly derived from nature and produced by the decomposition of anaerobic organic matter [24].

A policy needs to deal with the tofu industry waste to create a scenario for waste treatment, therefore the tofu industrial waste water can be processed before being discharged directly into the river.

This paper also modelled the waste treatment scenario according to field conditions. This aims to determine the impact of global warming that occurs if there is a scenario of waste treatment in the tofu industry. The waste treatment scenario chosen in this study refers to the ecoinvent 3.0 data, namely waste water treatment for domestic waste water organic. The process of waste water treatment for waste water was originated and contaminated by waste containing organic or soybean skin and waste water originated from the tofu production process. The greenhouse gas emissions come from the waste treatment process, therefore the total value of the overall level of global warming impacted to the environment during the production process with a scenario of waste water treatment is 4.76 kg of CO_2-eq and non-waste water treatment process is 3.84 kg of CO_2- eq. Table 2 shows the value of the global warming impact from the production of 1 kg of tofu.

WWTP (Waste Water Treatment Plant) used in this scenario is a WWTP that has a function to treat organic waste from soybeans and emissions data which obtained from secondary from ecoinvent 3.0. The uses of WWTP in the waste treatment process that come from the process of tofu production generate organic waste. The organic waste in WWTP will form methane gas[24].

Table 2. The value of the impact of global warming on the production process at 1 kg of tofu

Impact Process of global warming	Process type	Without cesspool process (current condition)	
		Kg CO_2-eq	%
Soybeans cultivation	*Background process*	1.53	39.84
Soybeans transportation	*Background process*	1.61	41.93
Production Process			
1. Soaking soybeans	*Foreground process*	0.02	0.52
2. Cleaning soybeans	*Foreground process*	-	-
3. Grinding soybeans	*Foreground process*	0.04	1.04
4. Boiling soybeans	*Foreground process*	0.57	14.84
5. Screening soybeans	*Foreground process*	0.02	0.52
6. Soybeans curd	*Foreground process*	0.05	1.30
7. Pressing (Tofu)	*Foreground process*	-	-
Total		**3.84**	**100**

Table 3. Inventory data waste water for making 1 kg of tofu

Process	Output	Total	Unit
Production Process (Foreground Process)			
1. Soaking soybeans	Waste water below	21	Kg
	Top waste water	2	kg
2. Cleaning soybeans	Waste water	18.75	kg
3. Boiling soybeans	Waste water	15	kg
4. Soybeans curd	Waste water	55.35	kg
5. Pressing process	Waste water	8.3	kg

In this study, methane gas has a value of greenhouse gas emissions, however the impact is not examined in this study, therefore further research is needed to minimise the methane gas that exits the WWTP system. Base on the waste treatment scenario, so this paper will comparison impact global warming between without waste water treatment process scenario and with waste water treatment process is shown in Table 4. The results of this study showed that the level of global warming produced by the tofu industry in Mampang Prapatan with a scenario of waste water treatment has a higher global warming rate compared to the case without waste water treatment. The calculation and processing of data with the scenario of waste water treatment displayed in the form of LCA diagrams with SimaPro 8.4 software are shown in appendix SM 2.

The high level of global warming in the scenario of waste treatment with a value difference of 0.92 kg CO_2-eq compared to the scenario without waste treatment is a common problem that occurs due to the additional waste treatment process. This waste treatment process has CO_2 gas emissions released in the system, therefore proves that the waste water treatment plant used to degrade organic material has the effect of forming methane and carbon dioxide (CO_2) gases [24].

In this research location, based on the difference between the case where the scenario was carried out and the case without the scenario, it can be concluded that the value global warming impact due to greenhouse gases that take place during the production process has different levels due to influence factors. Table 5 explains the important role of factors that influence the level of greenhouse gas emissions based on research conducted by other researchers.

Table 5 shows the results of research conducted by Blonk [25] which stated that global warming in the Netherlands was 1.9 kg CO_2-eq/kg tofu. Blonk's result had a smaller global warming impact compared to the case in SMEs Tofu Mampang Prapatan due to the dominant factors, namely (1) the research location is in the Netherlands, which is closer to the United States as a source of soybeans compared to Indonesia, therefore greenhouses gas emissions in the process of transporting soybeans is smaller. (2) The Netherland research used natural gas energy for the tofu production process. It should be noted that greenhouse gas emissions is smaller when the combustion process uses natural gas instead of firewood.

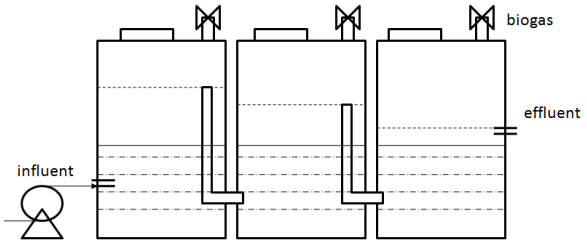

Figure 3. Scenario of WWTP at SMEs Mampang Prapatan

The research conducted by Meija [1] stated that global warming in the United States reached 0.982 kg CO_2-eq/kg. The research conducted by Meija has smaller global warming impact compared to the case in SMEs Tofu Mampang Prapatan due to the same dominant factors as stated by Blonk, namely (1) the research was conducted in the United States, where the United States is a source of soybeans, therefore greenhouse gases emissions from the soybeans transportation process are smaller. (2) The use of natural gas energy for boiler processes in the tofu industry, As noted before greenhouse gas emissions is smaller when the combustion process uses natural gas compared to firewood. In terms of soybean cultivation in SMEs Tofu Mampang, the value of global warming is greater than the results of the overall study by Meija[1]. This is because Meija [1] study did not take soybean cultivation into account.

Furthermore, the research conducted by Wahyudi stated that the impact of global warming in the Tofu Industry of Kajen Village was 1.849 kg CO_2-eq/kg tofu. Meanwhile, the results of research conducted by Sahirman stated that global warming released by the Tofu Kalisari Industry was 1.98 kg CO_2-eq/kg tofu. The research of Wahyudi [26] and Sahirman [27] have nearly the same global warming impact value; this is because the limitations of the research conducted by these two studies are gate. Due to differences in research limitations, greenhouse gas emissions are released in the production process is smaller compared to the case in SMEs Tofu Mampang Prapatan. This is because greenhouse gas emissions in the soybean transportation process are ignored.

Table 4. Comparisons of Impact global warming in every process and source energy

Global warming impact from the process	Process type	Without waste water treatment process		With waste water treatment process	
		kg CO_2-eq	%	kg CO_2-eq	%
Soybeans transportation	*Background process*	1.61	42.14	1.61	34.30
Soybeans cultivation	*Background process*	1.53	39.84	1.53	32.10
Use of firewood in industry	*Foreground process*	0.59	15.32	0.59	12.20
Use of electric in industry	*Foreground process*	0.11	2.70	0.11	2.20
Waste water treatment in industry	*Foreground process*	-	-	0.92	19.20
Total		3.84	100	4.76	100

Table 5. Recent study of the effects global warming on tofu products

	Blonk[25] (2008)	Meija[1] (2017)	Wahyudi[26] (2017)	Sahirman[27] (2014)	Research without waste water treatment	Research with waste water treatment
System boundary	Cradle to gate to retail	Cradle to gate	Gate to gate	Gate to gate	Cradle to gate	Cradle to gate
Research Location	The Netherlands	United Nation	Indonesia	Indonesia	Indonesia	Indonesia
Purpose	To understand the impact global warming from tofu production					
Inventory Data	The process of making tofu, transportation , soybean plantation, distribution, packaging, and tofu wholesaler	The process of making tofu, information, transportation, electricity use, waste treatment	The process of making tofu, information, transportation, electricity use, waste treatment	The process of making tofu, transportation.	The process of making, tofu information, transportation, electricity use, waste treatment	The process of making tofu, transportation , electricity use, separated liquid and solid waste treatment.
Trans-portations	1. Delivery of soybeans from cultivation to industry 2. Shipping from industry to market 3. Shipping pulp from industry to consumers	1. Shipping soybeans from a place of cultivation to industry. 2. Shipping packaging materials.	1. Sending soybeans from local traders to the industry. 2. Delivery of firewood from market to industry. 3. Shipping information from industry to market. 4. Shipping tofu from industry to consumer.	Shipping from industry to market	1. Shipping soybeans from the place of cultivation to the port. 2. Soybean delivery from port to industry 3. Delivery of firewood from market to industry	1. Shipping soybeans from the place of cultivation to the port. 2. Soybean delivery from port to industry. 3. Delivery of firewood from market to industry.
Fuel	Natural gas	Natural gas	Firewood	Firewood	Firewood	Firewood
Functions unit	1 kg of tofu					
Global warming impact (kg CO_2-eq)	1.9	0.982	1.849	1.98	3.84	4.76

The results of comparison between the SMEs Tofu Mampang Prapatan and the research conducted in other places that contribute to the high global warming impact can be seen in Table 2. The highest contributing factors are the soybean transportation process and

Table 6. The scenario of replacing firewood with LPG

Process impact of Global warming	With firewood energy kg CO_2-eq	With LPG energy kg CO_2-eq
Using energy for boiler process in the industry	0,59	0,31

soybean cultivation because these two factors use a lot of energy sources. In other studies, the process of soybean cultivation was not taken into account, hence the value of global warming was smaller compared to this study.

3.2.3. Scenario using of Liquefied Petroleum Gas

The fuel usage factor in the boiler system also gives high contribution to the value of global warming impact. The research conducted at SMEs Tofu

Mampang Prapatan found that the process uses firewood as its fuel energy source. The value of global warming impact from firewood is higher compared to natural gas from fuel which was carried out on Blonk and Meija research locations. The high global warming impact from heating value conditions in this study became the consideration for the scenario substituting fuel wood to another fuel with smaller value global warming impact. The condition that can be carried out according to the location of this research is the use of LPG as a firewood substitute, because natural gas is not available at this research site.

This scenario used LPG fuel data from ecoinvent 3.0. The boiling process of 10 kg soybean raw material requires energy of 40.102 kcal[28]., therefore it requires 0.87 kg in this scenario. The type of LPG chosen in this study was LPG which has the same criteria and types between the conditions thus it is possible to be done on the SMES Tofu Mampang Prapatan.

Table 6 shows the value of global warming impact if a scenario to replace firewood to LPG is in place. The result of using LPG was 0.31 kg CO_2-eq, therefore total process with the scenario of waste treatment and the scenario of using LPG was 4.49 kg CO_2-eq/kg tofu. These results prove that the use of LPG fuels has a better impact and has a smaller global warming value compared to firewood usage.

3.3. Repairing Analysis and Interpretation

This research shows that using waste treatment process at SMES Tofu Mampang Prapatan has a higher impact on global warming with a value of 4.76 kg CO_2-eq compared to the case without waste treatment process with a value of 3.84 kg CO_2-eq. This is because the plant releases greenhouse gas emissions when the process takes place. Based on the field condition, the scenario of a waste water treatment process is strongly recommended to reduce the level of COD and load of waste in the river, thus the damp waste treatment improves the environmental quality of the waste water of tofu industry [27]. Due to the high value of the global warming impact on the scenario of waste management, it is highly recommended to reduce the LPG usage in the scenario, therefore global warming value can be reduced by 4.49 kg CO_2-eq.

The comparison of the global warming value in each research location results in a variety of values due to differences in boundary systems that have been set by the researchers, selected inventory data, production sites, transportation data, as well as energy materials used for the production process. These differences are natural if the comparison factors are different, therefore the comparison factor must be equated to be able to compare the level of global warming. According to Table 4, what really needs to be emphasised is the origin of the soybean raw materials, as long as the soybean raw materials are used in industries in Indonesia, especially in this study are from the United States, this certainly contributes the most greenhouse gas emissions or hotspots produced during soybeans transportation. Furthermore, this study also calculated soybean cultivation in detail, thus soybean cultivation contributes to global warming which ranked second after transporation. Such conditions require a policy that can be carried out by the SMES Tofu Mampang Prapatan. The policy can be started from the use of raw materials in the production process, as well as increasing efficiency of firewood and electricity usage. In terms of energy used for the boiler process, it should be in accordance with Table 6 which explains that the scenario of using LPG can reduce the value of the global warming impact.

4. CONCLUSIONS

1 kg of tofu production has global warming impact of 3.84 kg CO_2-eq. If waste water treatment is included in the calculation, the impact of global warming increases to 4.76 kg CO_2-eq, and if a scenario of replacing LPG to firewood is used, the impact of global warming decreased to 4.49 kg CO_2-eq/kg tofu.

This research recommends waste treatment scenario to be done by the industry in order to protect the quality of river environment from the impact of waste water. Furthermore, the scenario of using LPG as a substitute for firewood is very useful to reduce the value of global warming impact from the boiler process. Although the results are higher, it can reduce waste. The process to

reduce the impact can be done with efficient waste water treatment process. This research also proves that the value of greenhouse gas emissions is different in each study conducted by different researchers; this is because the level of greenhouse gas emissions is influenced by the researchers in determining the boundary system in their research.

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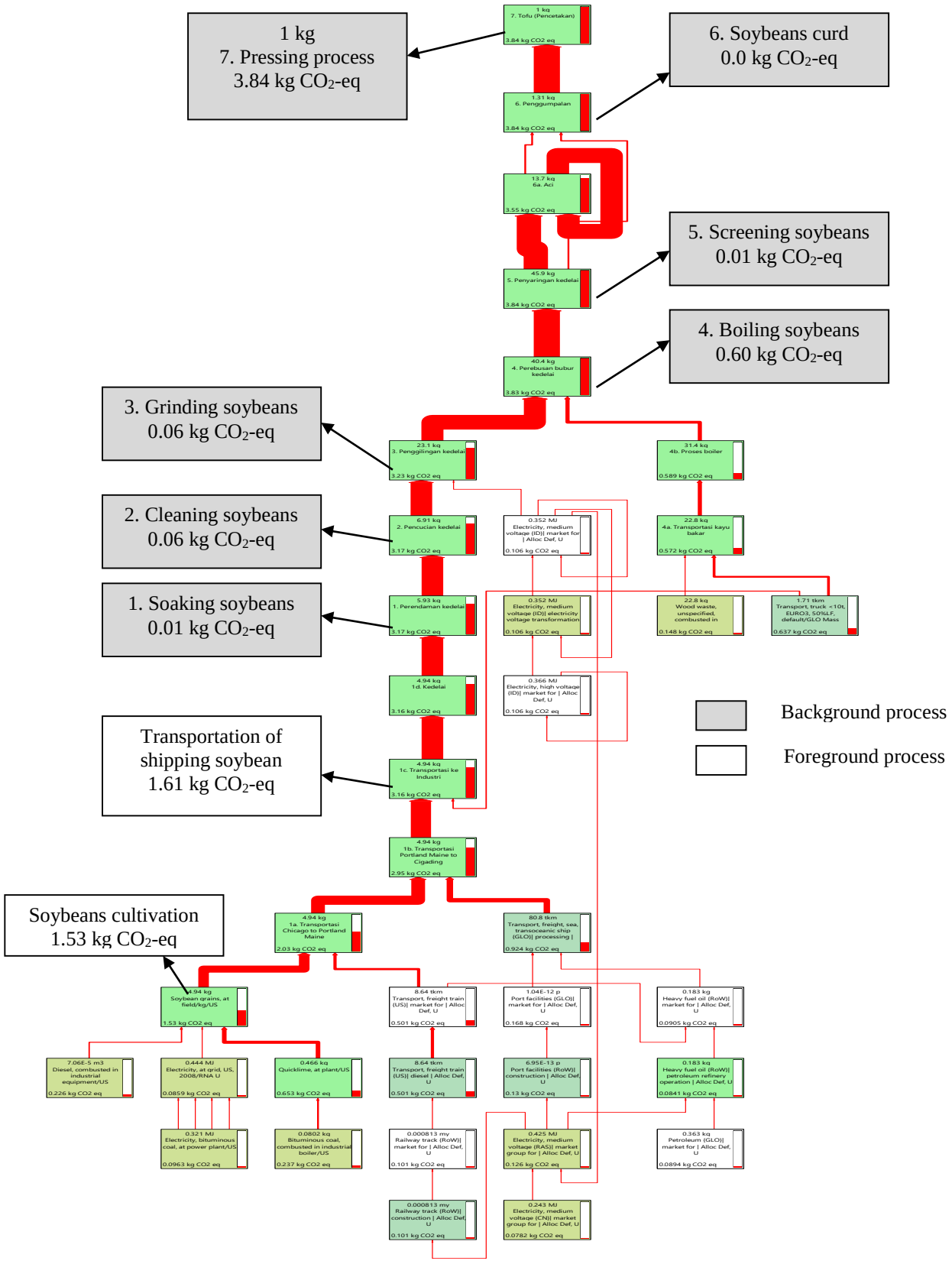
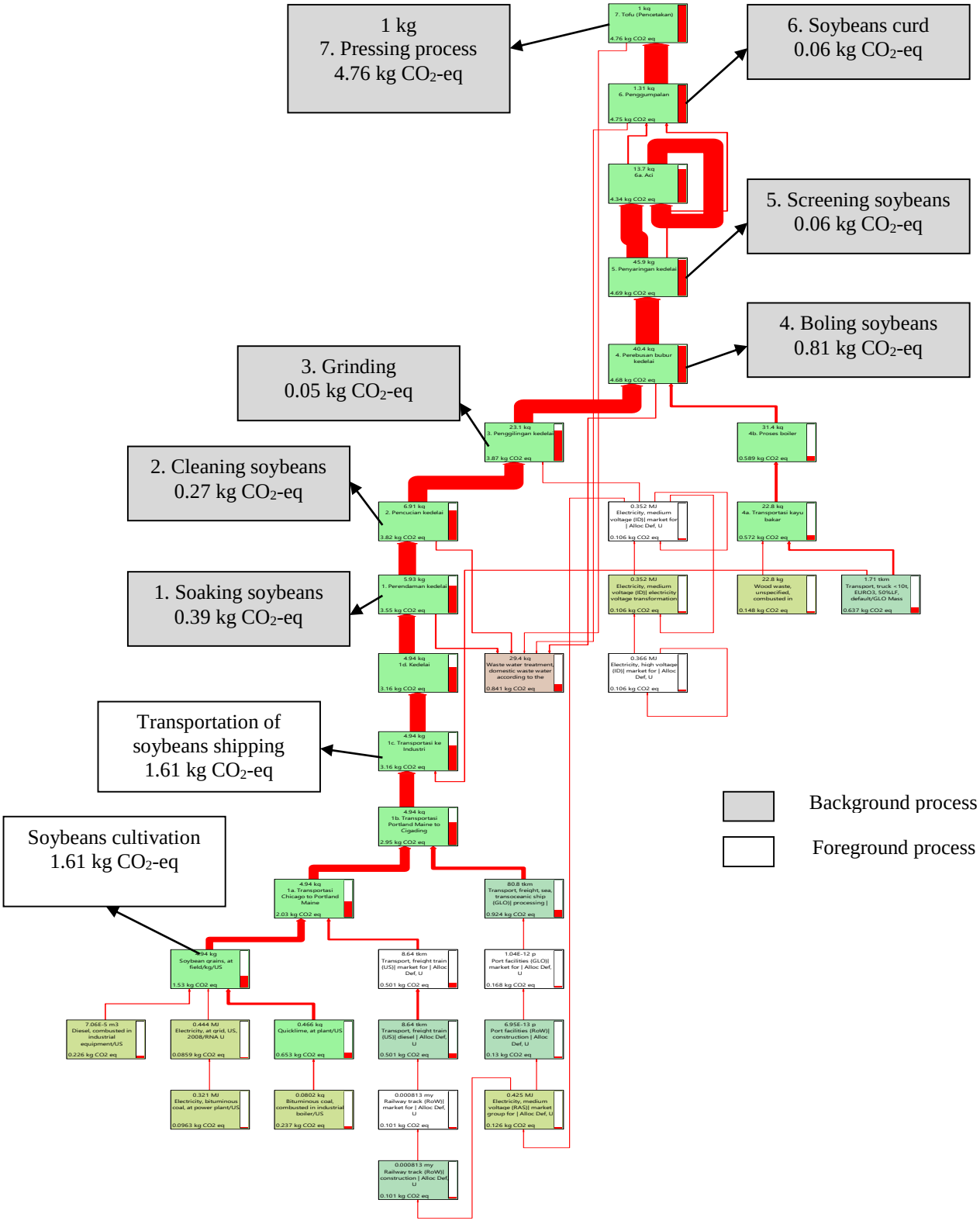
SUPPLEMENTARY MATERIALS (SM)

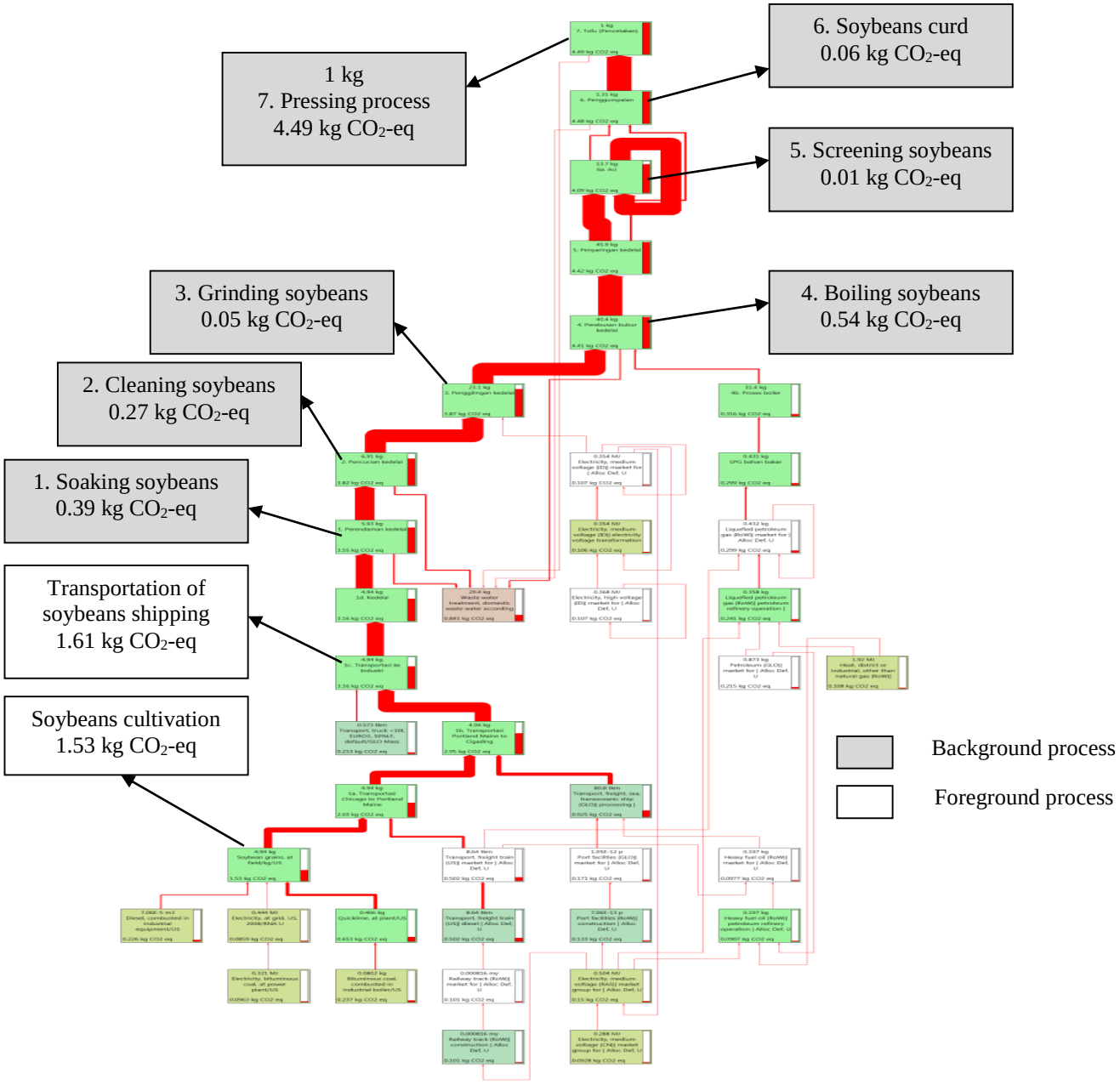
SM 1. The results of diagram LCA tofu without waste water treatment



SM 2. The results of diagram LCA tofu with waste water treatment



SM 3. The results diagram LCA tofu with waste water treatment and LPG usage



SM 4. Ecoinvent 3.0 Data as Secondary Data in Inventory Data

4.1. Use of raw materials

4.1.1 Soybeans raw materials

Data of soy beans raw materials originating from America used secondary data from ecoinvent 3.0 database.

Name of Input Process	Ecoinvent 3.0
Soybeans	Soybean grains, at field/kg/US

4.1.2 Water for raw materials

The use of raw water from ground water used secondary data from ecoinvent 3.0 database.

Name of Input Process	Ecoinvent 3.0
Water	Water, ID (Indonesia)

4.2. Transportations Usage

The use of transportation in the boundary system is one of the activities in the material chain of the tofu production process. Data regarding types of transportation and fuel usage by the transportation mode was obtained from secondary data from ecoinvent 3.0 database.

4.2.1 Soybeans of Transportations.

The mode transportations used to ship soy beans from the cultivation place to the industry.

a. Train Transportations

Name of Input Process	Ecoinvent 3.0
Train	Transport, freight train {US} | market for | AllocDef, U

b. Ship Transportations

Name of Input Process	Ecoinvent 3.0
Ship	Transport, freight, sea, transoceanic ship{GLO} | processing | AllocDef, U

c. Truck Transportations

Name of Input Process	Ecoinvent 3.0
Truck	Transport, truck <10t, EURO3, 50%LF, default/GLO Mass

4.2.2 Firewood Transportations

The truck transportation used to delivery firewood from cutting wood location to the industry.

Name of Input Process	Ecoinvent 3.0
Truck	Transport, truck <10t, EURO3, 50%LF, default/GLO Mass

4.3. Electric Energy Usage

The electrical energy usage is an activity in the tofu industry to obtain and process the production using electricity in the process of providing clean water and soybean grinders. The type of electrical energy was determined using secondary data from ecoinvent 3.0 database.

a. Electrical energy to drive the water pump.

Name of Input Process	Ecoinvent 3.0
Electricity	Electricity, medium voltage {ID}| market for | AllocDef, U

b. Electrical energy to drive a soybean grinding machine.

Name of Input Process	Ecoinvent 3.0
Electricity	Electricity, medium voltage {ID}| market for | AllocDef, U

4.4. Firewood usage

The firewood usage is an activity in the tofu industry to obtain and process the production using firewood in the boiler process to assist with the boiling process of soybean curd. The type of firewood was determined using secondary data from ecoinvent 3.0 database.

Firewood usage for the steam boiler process

Name of Input Process	Ecoinvent 3.0
Firewood	Wood waste, unspecified, combusted in industrial boiler / US

4.5. LPG Usage

The LPG usage is an activity in the tofu industry to obtain and process the production by using LPG in the boiler process to assist with the boiling process of soybean curd. LPG is used as a substitute for firewood. The type of natural gas was determined using secondary data from ecoinvent 3.0 database.

Name of Input Process	Ecoinvent 3.0
Liquefied Petroleum Gas	Liquefied petroleum gas {RoW}| market

SM 5. Emission Factors

Inventory	Unit	Emission Factors	References
Soybeans transportation	kg CO_2-eq	1.61	Ecoinvent 3.0
Soybeans cultivation	kg CO_2-eq	1.53	Ecoinvent 3.0
Firewood	kg CO_2-eq	0.59	Ecoinvent 3.0
Electric	kg CO_2-eq	0.11	Ecoinvent 3.0
WWTP	kg CO_2-eq	0.92	Ecoinvent 3.0
LPG	kg CO_2-eq	0.31	Ecoinvent 3.0