CHAPTER 2 - LITERATURE REVIEW

2.1. Study on Refrigeration System

The mechanism of refrigeration does not mean the process of adding coldness into an enclosed space. It is the process of absorbing the heat off from an enclosed space, and dispose the absorbed heat into somewhere else with the objective of lowering the temperature of the enclosed space and then maintaining the lowered temperature. Cold refers to the absence of heat, so in order to lower the temperature, it is the act of "removing heat" rather than "adding cold". There are many ways possible to do refrigeration, but there are three basic methods of heat transfer, which is convection, conduction, and radiation [Maheshwari *et al*., 2013].

There is also calculation to determine the efficiency of the refrigeration system, which is the coefficient of performance (C.O.P). According to Maheshwari et al. (2013), The coefficient of performance is the ratio of heat absorbed by the refrigerator to the work done on the refrigerant. The formula for C.O.P calculation is :

Theoretical C.O.P = $\frac{Q}{W}$

Q = Amount of heat extracted in the refrigerator or The capacity of refrigerator.

W = Amount of work done.

According to Rahman *et al*. (2019), there are two cold storage methods that is commonly used in Indonesia, which is land-based cold storage and vessel-based cold storage. However most of the cold storage used is land-based cold storage, and adding the problem to the supply and demand of cold storage in Indonesia, the cold storage availability and demand have a large gap, and it worsens on smaller islands other than Java, as shown below in Figure 1.

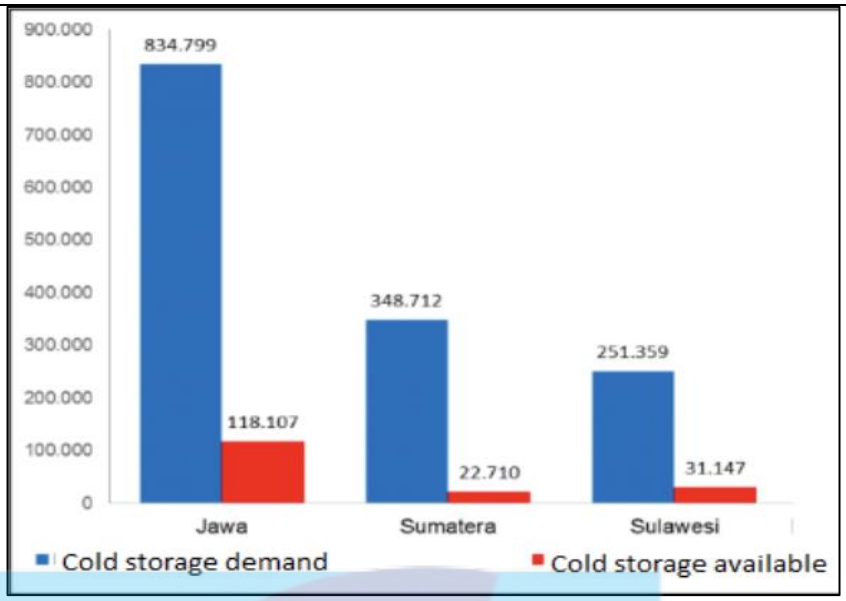

Figure 1. Demand and availability of land-based cold storage in Indonesia

Currently the widely applied refrigeration method in Indonesia is vapor compression system due to its simplicity. It is able to keep the temperature at a particular range below the freezing temperature of water, which is good for storing meat and ingredients, however this type has a problem. The problem lies at the vast space it needs for the installation, and it also requires a significant amount of energy consumption. Considering the problem that the vapor compression system has, researchers have found more refrigeration methods. Thermoelectric cooling system tackles all of the problem and inconvenience that the vapor compression system has [Rahman *et al*., 2019].

2.2. Refrigeration by Using Peltier Thermoelectric Cooling

According to Patel *et al*. (2016) and Rahman *et al*. (2019), thermoelectric cooling, also known as Peltier cooling, is a solid-state method of heat transfer through dissimilar semiconductor materials. Thermoelectric cooling system applies the Peltier effect, which is the conversion of electric current into a temperature difference from designated material. It works by using Direct Current (DC) to thermoelectric cooler system, then the heat is transferred from one side into the other side. The heat transfer causes the thermoelectric cooler or the Peltier module have a difference in temperature between both sides.

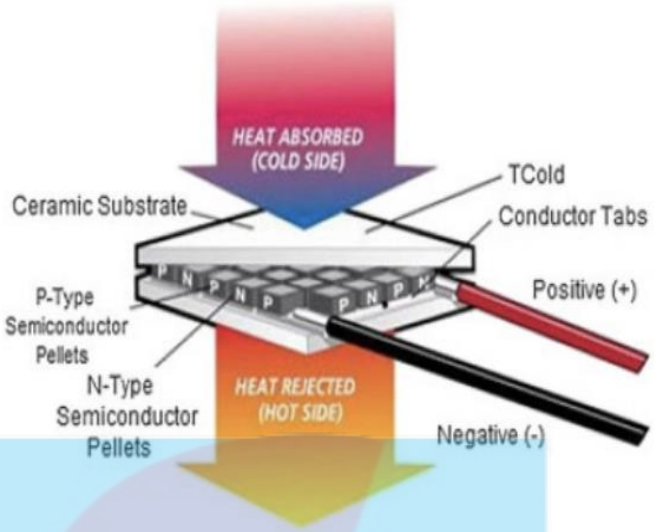

Figure 2. Structure of Peltier Module

The Peltier module consists of serial connections of low-level P-Type Semiconductor pellets and high-level N-Type Semiconductor pellets. The heat transfer is provided by using the variation in the energy levels of electron. The absorbing heat side or the cold side can be used as a cooler while the heat rejected side or the hot side will still continuously heat. To avoid damage on the hot side, its essential to dissipate heat for effective operation by combining the hot side with a cooler i.e. heat sink or water cooling [Fairuz Remeli *et al*., 2020].

According to Patel *et* al. (2016), compared to other refrigeration types, TEC have many advantages, which is :

- TECs did not have any moving parts because they are solid-state. Not having any moving parts mean that the reliability is better than other refrigeration methods that are currently used.
- TECs are compact, lightweight, relatively inexpensive, and quiet.
- TECs did not use any fluid or gas that can leak and damage the electronics or the environment.

From those advantages above, TEC seems to be the desirable refrigeration method. According to Fairuz Remeli *et al*. (2020), TECs are able to do temperature controlling, cooling, and refrigeration purpose because TECs can pump heat from a low temperature heat source to high-temperature heat source. However, TEC have a major problem, which is its efficiency. Their efficiency is not as good as its other refrigeration method, so their applicability is reduced [Patel *et al*., 2016].

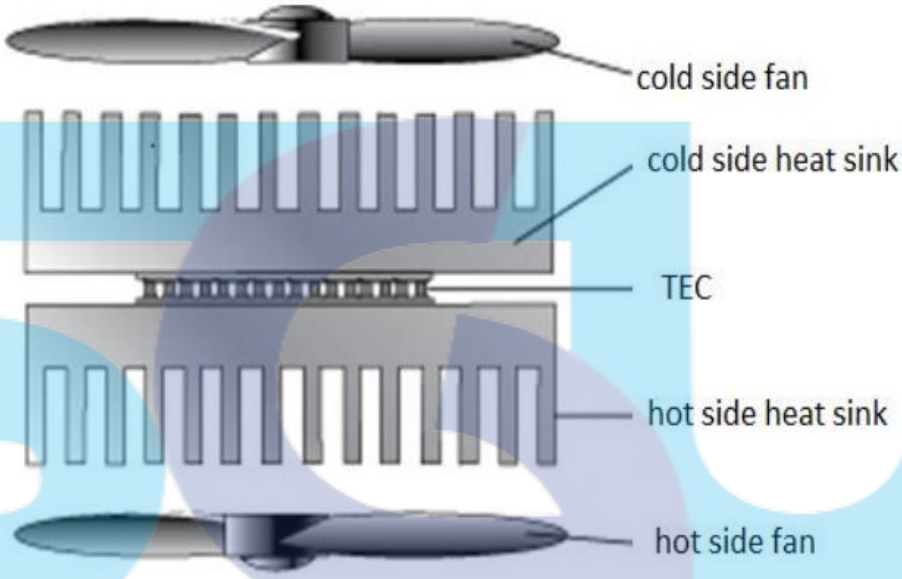

Figure 3. Configuration of Thermoelectric Cooler

Figure 3. shows the entire configuration of thermoelectric cooling system. There are some changes to the system to get the best thermal performance. The measure of the efficiency of thermoelectric cooler is based on the formula of COP discussed earlier, which is COP = $\frac{Qc}{Win}$. The extracted heat from the source is cooling power. The cooler can be operated at maximum COP depending on the current. There are recent improvements in the TEC materials, resulting in the improvement of the performance of TECs. But it is still not enough for application on domestic or industrial level. To prove this claim, Patel *et al*. (2016) have conducted an experiment using a single Peltier module, which has delta T of 51^{o}C and by using the COP formula, the COP value is 0.564432.

Although the COP is lower than expectations, Fairuz Remeli *et al*. (2020) also conducted an experiment using Peltier module with heat sinks for cold side and hot side, and the data shows that it is enough to cool down a box with initial temperature of 30^{o}C to 19^{o}C in approximately 10 minutes, as shown below in Figure 4.

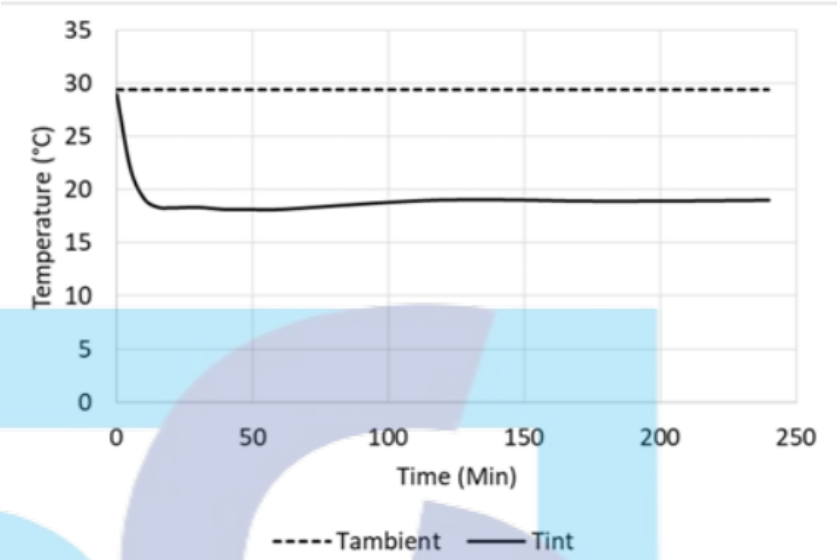

Figure 4. Temperature of the box versus time