CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 Data Collecting

The process of collecting the data was taken place in PT. Tirta Inevstama which produces AQUA. Founded in 1973, AQUA Group is the pioneer of Bottled Drinking Water (AMDK) in Indonesia, which then established a strategic partnership with Danone in 1998. AQUA Group brings the mission of inspiring Indonesians about healthy hydration. AQUA Group produces healthy, scientifically accountable Bottled Drinking Water and non-carbonated soft drinks.

AQUA Group applies Danone's values, which reflect unique business vision and ethics. The values of Humanism, Openness, Proximity, and Enthusiasm are fostered and continuously implanted in their employees to direct the Company towards a better direction. These values also guide in each of the Company's decision making and professional perspective.

Danone is one of the biggest food and beverage producers headquartered in France. With a mission of bringing health through foods and beverages to as many people as possible, Danone develops 4 primary categories in its business operation, i.e. Fresh Dairy Product, Early Life Nutrition, Water, and Medical Nutrition.

Through the mission and dual commitment for business and social growth**.** Danone aims at building a healthier future through healthy lifestyle, healthy Earth, and healthy ecosystem. In 2017, Danone unveiled a refreshed logo and its very first company signature: One Planet. One Health. These words reflect our vision that the health of people and the health of the planet are interconnected. It is a call to action for all consumers and everyone who has a stake in food to join the food revolution: a movement aimed at nurturing the adoption of healthier, more sustainable eating and drinking habits.

As a manifestation of its vision and commitments to responsible management of its operation, AQUA developed AQUA Lestari initiative. The initiative roots back to the idea from Danone's founder himself, Antoine Ridboud, about Dual Commitment—prioritizing the balance between business and social success. The Dual Commitment is also aligned with the idea from AQUA's founder, Tirto Utomo, i.e. that business should give social contribution. AQUA Lestari initiative is operated by establishing partnership with employees and stakeholders.

AQUA is sourced from selected springs with all preserved purity and natural mineral content. AQUA is packaged in hygienic process in plastic bottles of different sizes: 330 ml, 600 ml, (750ml), and 1500 ml, as well as 240 ml plastic cup and 19 l gallons, to maintain dynamic activities safe from dehydration.

In shortly, this research conducts and examines the life cycle assessment in accordance to the company's background and vision in sustainability of products, social and manufacturing itself. Thus, some data are needed to be proceed later as the input to compute the assessment and offer the alternative solution. The data input consists of life cycle inventory which consist of the energy and amount used in manufacturing the products to point of sale or distribution center. Then those data will be processed using life cycle assessment method to know which processes are contributing to the result (environmental impact), then used as the consideration to take action plan as the alternative solution. The alternative could involve some of data about costing. The detailed about company and data for this research will be shown below.

4.1.1 Product Specification

AQUA mineral drinking bottled was made of plastics with normal-tube bottle size with cap in the top. The material used mainly to produce this bottle was giving the most significance impacts towards environment. Since, plastic is non-biodegradable even until 5 years. In this research, the size of 1500ml (1.5L) would become the observed-object in the whole process. The product has some dimension measurements; height of bottle was 30 cm and diameter of 7.5 cm. While for cap, it has diameter of 3 cm with 1 cm width. The design was dominated with blue color and full-emboss in the bottle. The bottle as depicted in Figure 4.1. These bottles would be manufactured in SPS 1 (Small Packaging Size) area.

Figure 4.1 AQUA PET Bottle 1.5L
Source : https://aqua.co.id

4.1.2 Production Process

The production process of AQUA PET bottled drinking water 1.5L is consist of four main phases in which adopting the system boundary of cradle-to-grave so it will evaluate the activity of its entire life cycle from production until leave the factory and disposal or waste management. Thus in this case, the process begins in-site plant (in manufacturing plant PT. Tirta Investama) until the out-site activity such as delivery of product to the point of sale in Surabaya, East Java. The phases are explained below:

1. Phase of of raw material extraction

   The birth of a plastic bottle begins when crude oil and natural gas are extracted from the environment. Basically, plastic bottles are made of polymers, which are chemically bonded to create materials such as polyethylene. A plastic bottle made of polyethylene terephthalate has the resin identification code 1. Also known as PET, PETE or polyester, Polyethylene terephthalate (PET) is made from petroleum hydrocarbon which is the main ingredient used in the manufacture of most plastic bottles. PET is made by mixing hydrocarbons with chemical catalysts, triggering polymerization. During the production process, PET polymerizes to form long molecular chains. Then it transforms into plastic pellets or commonly shaped as plastic granules, as depicted in Figure 4.2.

Figure 4.2 Plastic granules (PET)
Source : www.tactiletreasures.co.uk

An extruder melts the PET and regrind mix at temperatures of about 500 degrees Fahrenheit. A screw inside the extruder compresses the PET mix and injects the nearly molten material into molds. The mold produces a bottle preform, which is sometimes called a parison, as depicted in Figure 4.3. The preform looks like a thick-walled test tube, often including the bottle's characteristic screw top. The preform cools as it travels to a machine called a blow molder.

Figure 4.3 Bottle Preform

The resin identification code 2 denotes high-density polyethylene (HDPE). It is economical and yields an efficient moisture barrier, making it the most widely used material for plastic bottles. It is made from petroleum, a naturally occurring liquid found in geological formations beneath the Earth's surface. HDPE is resistant to many solvents and has a high density-to-strength ratio. This material also used to make the bottle-cap.

Polypropylene material are then used to make labels. A label material made up of thermoplastic substrates. This label offers such properties as resistance to heat, cold, moisture, tearing and flexing. It is a tough material and works well for bottled water labels. These labels hold colors, as the color is transferred to the label via extreme heat. Those three main materials are then transformed to create component such as bottled water, cap and printing labels.

2. Phase of PET bottled drinking water production

   In production of bottled drinking there are some main processes involved started from the bottle making until bottle filling. Conveyor belts are used as the material handling in production process, including the component making. The detail as below:

   a. Bottling production

      The process begins with the PET mixture is being heated and placed in molds via a process called injection molding. Usually, the type of the mixture depends on the kind of the plastic to be made. Some plastics are harder while others are softer. The softer one will be used to create the bottle-preform then final bottle. While the harder one will be used as the cap of bottle. Then, plastic granules or pellets are forced into a heating hopper-after the bottle-preform- which liquefies them down pushing the liquefied plastic into a press that molds the bottle. Blow molding is similar to direct injection only that uses an air jet to blow the liquefied plastic film into the mold. It is used to create hollow shapes.

      The blow molding machine also used to create the cap, still using plastic granule but essentially using HDPE material. This entity was handled in a circular conveyor belt to be assembled in the top of bottle after bottle filling process.

   b. Stretching the preform

The preforms enter a two-part mold that closes around it. The inside of this mold is shaped exactly like the finished bottle. Inside, a long needle pushes up through the preform, which is suspended with the screw end facing downward. The needle stretches the preform upward toward the top of the mold -- which will be the bottom of the bottle -- and simultaneously blasts enough pressurized air into the preform to force it against the sides of the mold. This stretch blow molding process must happen quickly in order to maintain the bottle's integrity and consistent shape. It weld a separate bottom piece to the bottle during blow molding, while others produce a bottom from the preform along with the rest of the bottle.

c. Cooling and Trimming

The bottle must be cooled almost instantly or it will lose its shape when gravity causes it to creep downward in its malleable, heated state. Some manufacturers cool the bottle by circulating cold water or liquid nitrogen through the mold, others elect to fill it with a shot of air at room temperature. To keep the stability of temperature, the room was utilize using the AHU in which supplied by the chiller outside of the SPS 1 area. The mold typically yields a clean bottle, but some flashing may occur at the bottle seams, where the two mold halves met. If so, operators trim away the excess material and add it.

d. Water treatment and bottle filling

The spring water is supplied from the water sourcing in which located in different plant from manufacturing plant. The source located around one kilometer from factory and then transported using the stainless-steel truck (special design) and standardized pipe to the bulk storage or tank. The tank contains pure spring water and need pass several processes. Sterilization and filtering were proceed to kill the germ or bacteria so accordance with the food safety rules. This is carried out by using ozonator or ozone generator.

These spring water then flowed into automatic bottling machine to process the bottle filing. Then the water is filled into the bottle as immediately capped, to avoid the micro bacteria and keep it sterile.

3. Phase of finishing and packaging

The entity of filled bottle then will move to other process of blowing machine. In here, some of bottles perhaps in wet condition that's why this machine makes them to dry in order to ease the labelling process. Since, the wet bottles make the label difficult to stick on it.

After the bottle is dry in a hygienic and sterile room, the cutting-edge technology is used to wrap the label perfectly around the bottle. The machine namely bottle shrink applicator. It uses an advanced solution to print the desired label on the bottles with a heating technique.

Those filled bottle then move to finishing process. In which, one carton-box can be filled up to one dozen (12 items) of filled bottle 1500ml. These boxes are ready to be transported in pallets by forklift. Those boxes arrange in pallets ready to be moved to truck. The material handling using forklift. Within one day, there are around 5 forklifts that can accommodate the activity of product loading. By charging of approximately 2 hours each, the forklift can perform up to 4 hours non-stop.

4. Phase of transported to POS (Point of Sale)

   In the last phase, the product left from factory. The box packed from the factory then transported to POS or point of sale in Surabaya (to PT. ABC) with the distance of 292.6 kilometers. The products are transported using freight of lorry size 16-32 metric ton, some called it as wing box or HDT (Heavy Duty Trucks) 16-32 mtt. The vehicle can accommodate up to 1000 box packed containing around 18 liters of spring water.

Figure 4.4 simply represents the production process of AQUA until the delivery system.

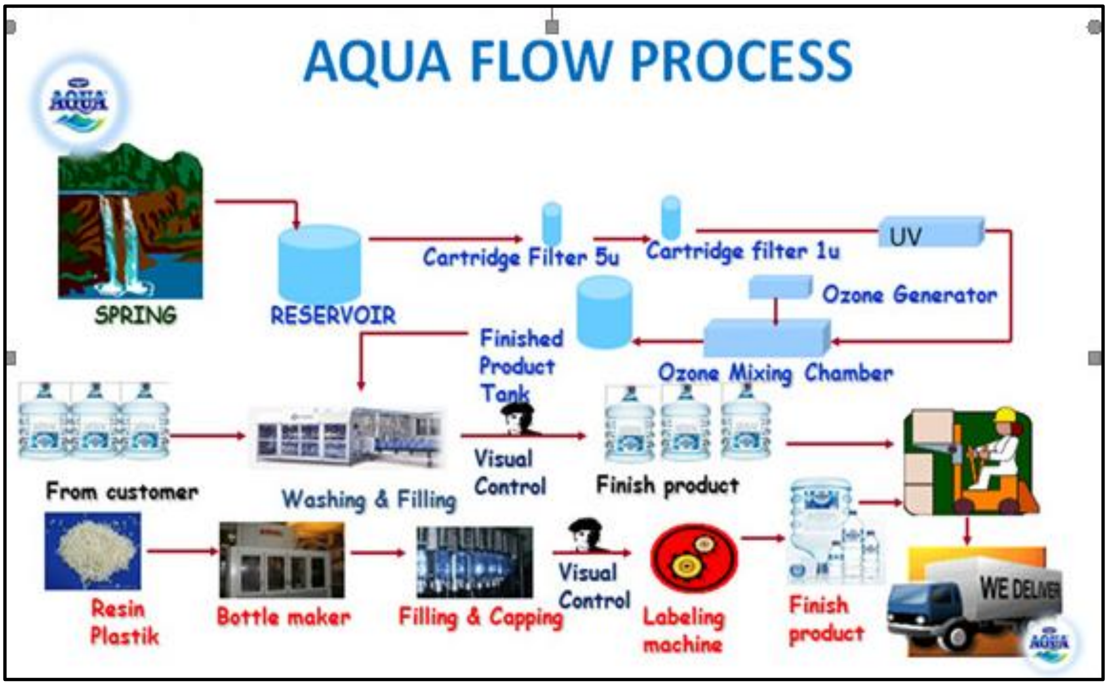

Figure 4.4 Aqua flow production process
Source : AQUA

4.1.3 Life Cycle Inventory (LCI)

The data about life cycle inventory would explain about the numerical data and amount of energy used to carry out the manufacturing process as explained more in point 4.2.2. The inventory consists of the process of extracting raw material until deliver it to point of sale or the distribution center in Surabaya, East Java. All the numerical data are conformed with its unit and flow-category as the input. While for the output, was carried out using software as well as the LCIA indicator.

4.2 Data Processing

In processing the LCA, there are some stages need to be completed in order to make the process and calculation is defined clearly. The entire process was computed by using the Ms. Excel, OpenLCA software verse 1.7 and manual calculation. The process and computation of LCA was carried out using OpenLCA, as well as the output result. While the rest – manual calculation and other statistical performed-had been done by Ms. Excel. The stages are explained in below:

4.2.1 Goal and scope definition

Goal and scope definition are the earliest stages before conducting LCA, here, the goal of this study is to assess the environmental impact of product PET drinking water bottle named AQUA 1.5L and to derive the solution or proposed alternative to attain efficient and environment-friendly. The scope of the study is defined as below:

1. The system that will be evaluated is concerning to the environmental impact in production process of AQUA 1.5L in PT. Tirta Investama, Klaten and simultaneously with the proposed alternative.
2. The study is limited to only evaluation of energy and material usage involved in production process of AQUA 1.5L.
3. Input from this analysis is include as material to produce the AQUA 1.5L. the material such as PET, water, carton and many more.
4. The computation and calculation are supported by Ms. Excel (Excel solver), Linear Programing Solver (LiPs) and OpenLCA software v.1.7 using CML baseline 2015 method assessment, Ecoinvent v.3.4 databases and any manual statistical or mathematical calculation performed.
5. Output from this calculation (by OpenLCA) shows the number and amount of environmental impact of produced from creating the AQUA 1.5L.

The functional unit for this study was defined as 1000 units of one-half-litre drinking water bottles made of Polyethylene terephthalate (PET) at point of sale in Surabaya (deliver to PT. ABC).

As with any LCA, assumptions had to be made to define and model the life cycle of PET water-bottle. Due to lack of detail available data, a relatively large number of assumptions had to be made for this study. This has resulted in the scope of the study being reduced with regard to ambition and application. One significant change in scope is that no comparison is now carried out between the different water-bottle types. It was determined that the data are simply not robust enough to support such comparisons. However, not all the assumptions are considered to have the potential to affect the outcomes of the life cycle inventories and impact assessment result significantly.

The system boundary of this study is adopting the cradle to grave, which is in this LCA focus on the AQUA 1.5L life cycle of drinking water bottles from raw material production to point of sale (out from factory) or transported until customer's hand. The waste management such as disposal or recycling of the product is not considered to be included in systems. The system boundary is shown in Figure 4.5 below:

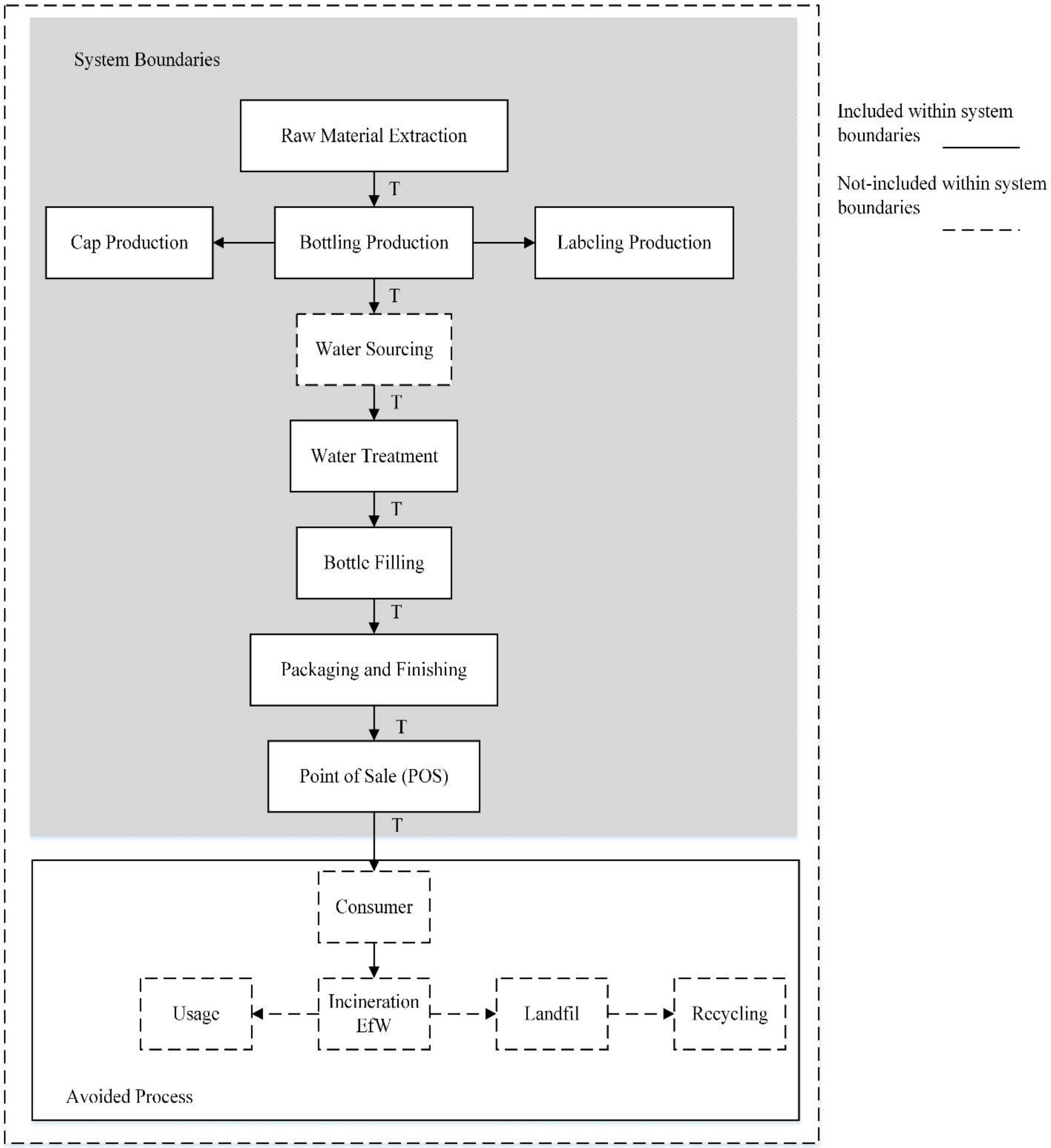

Figure 4.2 System boundaries applied

As can be seen from the figure, the following life cycle steps were included within the system boundaries:

1. Raw material extraction and production (i.e. Polyethylene terephthalate (PET), high-density polyethylene terephthalate (HDPE), Polypropylene (PP) etc.);
2. Transportation of raw material to converter;
3. Production of bottle-component (i.e. cap bottle made from HDPE material);
4. Production of bottle-component (i.e. empty bottle made from PET pallets or granule as the basis component);
5. Production of bottle-component (i.e. sticker label as representation of product knowledge, brands, ingredients and so on made from PP);
6. Transportation of component to water treatment (using conveyor and pipe);
7. Process of filtering the spring water in water treatment;
8. Transportation of sprint water to empty product;
9. The process of bottle filling from spring water tank;
10. Transportation of filled-bottle to packaging and finishing area (using conveyor);
11. The process of packaging and finishing (i.e. labeling and packaging);
12. Transportation of boxes-bottle to truck (using forklift);
13. Transported to point of sale in Surabaya using lorry.

Excluded from the system boundaries were: the ink used and the printing process itself; water sourcing; the glue to stick the boxes; use in the home; product wastage; and product disposal. This was due to lack of information about the types ink used for printing, the percentage of PET bottle wastage through the supply chain, the confidential area and complex process of water sourcing (i.e. frilling, filtering, etc.).

4.2.2 Life Cycle Inventory (LCI) Calculation

This stage explains the Life Cycle Inventory of PT. Tirta Investama –Danone AQUA in producing the water-bottle. In this case, bottle generated at 1 piece is used as the basis for calculation, while the functional unit of 1000 only shows the target amount. The form of this inventory analysis is databases that show energy and resources used and emissions collected to produce one functional unit in PT. Tirta Investama during its life cycle based on the below main phases :

1. Life cycle inventory of raw material extraction process
2. Life cycle inventory of PET bottled drinking water production process
3. Life cycle inventory of finishing and packaging
4. Life cycle inventory of transported to point-of-sale (POS) to Surabaya

Figure 4.3 represents the process flow of material and energy required in producing the PET water bottle.

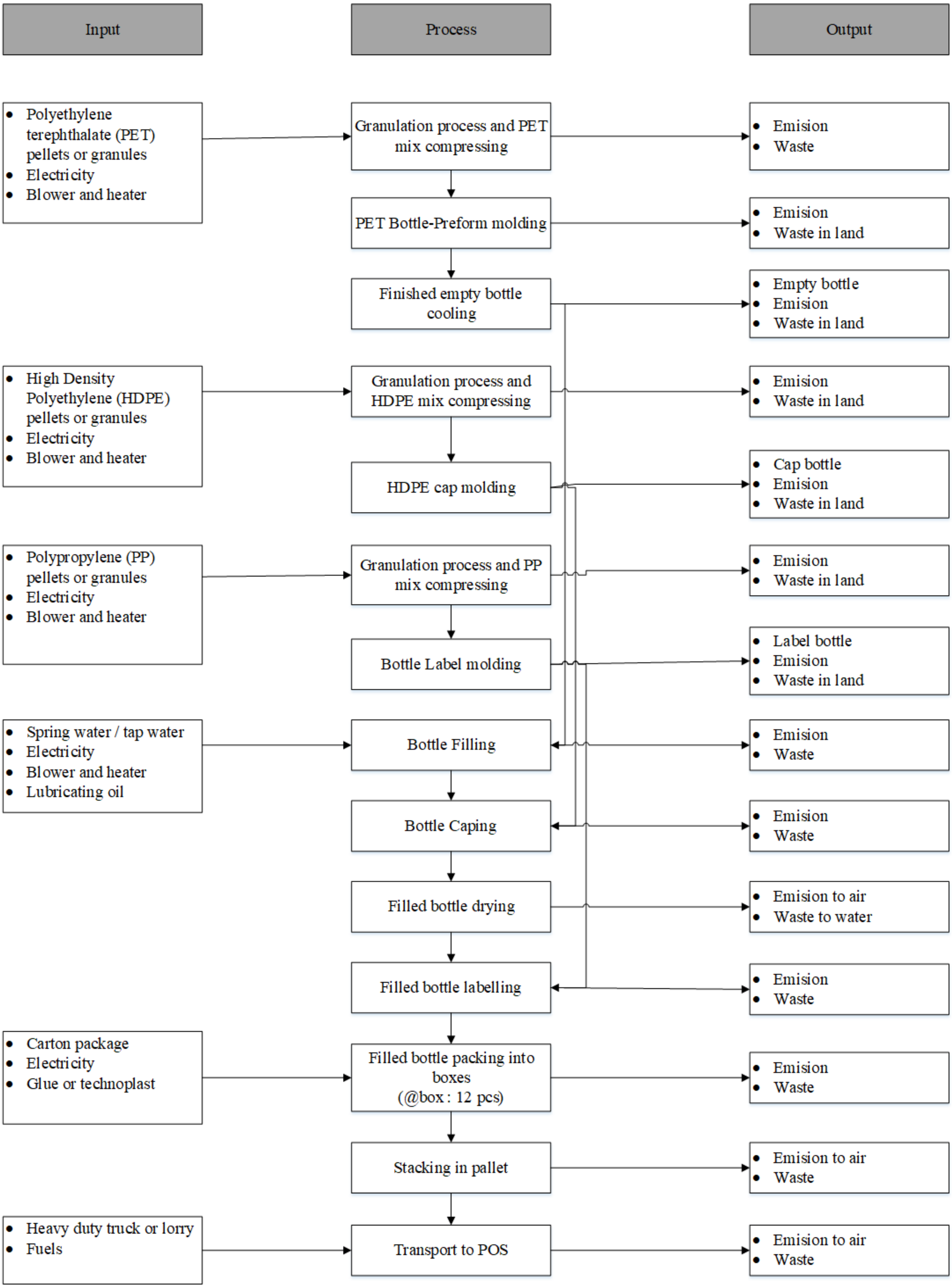

Figure 4.3 Input-Process-Output diagram of PET bottle production

The table of life cycle inventory involves the input data as shown in Table 4.1 and output data as shown in Table 4.2 from production process of AQUA 1.5L. In software computation all data available are provided by Ecoinvent verse 3.4 database. All the process was synchronized by the database availability. Then from above figure can be summed up as below:

Table 4.1 Input of life cycle inventory

Input	Flow	Amount	Unit
Material	Polyethylene terephthalate, granulate, bottle grade	0.00275	kg
	Polyethylene, high density, granulate	0.00198	kg
	Polypropylene, granulate	5.6E-4	kg
	Tap water	1.5	kg
	Beverage carton converting	2	m^2
	Lubricating oil	2.5	kg
Energy	Chiller 100kW	1	Item(s)
	Blower and heat exchange unit, KWL 250	1	Item(s)
	Conveyor belt	35	m
	Heat and power co-generation, 200kW electrical	1	Item(s)
	Transport using lorry 16-32 metric ton	1.5275*292	kg*km

Table 4.2 Output of life cycle inventory

Output	Flow	Amount	Unit
Product output	PET Drinking water bottle AQUA 1.5L	1000	Item (s)
Non - Product output	Solid waste	Output LCIA indicator	
	Emission to water		
	Emission to land		
	Emission to air		

4.2.3 Life Cycle Impact Assessment of Aqua 1.5L

In this study, the calculation of environmental impacts in the life cycle assessment method or the Life Cycle Impact Assessment (LCIA) was done completely as output in OpenLCA software. It adopted the impact assessment method of CML Baseline (2015). Then it is grouped in the 8 categories of impacts, namely Acidification potential (AP), Climate Change, Depletion of abiotic resources potential (ADP), Ecotoxicity, Eutrophication potential (EP), Human toxicity potential (HTP), Ozone layer depletion (ODP) and Photochemical oxidation. The total impact resulting from all stages in production of PET bottle in the PT. Tirta Investama throughout its life cycle is analyzed based on its influence on the impact categories produced. All impact categories produced from each life cycle stage are carried out in the same unit functional unit, 1000 one-half liter of AQUA. Figure 4.4 shows the environmental impact result, among those 11 categories, the biggest environmental impact produced from one functional unit was marine aquatic ecotoxicity as 404648013747,487 kg 1,4-dichlorobenzene eq/1000 water-bottle.

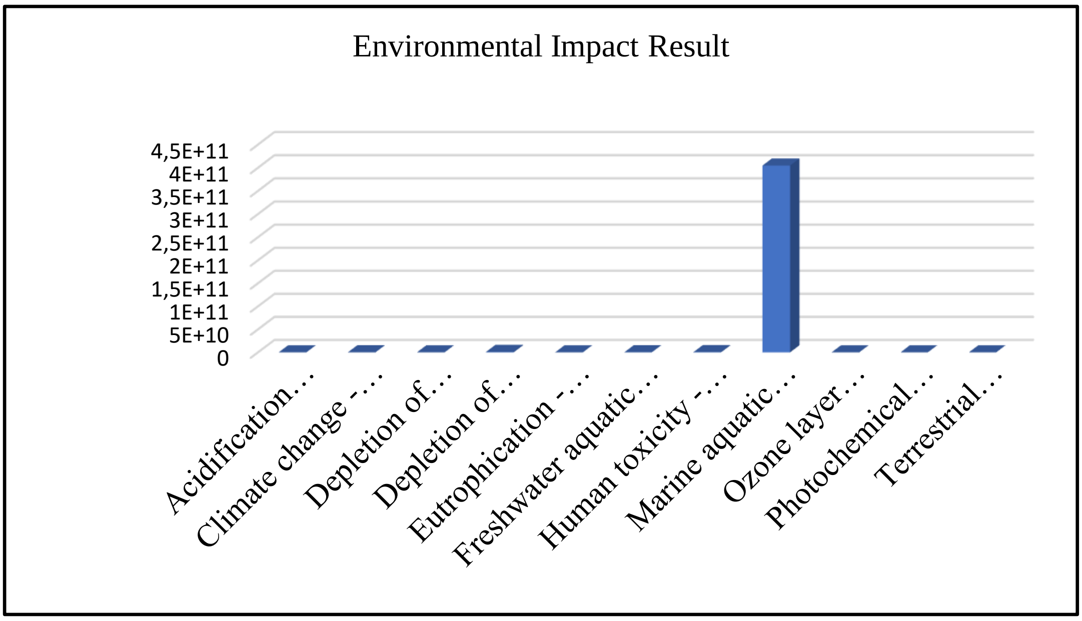

Figure 4.4 Life cycle impact assessment result of PET water bottle
Source : OpenLCA Software

4.2.4 Interpretation

From the environmental impact potential produced from water-bottle life cycle in AQUA-Danone, thus it is produced several results that contribute to each process as well as the environmental impact within the production phase, it produced below interpretation:

A. Result of contribution in impact category within life cycle: One Functional Unit

In producing 1.5liter of water drinking bottle, AQUA-Danone manufacturing plants went through several phases which were then analyzed based on the phase of their life cycle. Contribution process was done by calculating the impact produced based on 8 categories of production water-bottle which were calculated in one functional unit, which is 1000 bottles. Those process involved accumulation of each process or step through. The results of this calculation can be further analyzed to find out the phase or cycle stage of the production process which has the most significant influence on the environmental impact produced. Contributions from each environmental impact of water-bottle's life cycle were shown in Appendix A. While, as the most influence in environmental impact categories, the process contribution from marine aquatic ecotoxity were shown in Figure 4.5.

Figure 4.5 shows that the top 5 or the fifth-highest contribution to impact category results towards marine aquatic ecotoxicity (MAETP) was the process or life stages of

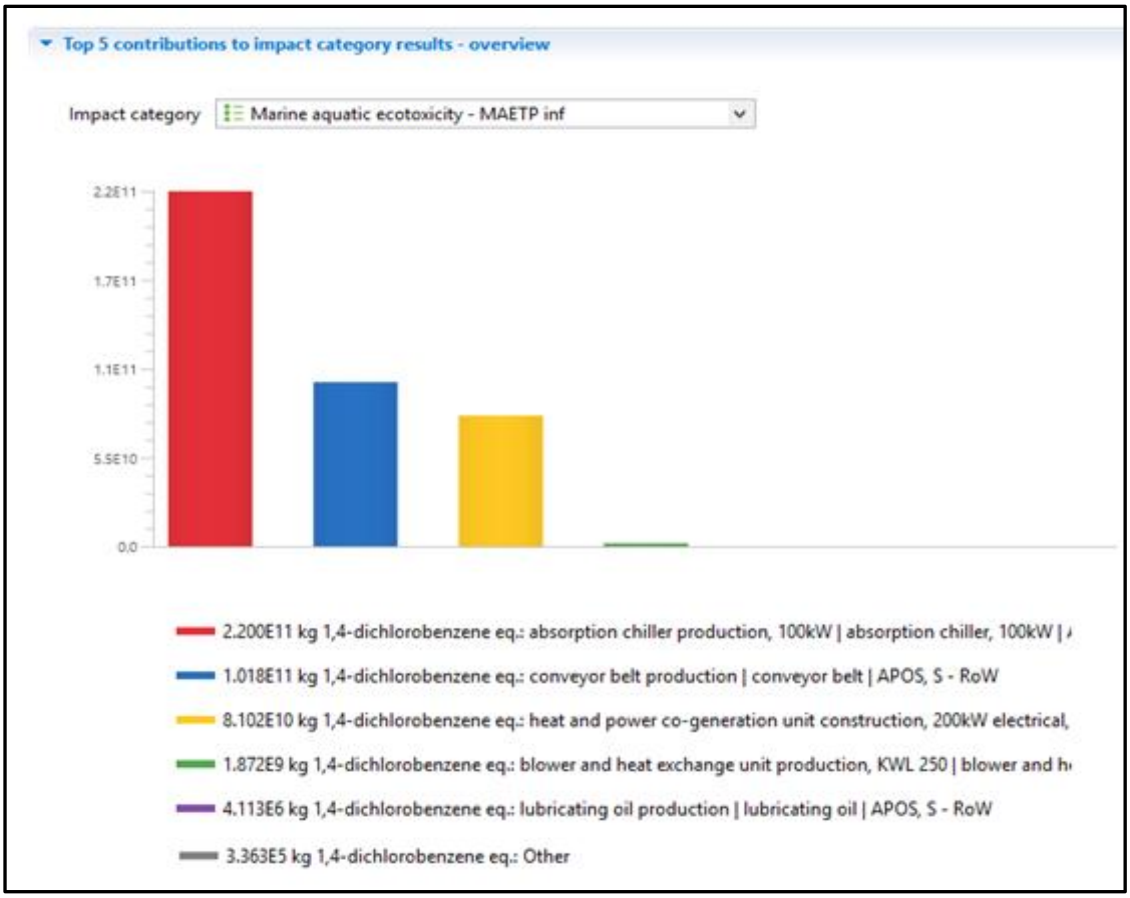

Figure 4.5 Contribution process of one functional unit towards marine aquatic ecotoxicity
Source : OpenLCA Software

absorption chiller production, conveyor belt production, heat and power co-generation unit construction 200kW, blower and heat exchange and lubricating oil production.

The process of absorption chiller production gave the most dominant contribution towards the results compare to other process. Since this life stage that include in whole production was related with electricity in water treatment phase that need this chiller to keep the room temperature stable and keep the humidity. Thus, this chiller requires large energy to run that process.

B. Result of contribution of absorption chiller production

In previous result, it is showed that marine aquatic ecotoxicity was the most dangerous impact category towards the environment. Then, this category becoming the reference in defining what process that significantly gave the contribution. In this result, proven that process in absorption chiller production gave the most significant contribution towards the result by releasing three different flow as depicted in figure below. Each figure represents different flow that specify to manufacturing activity within industrial area.

The Figure 4.6 represents the contribution tree with flow in occupation. The result contribution presents - that to produce 1000 PET water bottle as one functional unit- the process of absorption chiller production gives the highest contribution towards the industrial area especially the resource of land. It means that, from this process give 43.2% contribution from total process by giving the impact towards land area as much as 1,1E5 in meter square acre (m^2*a). It also means that land resources have potentially polluted from the activities of chiller absorption. The rest process such as heat and electrical power generation and conveyor belt production only consume around 29% and 24% respectively from whole process. Other processes are considered give no impact or not significant impact cause only contribute under 1%.

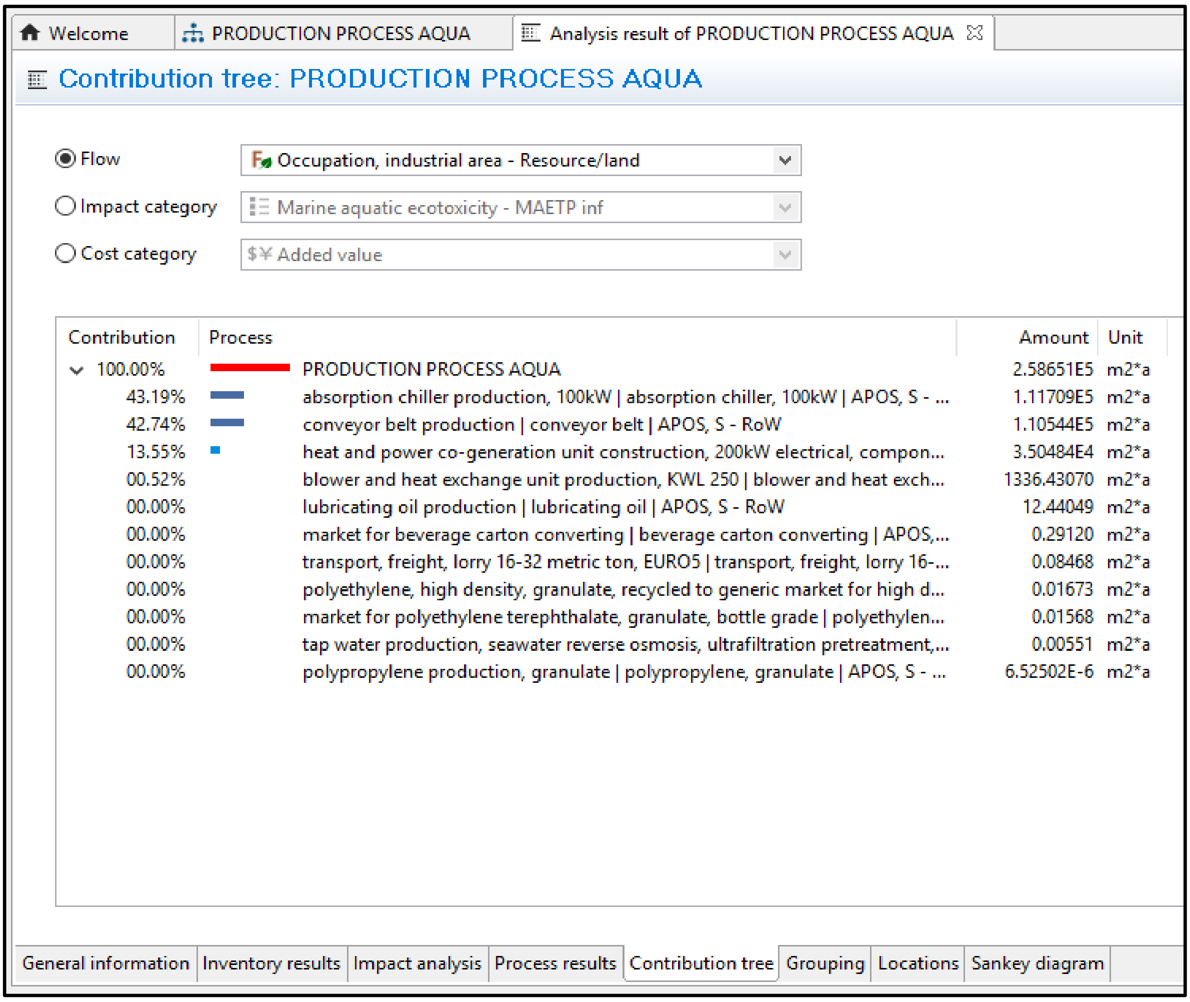

Figure 4.6 Contribution tree in absorption process in industrial area
Source : OpenLCA Software

The Figure 4.7 represents the contribution tree with flow in carbon dioxide that release in the air. The result contribution presents - that to produce 1000 PET water bottle as one functional unit- the process of absorption chiller production gives the highest contribution towards the resource of land in the flow of CO_2. It means that, from this process give 36.6% contribution from total process by releasing the impact to environment as much as 1,6 kilogram (kg) to the air. It also means that air resources have potentially polluted from the activities of chiller absorption. The rest process such as heat and electrical power generation and conveyor belt production only consume around 33% and 29% respectively from whole process. Other processes are considered give no impact or not significant impact cause only contribute under 1%.

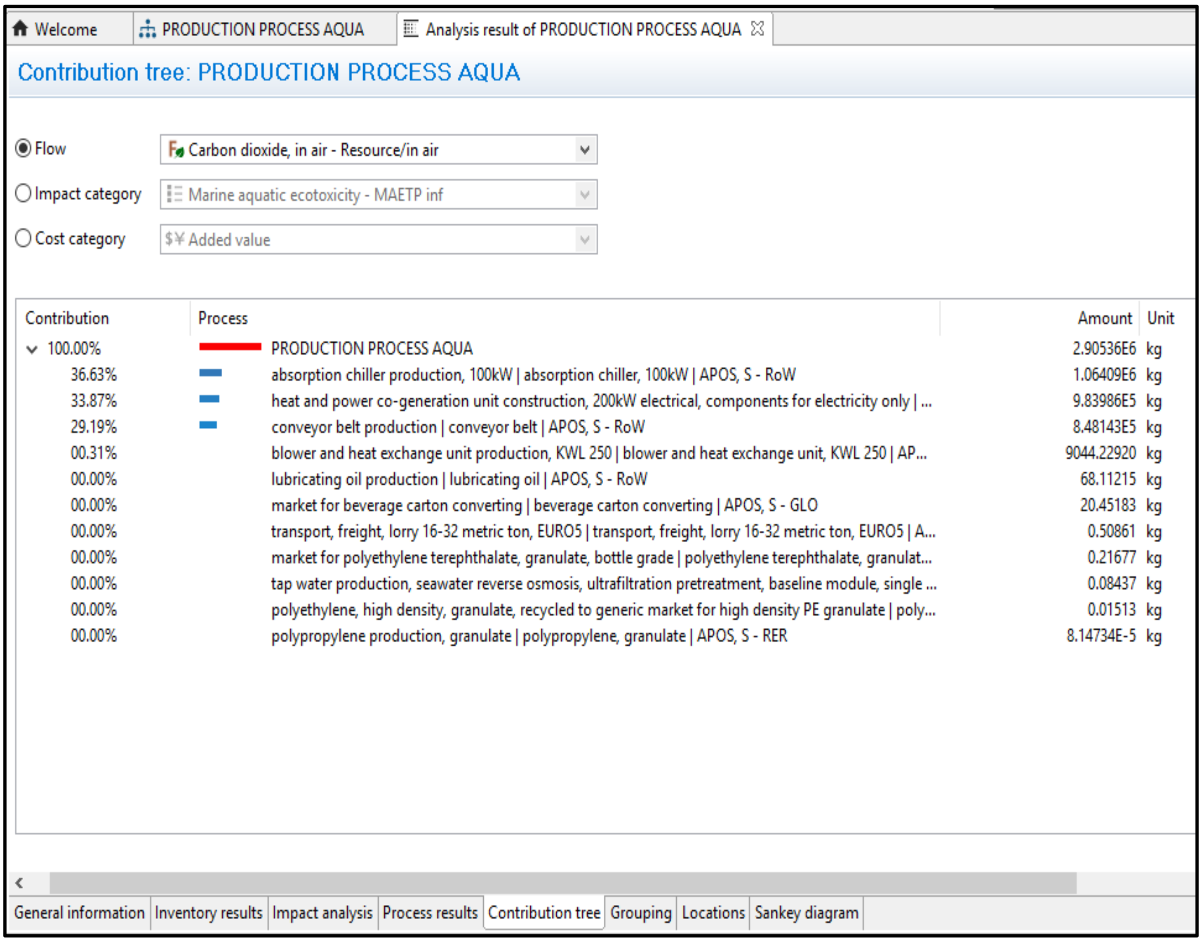

Figure 4.7 Contribution tree in absorption process with CO_2 flow
Source : OpenLCA Software

The Figure 4.8 represents the contribution tree with flow in energy required. The result contribution presents - that to produce 1000 PET water bottle as one functional unit- the process of absorption chiller production gives the highest contribution towards the energy especially resource in air. It means that, from this process give 60,85% contribution -from total process by absorbing the energy to run the process and activities - to environment as much as 5,9E4 megajoules (MJ). It also means that air resources have potentially polluted from the activities of chiller absorption. The rest process such as heat and electrical power generation and conveyor belt production only consume around 15% and 23% respectively from whole process. Other processes are considered give no impact or not significant impact cause only contribute under 1%. Therefore, from above figure represents that the main concern as the improvement or action plant should be look at energy usage or energy saving.

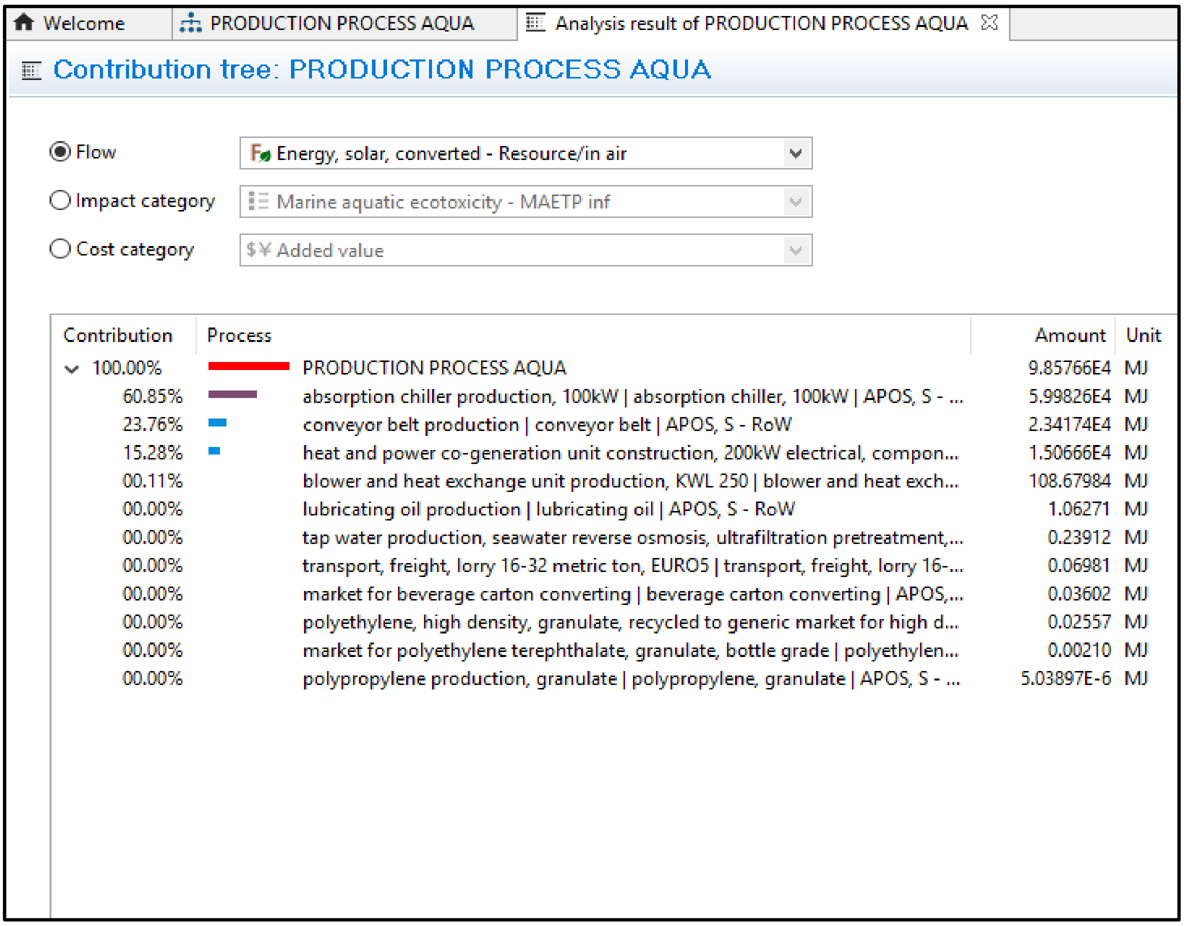

Figure 4.8 Contribution tree in absorption process in energy flow
Source : OpenLCA Software

4.3 Proposed Alternative (Eco-efficiency Assessment)

After conducting an environmental impact evaluation through the Life Cycle Assessment, a solution or improvement is needed to reduce the environmental effects caused by the PET bottle production process simultaneously to improve the productivity and efficiency performance in production process. The improvement can be generated through Eco-efficiency assessment. A tool that used to analyze the proposed alternative (solutions) in improving systems and environments by comparing economic values (Life Cycle Costs) and environmental effects (Life Cycle Assessment) on a process or product simultaneously. The eco-efficiency assessment also seeks to minimize the ecological damage caused by any manufacturing activities through evaluating process, lesser energy, material, hazardous substances usage and many more. Specifically, to increase the efficiency and productivity in company's production process by considering the economical principles.

The results of subsequent interpretations are carried out with environmental efficiency assessments to choose the best solution in accordance with the Environmental and economic fields in the Danone-Aqua manufacturing plant system. To maximize environmental improvements and increase these costs, optimization of environmental efficiency is based on the results of the Life Cycle Impact Assessment (LCIA) in the manufacturing plant.

From the LCIA, it shows that the energy consumption, depletion in resource (land) and CO_2 are the most contributed to the entire life cycle during the production process. Recall to process contribution to the result, the absorption chiller should be put in concern. Then to manifest the aim to increase the productivity concern –saving energy and cost from operational process- the strategies in HVAC (Heating Ventilating and Air conditioning) system should be applied in terms to attain the most cost-efficient and eco-friendly. Then the proposed alternative derived to design the new installation of centralized chiller in Small Packaging Size (SPS) 1 area. Since the initial system is often experiencing downtime and still using the water supply tank in each chiller, then the proposed design installs a new central water-storage supply tank to gain energy saving and reduce energy bills. To model it, need some input as LCIA results and the LCC. The LCC in this study is depicted in Table 4.2 in detail. Then it supported by previous study and reference as the constraint that had been conducted by Ozcan (2013) about hybrid and compressor system and Churcher (2014) and Gann about the HVAC system installment in new building.

Table 4.2 shows the input needed to compute the LCC, the cost is already converted into USD (1 USD = Rp. 14155) to maintain the data uniform. Table 4.3 shows the LCC that had done before (USD 1379150) to be inputted as the further calculation in Eco-efficiency. In this table, it is shown some similar alternatives in optimizing HVAC strategies with written references as the constraint. Yet, considering the correlated LCIA result impact category which is Global Warming Potential (GWP) and Ozone Depletion Potential (ODP). Since the data is not uniform, then need to be normalized first, as depicted in Table 4.4.

Table 4.3 Life cycle cost factors

Life Cycle Cost Input	Amount
Contain sensitive information. Please contact to 15522032@alumni.uii.ac.id or interpro.fti@uii.ac.id for more support.	
Total LCC	**USD 1379150**

Source : Danone - AQUA

Table 4.4 Environmental Effect and LCC calculation

Alternative	GWP (kg CO2 eq)	ODP (kg CFC-11 eq)	LCC	Source
Centralized chiller	95623496	9,38	1379150	This study
Hybrid System	156	3,452	0,074	Ozcan et al (2013)
Compressor System	160	3,526	0,069	Ozcan et al (2013)
HVAC system in new building	60798218	1,75	18515	Churcher (2014), Gann

Table 4.5 Normalization dataset

Alternative	GWP (kg CO2 eq)	ODP (kg CFC-11 eq)	LCC	Source
	v1	v2		
Centralized chiller	119.387	-.63002	149.988	This study
Hybrid System	-.82605	.83011	-.50891	Ozcan et al (2013)
Compressor System	-.82605	.87309	-.50892	Ozcan et al (2013)
HVAC system in new building	.45823	-107.317	-.48205	Churcher(2014), Gann

After normalizing the data, the Linear Programming (LP) model was created and completed and the results are optimal weights (vr). These computations were supported by Linear Programming Solver (LiPs) software. The vr value is used as input in the Eco-efficiency ratio calculation as shown in Table 4.5 The model is completed 4 times for each alternative. To illustrate, equation 4.1-4.4 is an example of a formulation for a centralized chiller installation.

Objective function:

$$Min\ z^{-1} = \frac{1}{150}\ x\ (119{,}4_{v1}\text{-}0{,}63_{v2}) \qquad (4.1)$$

Subject to

$$\frac{1}{-0{,}51}\ x\ (-0{,}826_{v1}+0{,}87_{v2}) \geq 1 \qquad (4.2)$$

$$\frac{1}{-0{,}51}\ x\ (-0{,}826_{v1}+0{,}83_{v2}) \geq 1 \qquad (4.3)$$

$$\frac{1}{-0{,}48}\ x\ (0{,}46_{v1}\text{-}107_{v2}) \geq 1 \qquad (4.4)$$

Table 4.6 Result model and corresponding weights

Alternative	**Eco-Efficiency Ratio**	**v1**	**v2**
Centralized chiller installation	0,5035	119.387	-.63002
Hybrid System		-.82605	.83011
Compressor System		-.82605	.87309
HVAC system in new building		.45823	-107.317

Based on the calculation of Eco-efficiency ratio, the results obtained that the alternative of centralized chiller installation giving as much as 50,3%. Since the percentage is quite high thus the alternative was chosen as one action plan as the most optimal alternative for controlling the CO_2, energy saving and resource (land) use that contribute to GWP and ODP emissions produce from PET bottle production process. Besides, this solution also can increase the productivity in terms of reducing the energy and cost simultaneously raising the number of bottles produced since the proposed system is working smoothly and diminish the downtime. Therefore, it makes decision maker to choose the right alternative to be used as a solution for evaluation on productivity and environmental impact on PET bottle production process in Danone Aqua. The recommendation is the same as the results of research conducted by Ali et al (2017) where the Direct expansion (DX) dedicated outdoor air system is shown to provide conditioned ventilation air at the required set point temperature and relative humidity in an energy efficient manner. Consider as the most optimum solution in terms of be a cost-effective energy efficient complement models.

4.3.1 Post-Implementation Reviews

In this review, aims to evaluate whether the alternative or project has met the objectives or not. Also, to determine how effective the proposed solution run. In here, the key point is the way operating cost and energy consumption is diminishing or not. There are some considerations such as the plant-layout (design) to install the centralized chiller (to put the central water storage tank) and also information such the audit or monthly record of energy consumption in SPS1 area.

The amended plant-design taking account to environmental impact and economical principles. So that, the amended design of centralized-chiller installation as depicted in Figure 4.9 was put to satisfy the construction installation of new chiller and water storage tank. The most significance different is the water supply tank is centralized into one (as hot and cold tank) then it distributed to cooling tower to be flowed into AHU (Air Handling Unit) and FCU (Fan Coiling Unit) in the room of screw cap line. By this design, the controlling for set temperature is maintained well. Besides, the energy and water supply can be saved as efficiently compared to initial model. Figure 4.9 shows the initial model plant-design in which it keeps and maintains the water supply tank in each chiller so that the water bill and electrical consumption was high and also the impact to environment (CO_2) is terrible.

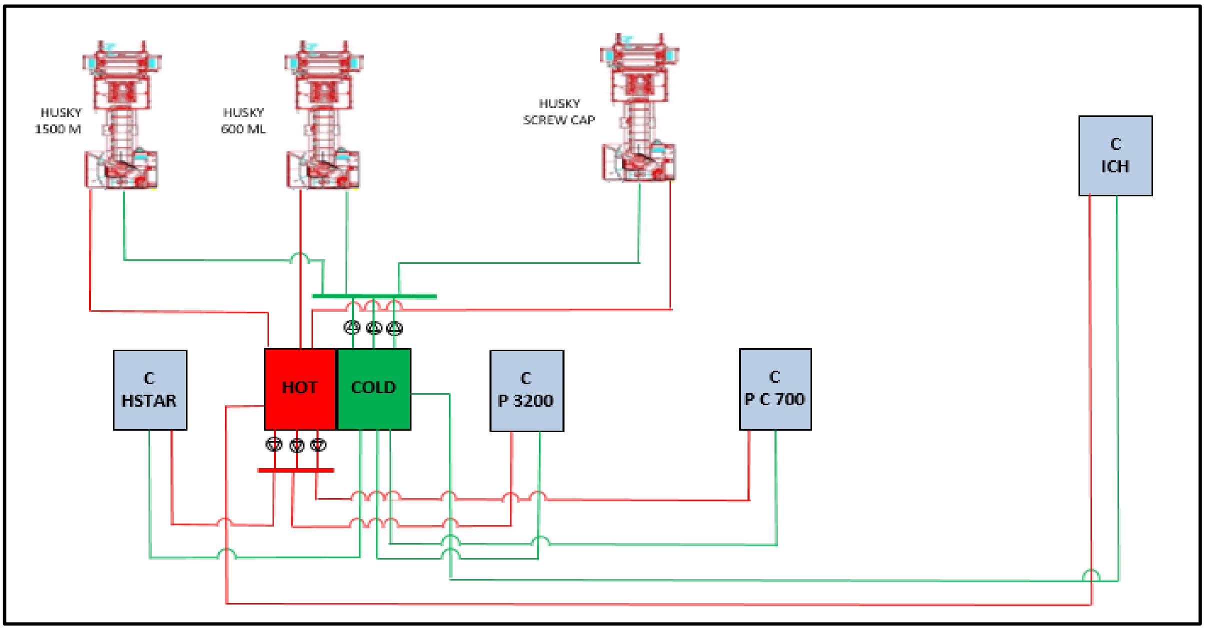

Figure 4.9 Layout of amended design SPS 1 manufacturing plant area

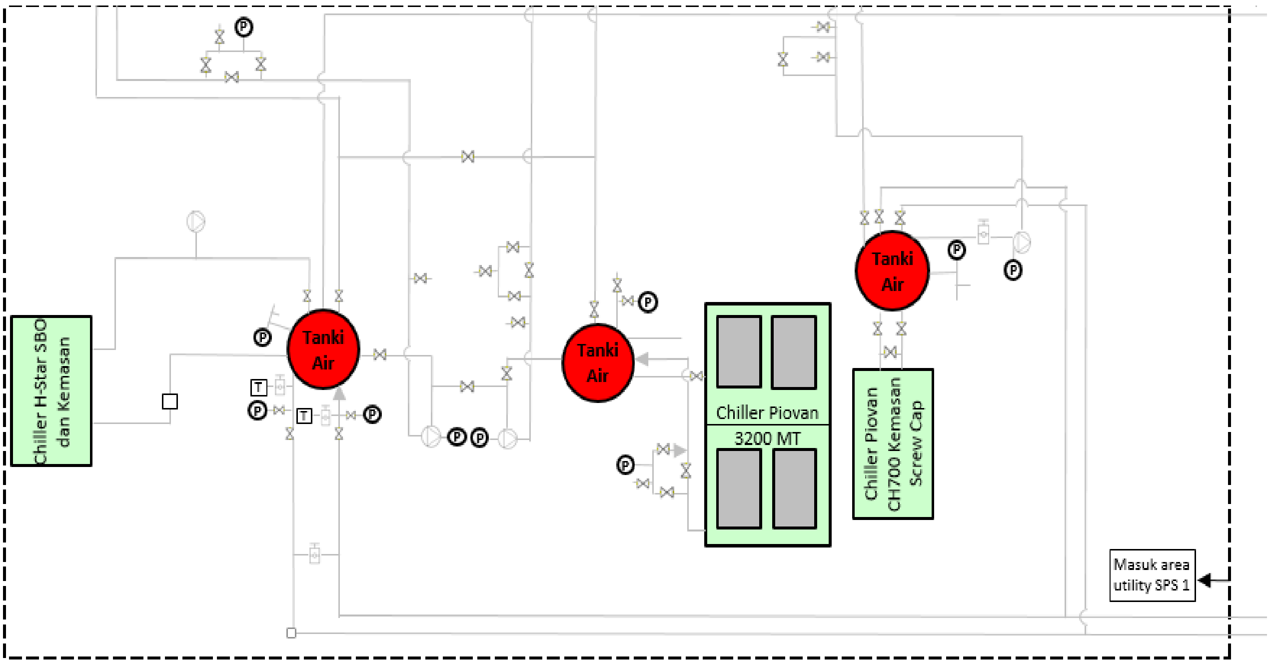

Figure 4.10 Layout of initial model design SPS 1 manufacturing plant area

Table 4.6 shows the summary of net saving as output from new installation of centralized-chiller. It represents the comparison of energy consumed and operational cost within 2 different period; after (May) and before (March) the alternatives applied. The reference unit then set to avoid the ambiguous, which is 4628868 pieces of bottles produced within the same month. Also consider that supply energy to line 1,5L estimates as 60%. Then it got a result that in March, the energy consumption recorded as 189476 KWh, then in May it reduced to 116862 KWh. The reduction was about 38,3% as well as the operating cost which reduced from Rp. 125054846 to Rp. 77128920.

Table 4.7 Summary of Net Saving

Energy Consumption	**Month**	
	March	**May**
Chiller SBO 1500-600 ML SPS1 (KWh)	5621	197,1
Chiller AHU 1500-600 ML SPS1 (KWh)	142488	108145
Indoor AHU SPS1 (KWh)	41367	8519,5
TOTAL ENERGY (KWh)	189476	116862
Operational cost (Rp)	125054846	77128920