CHAPTER V

DISCUSSION

5.1 Interpretation of Life Cycle Assessment

Conceptually, the most crucial stages in modeling the LCA began with setting the goal and system boundary. In this study, the system adopted the cradle-to-grave in which, it examined raw material extraction until the products are transported to POS (Point of Sale) in Surabaya. The point of adopting this boundary is the life cycle is examined until it left the factory. It excluded the customer usage and behavior, waste collection, end-of-life management and additional system boundary issues (e.g : infrastructure, material substitution etc.). The customer usage and behavior are excluded due to lack of information about the customer usage and satisfaction also no accurate data available about how long and treatment after-purchase phase, of course it needs long study and survey for market test. The management of waste from the PET bottle production also excluded, due to uncertainty concerning proportional of some PET bottle types diverted down different waste management routes currently prevalent in Indonesia. Since it requested the individual routes of landfill, energy from waste (EfW) and recycling should be assessed and report separately. Moreover, the waste management method assessed reflect the current Indonesia market situation in terms of disposal routes or where is still not known, the general market situation. While for collection and transport of used PET bottle to waste management was not included for landfilled or incinerated. Due to no available information about the distance and additional transport to the recycling facility. While for another additional system boundary issues, infrastructure (buildings, roads, construction and demolition, vehicles etc.) was not included within the system boundaries. The reason for not including the infrastructure, besides from practical

aspects, was that, based on experience from previous LCA studies, the contribution from these is negligible compared to the flows (e.g the mass of material, consumption of fuels and energy) included within system boundaries in the frame of functional unit.

The functional unit for this study produces 1000 bottles of PET drinking bottle then transported to POS (Point of Sale). Therefore, data for the inventory and impact assessment in this study are expressed on the basis of functional unit. The consistency of calculating and gathering the inventory data should be taken in accordance to avoid the bias and invalid results. Thus, the energy and material used for producing 1000 unit bottles (items) will be the reference flow to generate product system. Through product system, the results of environmental impact would be appeared as an asset to better perform life cycle assessment studies. However, a comprehensive Life Cycle Impact Assessment (LCIA) methods will be set as the most suitable for all data sets provided in OpenLCA-Nexus software.

By tradition, LCIA method is understood as a set of LCIA impact categories. This also reflected to OpenLCA, where selecting the LCIA method prior to calculating the product system. This study used CML-IA impact assessment method. This method created and proposed by some scientist from Leiden University in which contains some of impact categories and characterization methods. This method used in this study due to the most suitable for midpoint problem-oriented approach likely in Danone-AQUA. Moreover, this method also the most widely used since it provides vary of availability impact categories. Since it contains more than 1700 different flows (Ciroth et al., 2016). While the last stages in LCA after selecting the method assessment are generating and calculating the result.

The environmental impact produced from each life cycle stage are carried out in the same unit functional unit, 1000 one-half liter of AQUA. As illustrated in Figure 4.7, the result showed that among 11 impact categories, the largest contributions from the PET bottle was addressed to marine aquatic ecotoxicity as 404648013747,487 kg 1,4-dichlorobenzene eq. It means that, this category was put much concern with the impacts of toxic substances related to marine ecosystem (Kani et al.,hai 2019). Means that to produce 1000 PET bottle, will emmit the toxic substances as expressed in 1,4-dichlorobenzene equivalent per kilogram and its time horizon is infinity in nature.

Additionally, the scope of this indicator can be applied to global/continental/regional and local scale. Therefore, the further study can be applied broader than this.

The results should go in depth-analysis to recognize what are the process that contribute to the result. As illustrated in Figure 4.8, it clearly shows that the production of chiller absorption was contribute the most to the results. Then go narrow it down to know what specific flow that caused of this. Result shows that the flow of Carbon Dioxide (CO_2) in the air, occupation in land resource and energy converted –as resource in air- are the most flow contributor to the result, represents as much as 36,6%, 43,2% and 60,85% respectively from total process.

These results indicate that major process that used and related to absorption chiller (such as husky machine that produce screw cap) contribute to high energy input to drive the motor componnet such as compressor etc, so it consumes a lot of electricity. This also leads to more releasing of CO_2 emissions. Then in terms of industrial area –occupation of land resource-, the building installation or any changes related to chiller should be taken a lot since it needs much and even bigger available space to place the component of water cooled chiller. Therefore, appropriate measures should be taken for the proper water chiller installation that consider those three flow.

Thus, the environmental improvement opportunities were target towards the chilled water air conditioning or HVAC (Heating, ventilation, and air conditioning) system strategic in order to increase the environmental efficiency of industry simultaneously in cost-effectiveness.

5.2 Result of Proposed Alternative

In the real system, the manufacturer experienced the frequent downtime of water cooled chiller itself of course it affects to productivity and energy consumption. By this condition, can be taken account to be more focus to seek for optimizing in HVAC system strategies by proposing action plan of centralized-chiller. The further method using Eco-efficiency assessment. Basically, this method was the most suitable in concerning both ecological and economical principles. The alternatives derived based on the condition of existing (initial) system that no longer perform well.

This alternative is suitable with the condition of existing water-cooled chiller performance. The water-cooled chillers have water cooled condenser connected with cooling tower and are usually preferred for medium and large installations where there is sufficiency of water. In addition, they are also preferred in cases that is demanded constant performance of the system, independently of the ambient temperature (industrial air conditioning, air conditioning of digital systems etc), because the capacity of the water-cooled chillers are not affected by the ambient temperature fluctuations. In addition, further economic benefits may take place if cooling power is generated through GAC, since air conditioning is mostly needed in the electricity peak hours (central hours of summertime days) (Chicco & Mancarella, 2007). The alternative also considers the cost and energy power, as suggested by Haines & Wilson (2003) that a water-cooled chiller consumes 10 percent less power than air-cooled chillers.

The components of cooling equipment are included in the package of chiller and cooling tower in which the major component of cooling tower consist of pumps and basin. Pumps will supply the water to the cooling tower and generate water flow that facilitate the cooling. In the initial system, as depicted in Figure 4.13, the three cooling towers are equipped by each water storage supply tank. A cooling tower uses pumps to circulate the water supply. In which, the pumps consume a lot of power. Since too much pumps and ducts circulate to Fan Coiling Unit (FCU) and Air Handling Unit (AHU) so that in the proposed alternatives, the water supply tank (storage) is centralized in one tank only, hence, the initial system still keep 3 different water supply tank, of course there are much ducts and pumps and other refrigerants work and consume lot of electricity. Hence, water-cooled chillers offer optimum efficiency when compared to the level of power consumption Therefore, this alternative derived as centralized-chiller installation aims at increasing the productivity concern –saving energy and cost from operational process.

By using the Eco-efficiency, some input should be taken account, since it involves the life cycle costing. The cost calculation consists of the investment or project cost, estimated maintenance cost per year and energy cost per year, discount rate, years of operation and equipment value final year. All of these costs were converted into USD. The cost behind investment include as installation, engineering design, building etc, while for the estimated energy cost is recorded as monthly. The maintenance cost keeps maintaining the actual cost since not all the project is totally change –some of system,

components, equipment etc. are exist- thus, the record of using the actual data are strongly considered to avoid invalid data, bias and gain the better results. The years of operation also pick as average which is 15 years of operating chiller, depends on the chiller size and specification. Those cost will generate the LCC as much as USD 1379150 that will be inputted into equation and linear programming.

The alternative is supported by couples of references related to optimizing HVAC system strategies in cooling equipment, such as the hybrid chiller system, replacement of chiller system and constructing HVAC system in new building. In Eco-efficiency calculation, it involves the LCIA (Life Cycle Impact Assessment) result that related to previous issues. The impact categories are only inputted two –GWP (Global Warming Potential) and ODP (Ozone Depletion Potential)- because lack of available source or information related to that LCIA and LCC. Besides, those 2 impact categories are strongly correlated to 3 flow most contribute to result of LCA, such as Carbon Dioxide (CO_2) and energy converted issue. The other issue such as material welfare and ecosystem health can leads adverse effects in climate change and greenhouse gases emission to air. That's why this GWP was selected to develop this Eco-efficiency model. The GWP100 also means the emissions are last for time horizon 100 years. It is expressed as factors in this impact category (kilogram carbon dioxide/kilogram of emission). While, for the protection of ecosystem, human health comes under the ODP category indicator. This also related to extraction of mineral and fossil fuels due to the input of system and energy used in HVAC system. Also, the other references are using the different impact assessment method from this study, so that it leads to less variation of impact category. From completing the Eco-efficiency model, it obtained the result expressed as EER (Eco-efficiency Ratio) as much as 50,3%. It indicates that this project or proposed alternative will give an efficiency ratio in Ecological and Economical concern for about 50%. Therefore, this alternative was chosen to be implemented in the real system.

Post-implementation reviews then put much concerning in whether the project or alternative has met the objective or not. It can be reviewed from the summary of net saving within 2 periods –on March and May. March represented the initial system and May was the new system applied. The reason why April was not included as the review or comparison was on that month the project was still running. Then, to avoid shutdown or off-production, during the project running, the temporary installation was generated to

accommodate the on process production. Thus, the new system is completely working on May. Among those centralized chiller installations, the power or energy was reduced from 189476 kWh to 116862 kWh. It is assumed that this month produces the same unit of bottle which is 4628868 pieces. It is estimates around 38,3% of power or electrical used are reduced. This percentage indicates that the new system is better than the old system. Since, the new system -installing the centralized -water supply tank- can control the set temperature and water-cooled circulation to AHU and FCU properly, so that the cooling equipment will drive the energy flow properly. The new design also reduces the ducts and some pumps that initially leads to higher energy consumption and bill.

This power saving also affects to the lessen of operational cost that includes in electrical bill. The limitation in this review also the comparison or summary of net saving only recorded monthly, since lack of available information related to energy consumption. Besides, the audit for energy report was conducted annually so the complete information and record will be more valid within one full year. In shortly, by applying this alternative, the manufacturer can gain the goal to attain the energy and cost-effectiveness by considering the environmental and ecological principles.