ANALYSIS ON THE PERFORMANCE OF ADSORPTION ROUTE IN A TROPICAL REGION

WAN NURLISA WAN AHMAD

This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Mechanical Engineering (Hons.)(Automotive)

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

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UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Analysis on the Performance of Cooling System by Adsorption Route in a Tropical Region* "is written By *Wan Nurlisa Binti Wan Ahmad.* I have examined the final copy of this project and in our opinion it is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

Signature ....
Name of Supervisor: Dr. MOHAMAD FIRDAUS BIN BASRAWI
Position: SENIOR LECTURER OF MECHANICAL ENGINEERING
Date: 21 JUNE 2013

UNIVERSITI MALAYSIA PAHANG
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Signature	....
Name of Panel:	Dr. ABDUL ADAM BIN ABDULLAH
Position:	SENIOR LECTURER OF MECHANICAL ENGINEERING
Date:	21 JUNE 2013

STUDENT'S DECLARATION

I hereby declare that the ideas, designs, analysis, results and conclusions in this project are entirely my own effort, except for quotations and summaries which have been indicated and acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature ....

Name: WAN NURLISA BINTI WAN AHMAD

ID Number: MH09057

Date: 21 JUNE 2013

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ABSTRACT

Nowadays, adsorption chiller attracts attention to be used in cooling system in tropical region due to their minimum heat required and environmental friendly characteristics. The objectives in these studies are to study about the stable solar driven cooling system by adsorption route in a tropical region and to study about the performance of cooling system in the tropical region. The complete cooling system flow is starting from the solar intensity, then absorb by the solar plate collector, the energy is directly stored to the storage water tank to be used for the two beds of the adsorption chiller and lastly it will be supplied cooling energy to the residential building. Solar data and residential cooling load in the tropical region are obtained from the journal. In order to get the best performance of cooling system in term of cost and emission produce, there are 3 difference cases that used different component and energy source. By using the storage water tank as a main component to store the energy from the solar plate collector, two auxiliary components are also chosen when the volume of the storage water tank is reduced to 60% and 30% from the original volume, they are electric heater and natural gas boiler. It is another alternative to get higher heat energy in the water storage and they also act as a backup system for the solar plate collector. The best cooling system in term of cost and emission produce is the boiler with 30% reduction of original volume storage water tank which is RM 2355 for the installation and RM15.98 per month for energy cost. While, monthly cost for conventional air-conditioning is RM333.54 that used 55kW for the whole residential building. For the emission produce per month for this case are 33g for CO_2, 1.97g for CO and 3.61g for NO_X, it is contrast with conventional air-conditioning which is 1446.56g for CO_2, 13.63g for CO, and 9.34g for NO_X.

ABSTRAK

Kini, penjerapan pendingin mendapat perhatian untuk digunakan di dalam system penyejukan terutamanya di kawasan tropika..Hal ini kerana, pendingin ini hanya memerlukan tenaga yang kecil untuk berfungsi dan ianya bersifat mesra alam. Objektif dalam kajian ini adalah utuk mengkaji tentang system penyejukan yang menggunakan kestabilan tenaga solar di rantau tropika dan juga membuat kajian mengenai prestasi system penyejukan di rantau tropika. Aliranl engkap system penyejukan bermula dari tenaga solar, kemudian diserap oleh plat pengumpul suria, tenaga suria kemudian disimpan ke dalam tangki simpanan air yang akan digunakan oleh pendingin penjerapan dan akhir sekali tenaga ini akan dibekalkan untuk digunakan untuk menyejukkan bagunan kediaman. Data solar dan bekalan penyejukan kediaman di kawasan tropika diperolehi daripada jurnal. Dalam usaha untuk mendapatkan prestasi yang terbaik daripada system penyejukan dari segi kos dan nilai pencemaran yang dihasilkan, terdapat 3 kes yang berbeza yang menggunakan komponen yang berbeza dan sumber tenaga yang berlainan. Dengan menggunakan tangki air simpanan sebagai komponen utama untuk menyimpan tenaga dari plat pengumpul suria, dua komponen tambahan juga dipilih apabila jumlah tangki air simpanan dikurangkan kepada 60% dan 30% daripada jumlah asal. Komponen tambahan yang digunakan ialah pemanas elektrik dan juga pemanas yang menggunakan tenaga semulajadi. Sistem penyejukan yang terbaik untuk kos dan pencemaran yang dihasilkan dalam kajian ini ialah pemanas air yang menggunakan gas semulajadi dengan pengurangan sebanyak 30% dari isipadu asal simpanan tangki air. Sebanyak RM 2355 untuk kos pemasangan dan RM15.98 untuk kos tenaga bulanan. Kos bulanan untuk penghawa dingin ialah RM333.54 yang menggunakan sebanyak 55kW untuk keseluruhan rumah. Manakala pencemaran yang dihasilkan ialah sebanyak 33g untuk CO2, 1.97g untuk CO dan 3.61g untuk NO_X. Ianya berbeza dengan penghawa dingin yang mana 1445.5g untuk CO_2, 13.63g untuk CO, dan 9.34g untuk NO_X.

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LIST OF ABBREVIATIONS

SPC	Solar Plate Collector
AD	Adsorption
G.I	Galvanized
AUX	Auxiliary Energy
SH	Space Heating
Chill.	Chilled water
SOLAR	Solar energy
DHW	Domestic hot water
COP	Coefficient of performance

CHAPTER 1

INTRODUCTION

This chapter explains the overview of project background, the problem of the project, the objectives of the project and project scope.

1.1 Project Background

Within the increasing of population of living standard, especially in developing country, modern industrial industry play an important role in providing comfort to human life. Air-conditioning and refrigeration machines are mostly full-filled the human working life. All this kinds are responsible for the emission of hazardous greenhouse gasses and require electricity as the driving source. Growing concern over global warming is highlighting the environment friendly and energy saving technology is focused in this modern scientific community as important to reduce the emission of gases which caused the polluted environment.

Chiller systems are commonly used to provide cooling energy for commercial buildings with central air-conditioning and yet their operation could take up over half of the annual electricity consumption of commercial buildings in tropical regions (F.W. Yu, K.T. Chan, et al. 2011). A chiller cooling system removes heat from one element and deposits into another element. In large data centers the chiller is used to cool the water used in their heating, ventilation and air-conditioning units or liquid can then be circulated through a heat exchanger to cool air or equipment as required.

Adsorption chiller machine provide opportunities for energy saving because they can use heat to produce cooling or heating, instead of electricity used by conventional air-condition system. Adsorption process is the adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to a surface. Adsorption is a different process from absorption, in which a substance diffuses into a liquid or solid to form a solution. They are attractive as they can use low-temperature heat such solar energy, natural gas, waste heat for cooling. Compare to conventional air-conditioners, adsorption chiller consume very little power for operation. This type of machine provides reliable and noise-free cooling as they have only few moving parts. Another advantage of adsorption machine is that they use environmentally working fluid pairs (silica gel-water) which do not deplete the ozone layer of the atmosphere and it is contrast with the conventional air conditioners working fluid.

The use of adsorption system has been increase because they do not use ozone depleting substances as refrigerants. Dependency on using the primary energy sources by adsorption chiller can be reduce as adsorption technology is very attractive to produce necessary cooling by utilizing low-temperature heat source such as renewable heat, and triggered by the potential of waste energy offers advantages to the adsorption cooling or adsorption chiller system. Solar energy is the best heat source due to strong potential for significant primary energy savings.

The main application of this adsorption chiller is the production of cold water. The demand for the production of cold water for air conditioning or process cooling is apparent in many areas of domestic power suppliers or the industry. The operation of chiller systems could take up over half of the electricity consumption of air-conditioned buildings in subtropical regions.

Figure 1.1 shows the simple mechanical construction of adsorption design, where it is classified as closed systems. These are thermally driven chillers provide chilled water, which is either used in air handling units to supply conditioned air.

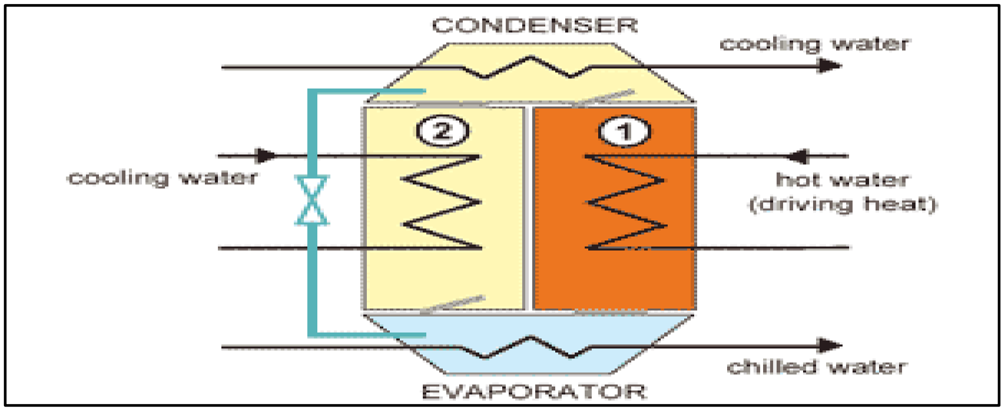

Figure 1.1: Basic adsorption chiller system [1]

Adsorption machines have been present at the market for a long time and it is commonly used in industry, government's buildings and university. The demand on adsorption chillers has been increased after Kyoto Protocol (1997) due to ability to utilize low-temperature heat for air conditioning purpose [1], [2]. Kyoto protocol set the legally binding targets on greenhouse gas emission from industrialized countries. This protocol gives the response to rising concerns about the climate change and it was only first step in the fight against the climate change.

The ability for adsorption chiller use solar energy as its driving energy is a new technology alternative that highly promising solution against the climate change. Adsorption chillers are able to produce cool water with low temperature heat cooling system around (65℃ to 85℃). Compared to conventional air conditioners, this chiller consume very little power for operation as they have few moving parts, low noise and vibration. Most of AD chillers are environmentally friendly as they use water as coolant, silica gel as working pair and solar as heat driving source.

1.2 Problem Statement

Nowadays, adsorption chiller that acts as cooling system becomes more important to human life to comfort their living activities. This project was developed because of the awareness about the performance of cooling system that will effect to the environment. The major barriers to commercialize the adsorption chiller in the tropical region or Malaysia as specified are about the weather. In Malaysia there is inconsistent temperature data due to wind speed, cloud cover and rainfall because Malaysia has two monsoon winds seasons in a year. So, the solar energy is unpredictable. On the other hand, there is a problem in cooling load for residential building with the solar as energy source for adsorption chiller because there is difference energy demand during day and night time for cooling load and energy supply.

1.3 Objectives

1. To study about the stable solar driven cooling system by adsorption route in tropical region.

2. To study about the performance of cooling system in tropical region.

1.4 Scopes of the Project

The scopes of work for this project are:

1) **Small-scale model**: Small-scale model developed with specification for specific heat of Cooling, Q is in the range 1-10 kW. In the effort to maximize the performance of cooling system for adsorption chiller is by minimize the use of energy sources like electricity.
2) **Residential home**: A small-scale adsorption chiller designed focused for small individual residential homes. The design must be concerned for space cooling.
3) **Solar plate collector**: A second trend is reducing the driving temperatures of the adsorption cycles with focusing more in solar plate collector efficiency.
4) **Silica gel-water:** Used as working pair for water cooling adsorption chiller and simple silica gel-water adsorption chiller is developed to use low grade heat source.
5) **Tropical region temperature:** Based on the tropical region temperature the clarities data target temperature for (cooling temperature), and also for driven temperature (heat source) must be specific.
6) **Coefficient of performance, COP**: For output data come out with coefficient of performance, COP from the input data which is suitable used for tropical region temperature data.

1.5 Thesis Outline

Chapter 1 contain explanation on the introduction of the project which consists of the overview of the problem statement, objectives, and scope of the project

Chapter 2 is more focused on literature review. Explanation will be focused on the tropical region temperature and solar radiation, solar plate collector, large storage water tank, auxiliary component as a backup to the system, adsorption chillers and about the cooling load demand for the residential building.

Chapter 3 views the methods that are used in completing the project from the beginning to the end. This includes project data collection, data selection, flow analysis, compare with other studies, and lastly propose the best combination of cooling system for residential building.

Chapter 4 explains the results regarding the analysis of combination of cooling system. Discussion is included for each result to affirm the results are appropriate with the whole component of the cooling system. The graphs are built based on the data and calculation to make it clearer to understand.

Chapter 5 concludes the overall of the project and some future recommendation for further development of this project are being discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, it basically describes more about the studies on adsorption chiller and the performance of cooling system in tropical region that going to use in residential house which has been done earlier by other researchers. It also discussed about the tropical region temperature, solar radiation, and silica gel-water as the working pair and solar collectors as the heat source which has been used in this experiment. The last factor to be focussed is about the large storage water tank with others auxiliary components as heat storage to supply to the chiller.

2.2 Tropical region (Rainforests)

The countries with tropical region or mega thermal climates are belong to Group A in the Koppen Climate Classification. This group contains countries from South America to Asia such as Brazil, Nigeria, Malaysia and Indonesia. The map below shows the location of the world's tropical rainforests. Rainforests cover only a small part of the earth's surface. The rainforests of Asia stretch from India and Burma in the west to Malaysia and the islands of Java and Borneo in the east. Bangladesh has the largest area of mangrove forests in the world.

In Southeast Asia the climate is hot and humid all year round. In the mainland Asia it has a subtropical climate with torrential monsoon rains followed by a drier period. Warm and wet describes the tropical rain forest climate. The average annual temperature is above 20 C, there is never a frost. Rainfall varies widely from a low of about 250cm of rain per year to about 450 cm/year. That means a range from about 8 to 14 feet of rain per year.

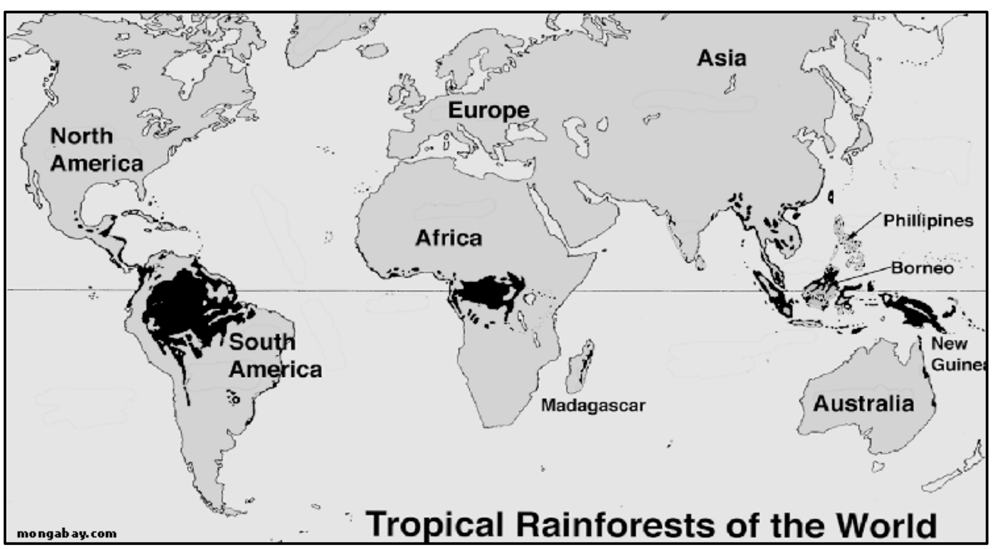

Figure 2.1: Location for Tropical Rainforest [5]

From the map of the tropical rainforests, a band around the equator from 23.5° N (the Tropic of Cancer) to 23.5°S (the Tropic of Capricorn) (red lines on map, right). Because the Earth tilts 23.5 degrees on its axis as it travels around the sun, at some point in the year (the solstices, June 22nd in the north, December 22nd in the south) the sun will be directly overhead on one of these lines. At the equinoxes the sun is directly over the equator.

Within this band, solar radiation is most intense, and thus the surface of the planet warms the most. The warmth leads to a lot of evaporation, and as warm, moist air rises, it cools, the water condenses, and the water falls back to the earth as rain. Thus, the warmest areas of the planet also tend to be the wettest, and this sets the stage for the tropical rain forest.

Not all of the land in the tropics is tropical rainforest. Some areas are too cold (mountaintops), or are too dry (the far side of a mountain range from the ocean gets less rain). In some places there may be a lot of rain, but it falls seasonally and the long dry season prevents a tropical rainforest from developing.

2.2.1 Ambient temperature condition

The average ambient temperature of a tropical region varies throughout the day as shown in Figure 2.2. During 13:00-16:00 the temperature was highest and found to be (30.62-31.37) °C, whereas minimum temperature of 24°C was recorded at 06:00.

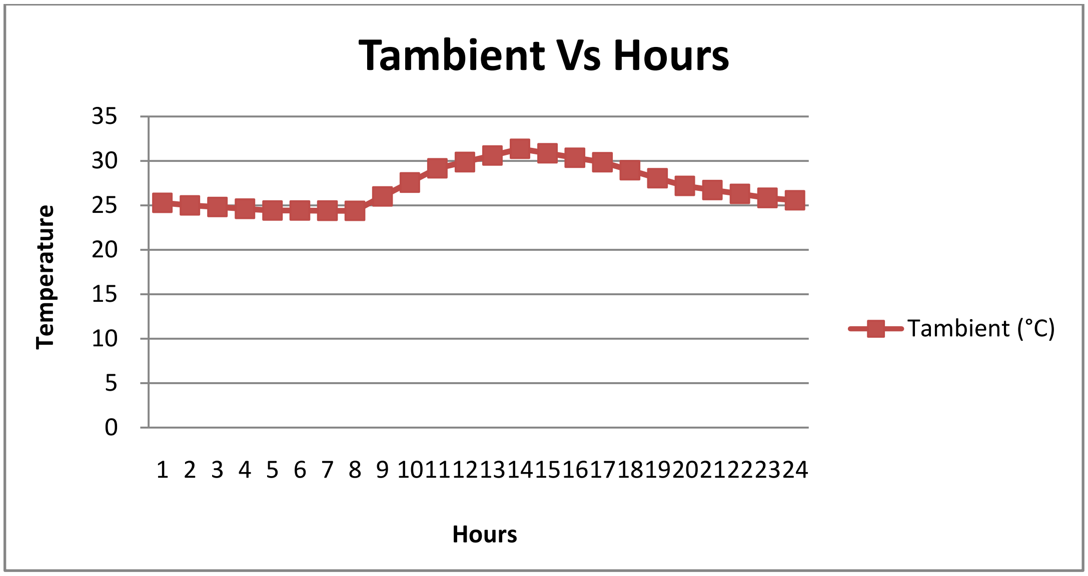

Figure 2.2: Ambient Temperature Versus time

2.2.2 Intensity of radiation

Solar energy received at the Earth's surface can be separated into two basic components which are direct solar energy and diffuse solar energy. Direct solar energy is the energy arriving at the Earth's surface with the Sun's beam. The Sun's beam is quite intense, and hence has also been described a 'shadow producing' radiation. Sunshine duration is defined to be the sum of all time periods during the day when the direct solar irradiance equals or exceeds 120 W/m2. This measurement is only obtained from configurations that measure direct solar irradiance.

2.3 Solar collector as heat collector

Solar adsorption cooling system is based upon solar thermal utilization and allow for lower driving temperature. Tsoutsos et al. (2003), [3] reported that the combination of an adsorption chiller with solar collectors offered a technically simple and energy saving solution. Flat plate solar collectors could easily produce hot water to regenerate the adsorbent of the chiller. Solar collectors acted as power source for the solar cooling system in the adsorption chiller.

In an effort to utilize solar energy as heat source, Critoph (1986) [4] had studied the performance limitations of adsorption cycles for solar cooling. From the experiment they conclude that, activated carbon-methanol combination was preferable for solar cooling will give the best performance achievable in a single stage of cycles. From further research from D.C.Wang (2005) [8], used methanol with silica gel instead of water as result the system could operate below 0°C temperature in evaporator.

There are two basic types of solar energy collectors used for the heating of air or water. They are the flat-plate type collector and the concentrating collector shown in (Figure 2.3). The concentrating collector focuses the direct rays of the sun which are incident on a reflector onto a smaller absorbing area. The flat plate collector involves no focusing of the radiation. It absorbs the direct rays and also is capable of absorbing diffuse radiation -- that is, the portion of the suns' energy which is filtered through clouds or is reflected from other objects. Because of the focusing effect, a concentrating collector can heat an absorber to a much higher temperature than can a flat plate collector. But, because of the use of only direct rays, the concentrating collector must continually "track" or "follow" the sun across the sky. The flat plate collector may remain stationary since it does not require direct radiation to operate.

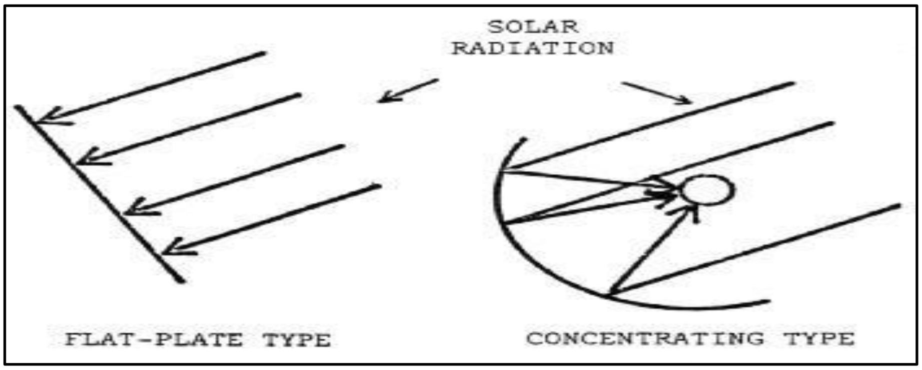

Figure 2.3: Two basic types of solar collectors.

Source: Agricultural Engineering Purdue University

2.3.1 Flat Plate Solar collector properties

Flat-plate collectors, developed by Hottel and Whillier in the 1950s, are the most common type. Flat-plate collectors are capable of providing the moderate temperatures required for space heating or cooling, up to about 250°F. They have the advantages of using both direct and diffuse solar radiation, no need for tracking the suns' path across the sky, and requiring less maintenance. Solar collector is designed to collect heat by absorbing sunlight and then solar panel is an assembly of solar cells that converts sunlight into electricity. Solar is a very good option as the heat source of an adsorption chiller because simpler and cheaper solar collector such as flat plate and evacuated tube can activate adsorption chillers. The useful energy received by the solar collector can be calculated according to instantaneous efficiency of solar collector arrays.

2.3.2 Types of flat plate collectors

There are variation types of configuration of flat plate solar collectors that can be clarified according to their size, adsorber size and the efficiency of the plat. The selection will be made depend on the compatibleness to the adsorption chiller system. Figure 2.4 show the daily energy production of three flat plate of solar system.

Daily energy production ($kW_{th}.h$) of three Flat plate solar thermal systems.			
Configuration	Direct active	Thermo siphon	Indirect active
Overall size (m^2)	2.49	1.98	1.87
Absorber size (m^2)	2.21	1.98	1.72
Maximum efficiency, η	0.74	0.68	0.61

Figure 2.4: Daily energy production of three flat plate of solar system [7]

Flat-plate collectors are capable of providing the moderate temperatures required for space heating or cooling, up to about 120°C. They have the advantages of using both direct and diffuse solar radiation, no need for tracking the suns' path across the sky, and requiring less maintenance. They are mechanically simpler than the concentrating type. For these reasons, the flat plate collector is the logical choice for space heating needs.

There are many different designs of flat-plate collectors, but all have two basic characteristics in common. These are a plate to absorb the suns radiant energy, causing an increase in plate temperature, and a circulating fluid, such as air or water, which picks up the heat absorbed by the plate and transfers it to a point of use or storage.

From this research, we focused more on thermo siphon flat plate solar collector due to the characteristic that full filled the demand for this study.

2.4 Adsorption chiller

Sorption can classify into absorption and adsorption. Absorption is the process in which a substance in one phase is incorporated into another substance of a different phase (e.g. gases being absorbed by a liquid). Adsorption is referred to the use of a solid for adhering or bonding ions and molecules of another substance onto its surface. Adsorption is an exothermic process, with the adsorber to be cooled by a coolant so as to maintain the adsorption process. This process of adsorption concerns separation of a substance from one phase, accompanied by its accumulation or concentration on the surface of another. Both absorption and adsorption are used to provide thermal compression of the refrigerant instead of mechanical compression. Main differences between adsorption and absorption are in the nature of the sorbent and the duration of the sorption cycle [9].

2.4.1 Adsorption chiller properties

The Adsorption Chiller is very attractive as they can only use low-temperature heat source such as waste heat and solar energy for cooling process. It consume very little power for the operation, they also have few moving parts as result low noise and vibration when it is functioning. This chiller also contains only water as a refrigerant and a proprietary, permanent silica gel (lasts 30 years) as an adsorbent. The evaporator section cools the chilled water by the refrigerant (water) being evaporated by adsorption of the silica gel in one of two adsorbent chambers**.** The hot water regenerates the silica gel in the second of the two adsorbent chambers. The water vapor released from the silica gel by the hot water will be condensed in the condenser section, which is cooled by cooling water such as from a cooling tower.

2.4.2 Two beds Adsorption chiller

Two-bed adsorption chiller represents the most basic module for this single stage system which utilizes the adsorbent–adsorbate characteristics to effect useful cooling at the evaporator.

According A.H.N.Khalifa [10], two beds adsorption unit can give continue cooling effect, contrary to single bed adsorption unit. In this single stage, a silica gel-water adsorption chiller can effectively use such low temperature waste heat without corrosion and electric energy consumption. According B.B.Saha (2001), fixed adsorbent beds are usually employed as these cycles can be operational without moving parts other than magnetic valves. This results in low vibration, mechanically simple, high reliability and very long life time.

2.4.3 Small scale of adsorption chiller

There are already many researches develop the product of silica gel-water adsorption by using solar collector plate as driving source, however it is very small portion of the researcher do the research in small scale of adsorption chiller that can be used in small residential building. The idea in building a small-scale of this chiller is important so that we can change the air-conditioning user into the adsorption chiller for cooling system in the house due to reduce the ozone climate. Development of small scale adsorption chillers about 2kW is new and allows sorption cooling to enter the markets for individual homes, small residential building, and also for small commercial applications[15].

2.5 Silica gel as adsorbate

Figure 2.5: Silica gel as adsorbate

Source: Advanced International Group, ISO 9001:2000 in (2011)

In the chiller, a two bed continuous cycle with finned heat transfer tubes was introduced as adsorption units. According to G.Z. Yang (2006), Silica gel particles were packed around the finned heat transfer and fixed by wire mesh. This particle has high capacity absorbent and desiccant consisting of granular highly porous silica. It can adsorb up to 40% of its own weight of water in its internal pores by physical absorption. Indicating Silica gel is basically identical to white silica gel but contains a small quantity of a moisture-sensitive indicating material. The gel is then blue when in the dry condition and turns pink when saturated with moisture. This provides the ideal desiccant for tank and transformer breathers.

2.6 Silica gel-water

In helping the adsorption chiller operation, there are a substances or known as working pair to make the adsorption process become more efficient. They are Silica gel-water, activated carbon-methanol, also the other two types of working fluid pairs which are LiBr-water and Water-Ammonia are selected as the medium transfer for adsorption chiller. Critoph [4] studied that there is limitation performance of adsorption cycles for solar cooling and conclude that the preferable working pair is the combination of carbon-methanol. In (1997) Ortel used the methanol with silica gel instead of water to operate the system at an evaporating temperature below 0°C. In using basic adsorption cycle, Li and Sumathy (1999), [11] have presented the solid adsorption pair by using the activated carbon and methanol for the operation of solar-powered the ice-maker.

According to the single stage or 2 beds adsorption chiller, Adsorption chillers using silica gel–water working pairs have been well accepted and thus commercialized; because such cooling systems can be powered with 60–90 °C hot water directly [R.Z. Wang, R.G. Oliveira, 2009].Silica gel is a granular shape, porous dorm of silicon dioxide made synthetically from sodium silicate. The characteristic of silica gel are tough and hard. It is more solid than common gel such as gelatin or agar. In the 1920s, Hulse suggested a refrigerator which utilized silica gel–SO_2 as a working pair and reached the evaporation temperature of about −12 °C, to store food on trains. [G.E. Hulse, 1929].Adsorption chillers using silica gel–water working pairs have been well accepted and thus commercialized; because such cooling systems can be powered with 60–90 °C hot water directly [R.Z. Wang, R.G. Oliveira, 2009].

Silica gel-water adsorption chiller technology is an effective way of converting waste heat to useful cooling. It has been commercialized in Japan for more than a decade. The using of silica gel-water pair is well suited to this temperature range, according to Chua et al. (1999) had discussed that studied adsorption refrigeration cycle by using this pair which can be driven by 80°C heat source temperature with 30°C as cooling source. In the economic scope, the development and adsorption chiller with silica gel-water as the working pair and the system had no refrigerant valves (Y.L.Liu, 2005). The elimination of valves reduced the cost of chiller and made it more reliable because there were less moving parts.

2.5.1 Silica gel-water properties

Based on the chosen working pair which is silica gel-water, here have a description about the properties of silica gel and water. Silica gel has high surface area around 800 m^2/g and allows it to adsorb water readily, making it useful as a desiccant (drying agent). Once saturated with water, the gel can be regenerated by heating it to 120 °C (250 °F) for two hours. Some types of silica gel will "pop" when exposed to enough water. This is caused by breakage of the silica spheres when contacting the water (Spence Kondeet al.2011).

According to Ruthven DM. (1984) had discussed that silica gel is a partially dehydrated form of polymeric colloidal silicic acid. Commonly used adsorbent is silica gel it is a porous, amorphous form of silica (SiO_2). Due to its unique internal structure silica gel is radically different to other SiO_2-based materials. Silica gel-water is also able to be driven by heat of relatively low and near ambient temperature.

The adsorptive property of silica gel arises from its tremendous porosity. It has been estimated that $1m^3$ gels contains pores having a surface of about 2.8x107 m^2. The dimensions of the pores are sub-microscopic (20-200Å) (B.B.Saha et al. 2001). Silica gel adsorbs vapor from a gas mixture until the pores of the gel are filled.

Typical Analysis (Dry Basis)
SiO2…………………… 99.7%
Fe2 03 …………………. 0.01%
A12 03 ………………… 0.03%
Ti02 ……………………. 0.04%
Na2 0 ………………..… 0.04%
Ca0 ………………..…...O.04%

Figure 2.6: List of Dry basis analysis of silica gel [14].

2.5.2 Application of silica gel-water

According to B.B.Saha[14], had discussed thatSilica gel-water has been chosen as the adsorbent-refrigerant pair because the regeneration temperature of silica gel is lower than that of active carbon and water has a large latent heat of vaporization. Water is used as the working medium. Dry silica gel attracts and adsorbs water vapor until it is saturated, and regenerate. E.J Bakker [15] said heating the silica gel releases the water vapors at a pressure that allows it to condense at ambient temperatures, the cycle of adsorption and desorption can be repeated. The silica gel can be regenerated efficiently at lower driving temperatures and cannot be pumped from generator due to its solid characteristic.

2.6 Auxiliary Component

All solar hot water systems rely on thermal storage in one way or another. Flat plate panels will generate heat at a given percentage of the home's hot water needs during the sunlight hours, and then it is stored in a thermal medium or large water storage tank of some sort as backup heat source. Usually, this thermal medium is plain water because, quite simply, water is the best material on Earth for storing heat. For this reason, the solar storage tank is sized differently if radiant heating is involved. In other words, the amount of water needed for storage of the heat generated during the day is much less if that thermal energy can be stored in the radiant floor.

This storage play the main role to keep the heat temperature without any heat loss and it is quite impossible because of the characteristic of the heat is the energy cannot be produce nor destroyed and it can easily change to other forms. So, the presence of the auxiliary component will help to supply the heat source when there is temperature heat loss in the water storage.

Natural gas boiler and electric water heater able to supply the heat when the water storage insufficient heat to supply to the adsorption chiller. These components are the second choice as heat source and the system not fully depend on this component to gain the heat source. This boiler will be able to overcome their higher first cost compared to electric heat source because gas-fired systems produce lower electrical demand costs. This system, gas boiler burns gas to heat up water. The boiler used in the home for the express purpose of heating work by burning gas to boil water in water tank storage. The water is then circulated throughout tank that uses the hot water coils to the adsorption chillers by hot water.

Electric water heater will use the electric power to supply the heat source to the water tank storage. Costs for the electric power use can be minimised as this types of auxiliary just a backup system to be used with the solar heat water storage. There are two main factors to consider in choosing the auxiliary component to be used with the storage water tank. The factors are energy source that going to be use whether natural gas or electric and the place or area to be used. The figure showed the difference between fuelled by gas and electricity.

Type	Factors to Consider
Natural Gas	Requires a slightly larger up-front investment Must be vented outdoors for safety Units with sealed combustion or power venting increase safety Usually cost less to operate Not affected by power outages (tank-style only)
Electric	Generally cost less than gas models Easy to maintain Requires no combustibles or venting Heats water quickly Offer high energy factor ratings

Figure 2.7: Difference between fuelled by natural gas and electricity

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes methodology of developing the adsorption chiller and in this project it was focused on the analysis on the performance of cooling system by adsorption route in a tropical region. The adsorption chiller simply design to able provide cooling system with friendly environment, economical and small scale that suitable for small building especially residential building. This experimental procedure is to collect the data for tropical region temperature, proposed the best design of adsorption chiller and do the calculation. The calculation is based on the formula and the temperature data. Lastly plot the graph to get the performance of the cooling system using several factors that will affect the adsorption chiller performance. Do the analysis and compared the expected result with the other results from other journals.

Flowchart system detailing the task need to complete was drafted out. This flow chart (Figure 3.1) shows the overall flow of project in step by step process. There must have a triangular in the flowchart, means that the result obtain from the experiment can be change if the result if failure. Due to that, the experimental procedure needs to conduct again until the expected result is achieved.

The design of the experiment is a main task need to consider in this chapter. In this study, the design of the experiment is using two stage of adsorption chiller (silica gel-water and solar energy source).

3.2 RESEARCH METHODOLOGY

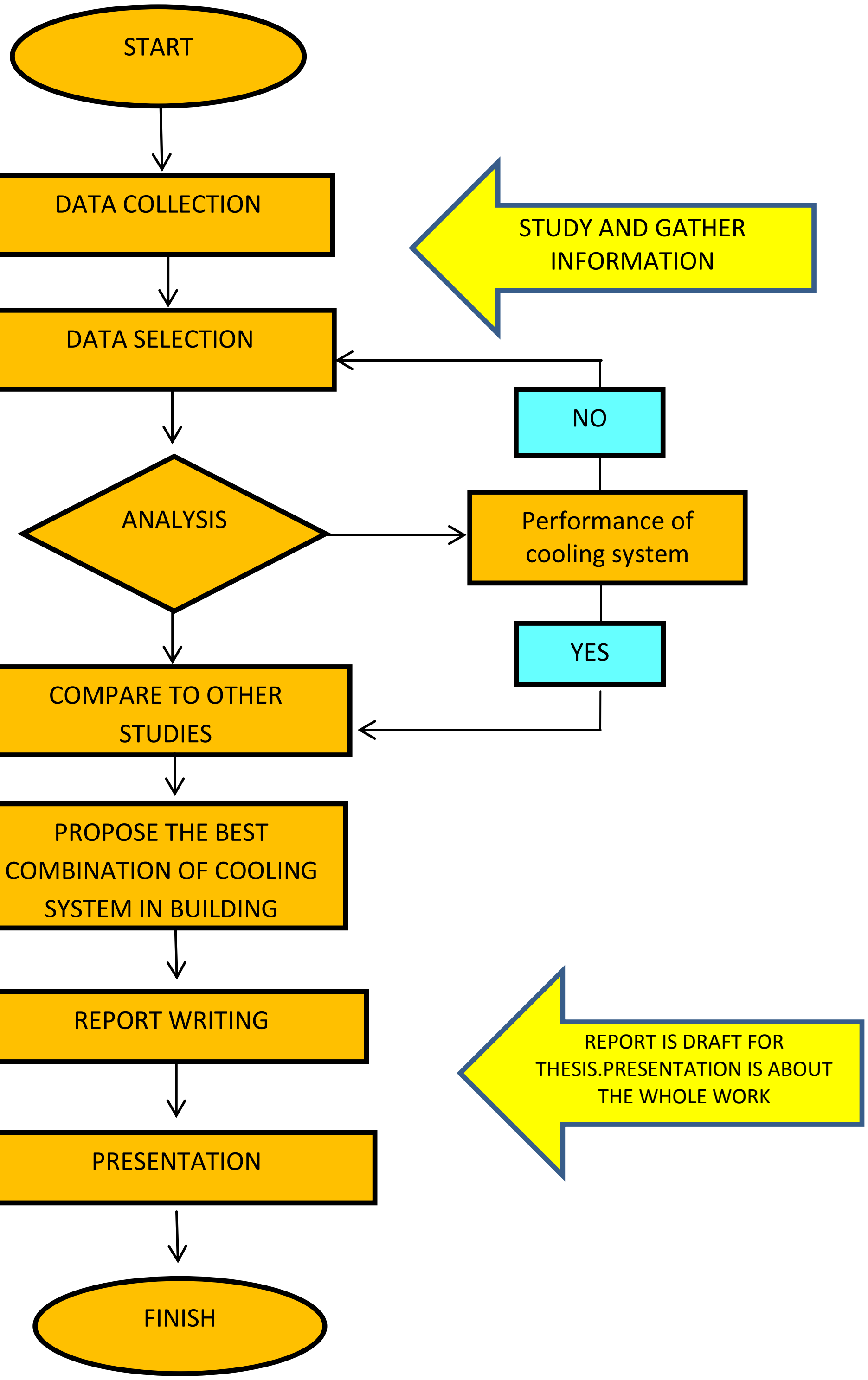

Figure 3.1: Process Flow Chart of Study

3.3 Data Collection

First step after get the title is finding the suitable literature review in order to get some idea and clear situation about the research. All the information is gathered in data collection. The data collected provide information regarding the topic which is analysis on the performance of cooling system by adsorption route in a tropical region. The method of data collection based on this research is getting the data such as ambient temperature, solar irradiation, and cooling load from supervisor. Other than that, all the data information collected from the internet. These two methods are combined and will get the appropriate targeted data for this research.

3.4 Data Selection

From the data that have been collected, the results for the students are processed. According to the data, there are 12 hours during daytime that have the value of the irradiance and there are no irradiance reading for the other 12 hours during nighttime. Values for solar irradiance are high at 1 p.m. and 2 p.m. which about 0.61 kW/m^2 and the lowest value are taken during early morning and late evening. The efficiency and area of the solar plate collector is important to get the maximum value of the temperature. For the water storage tank, the volume of water is the main factor in order to have high capacity to store the heat with minimum heat loss. The two beds of adsorption chiller are selected because we need the continuously cooling process and residential house is the aim as a subject to be cooled because of their low cooling load demand. Other than that, data for cooling load demand are selected from the residential house.

3.5 Analysis

The analysis is one of the important step when it play the main role to get the performance of cooling system from 3 difference cases from cooling system. In this step, the analysis can get from the calculation the data of the solar global radiation have been analysed with simple calculation and equation. In order to get the significance different between each cooling system, the data of the component efficiency, area, and temperature have been analysed. On the other hand, the average data was calculated or used before started to analyse data for each component. Microsoft excels is used in this analysing data to get the comparisons between the system. Each result that obtained will relate to the others result in the graph.

3.6 Overall Flow of Cooling System

The solar irradiation data at tropical region were used to estimate how much energy is transmitted through the flat plate solar collector. The collector plate absorbs as much of the irradiation as possible through the glazing in the water heating mode, but there is still losing a little heat as possible upward to the atmosphere and downward through the back of the casing. Then the collected heat is transferred to the water. Whillier’s procedures already do the analysis about the performance of solar collectors. It is assumed that the temperature, pressure and concentration throughout the adsorbent bed are uniform.

Continuously calculation is made at the storage water tank in order to get the value for heat transferred from the solar plate collector. At this stage, the efficiency and the volume of tank and water are the main parameters that should be considered. The calculation should be related to the previous and the next stage which is at the adsorption chiller. Here, we already set only and above 60°C temperature of water from storage water tank can be switch on the adsorption to be well functioning. It is an advantage when the adsorption properties is can be operate at low temperature of heat source.

The auxiliary component such as electric heater and natural gas boiler are added to multiple the types of cooling system and study the performance for each system. For the both cases, we try to reduce the volume of the water tank to 60% and 30% from the original tank volume and natural gas for boilers used as a backup component to get enough heat sources. The variation cases have been used to get the difference effect in term of cost, maintenance, and also environmental effect.

The last stage of the cooling system is placed at residential house. This is the main objective which is to cool the house especially during the night time only by using the solar as the heat source. So, again the calculation is needed in order to get the appropriate value to achieve the target.

3.7 Types of Cooling System

The structure of overall flow of cooling system process is designed differently in several types. In this study, there are 3 types of cooling system which are cooling system with water storage, cooling system with water storage and electric heater and cooling system with water storage and boiler. In the process of adsorption chiller it started from the solar collector as driving heat source. Solar had strong potential for significant primary energy for this full cooling system process. The heat distributed to the water tank and also important for the adsorption to be act as cooling system. The energy from solar collector is generated to heat the water in the water tank. The heating water functioned to make the water in the water tank is heated efficiently in term of helping the solar collector in supply the energy. The next step is about adsorption chiller which has two beds of single stage. In this studied, a compact cooling system of adsorption chiller with a cooling capacity in the range of 1-10 kW is designed and the experimental calculation is conducted. There are several factors should be collected in the adsorption chiller which are the working pair that going to use, the arrangement of the beds and also about the coefficient of performance for this adsorption chiller. Last step is the cooling system is supplied to the residential building area. Here, cooling load of the building should be analysing in order to stabilize the using of cooling system in day or night time.

3.7.1 Conventional Cooling System

In general, air conditioning system is a conventional cooling system that mostly of us nowadays used to cool the space such as office, school, class, supermarket and others building. In centralized air conditioning system, large compressor, condenser, thermostatic expansion valve and the evaporator are accommodated in the provided space. The components perform all the functions similar to a typical refrigeration system. However, all these parts are larger in size and have higher capacities.

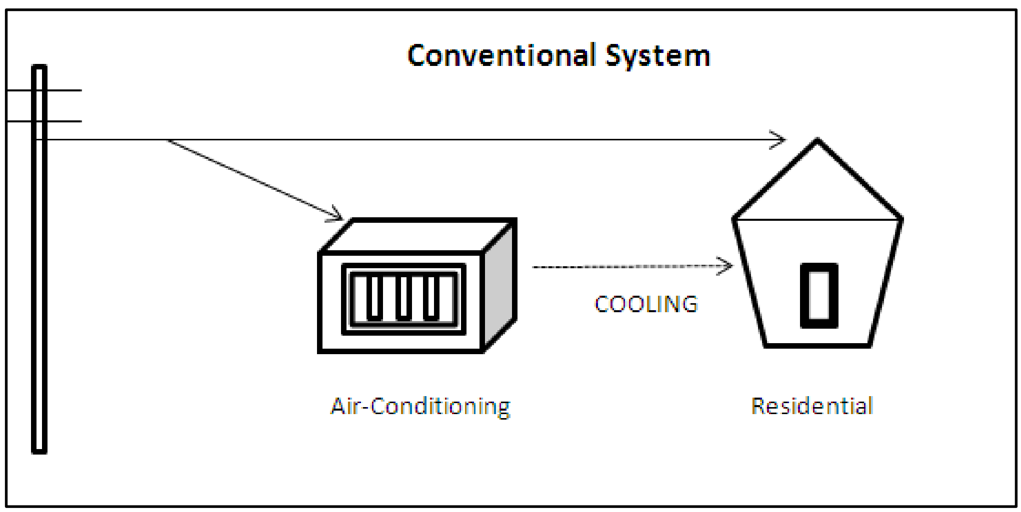

Figure 3.2: Conventional cooling system at house

3.7.2 Case 1

Figure 3.3shows the structure of overall flow of cooling system process with a large water storage without used any auxiliary component. The main heat source is from the solar energy. So, the area for solar plate collector must be bigger in order to support all the heat required to cool the residential. The variation cases have been used to get the difference effect in term of cost, maintenance, and also environmental effect.

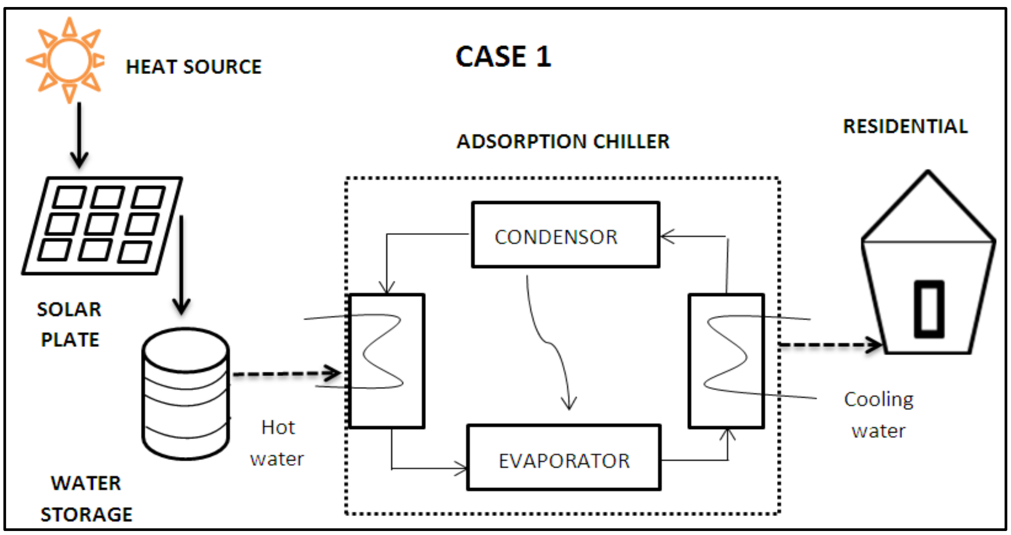

Figure 3.3: Cooling system with water storage

3.7.3 Case 2

Figure 3.4 shows the structure of overall flow of cooling system process with water storage and electric heater is the auxiliary component. For the case two, we try to reduce the volume of the water tank to 60% and 30% from the original tank volume and electric heater as a backup to get enough heat sources from electricity to support the water tank temperature. The electricity from grid is supplied to the heater and the heat generated is supplied to heat storage. The variation cases have been used to get the difference effect in term of cost, maintenance, and also environmental effect.

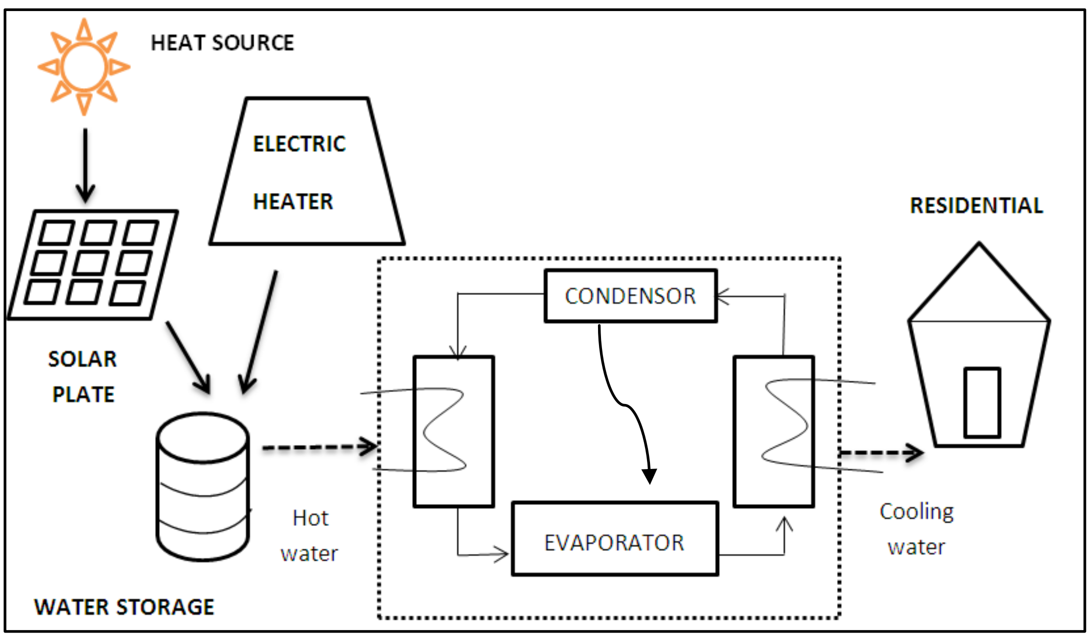

Figure 3.4: Cooling system with water storage and electric heater

3.7.4 Case 3

Figure 3.5 shows the structure of overall flow of cooling system process with water storage and boiler is the auxiliary component. Natural gas is used as another heat source for the boiler and the heat generated is supplied to the heat storage. For the case two, we try to reduce the volume of the water tank to 60% and 30% from the original tank volume and natural gas for boilers used as a backup component to get enough heat sources. The variation cases have been used to get the difference effect in term of cost, maintenance, and also environmental effect.

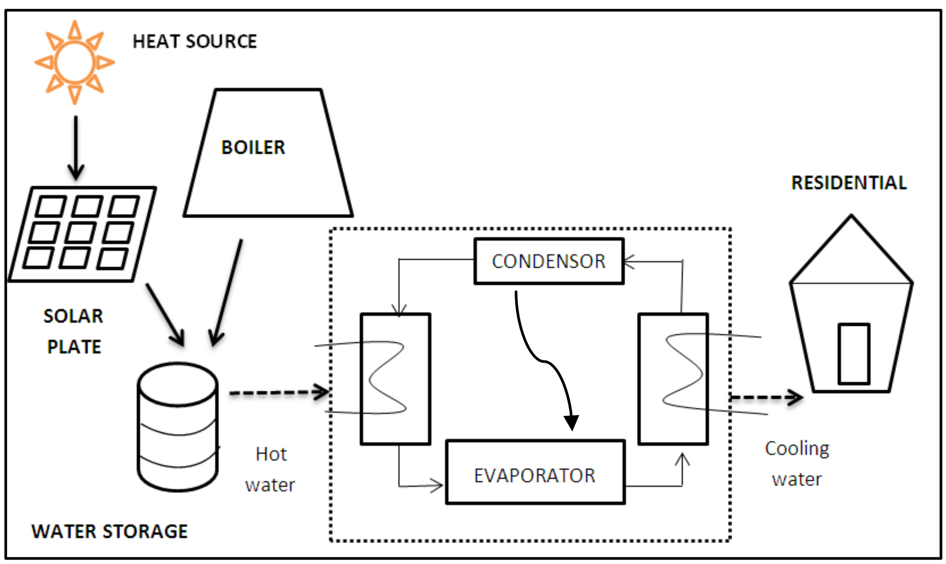

Figure 3.5: Cooling system with water storage and boiler

3.8 Data Collection

The graph below shows that the comparison between the ambient solar irradiation and ambient temperature in the tropical region. The graph shows maximum value during the daytime especially at 1400 which the peek time for solar irradiation in tropical region area. It is same concepts with ambient temperatures which is high during the daytime and reduce at the night time.

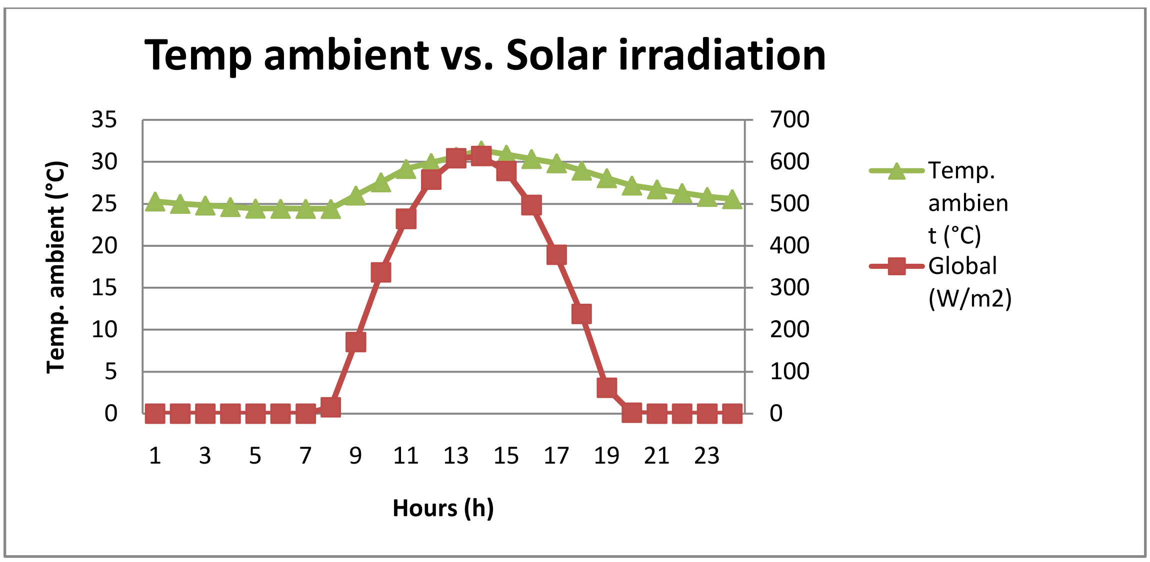

Figure 3.6: Pattern of temperature ambient with solar irradiation

3.9 Mathematical Modeling

Cooling demand, Q_2 was obtained from [18], [19] which are the data in cooling load demand for 3 residential houses in 24 hours. From the available data, heat demand can be calculated in equation 1.

$$Q_{heat\,,demand} = \frac{Q_{cool\,,demand}}{COP} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

COP: Coefficient of performance

Figure 3.7 shown the important parameters in the two-beds adsorption chiller should be taken to get the value for temperature reduces, T_{reduce}.

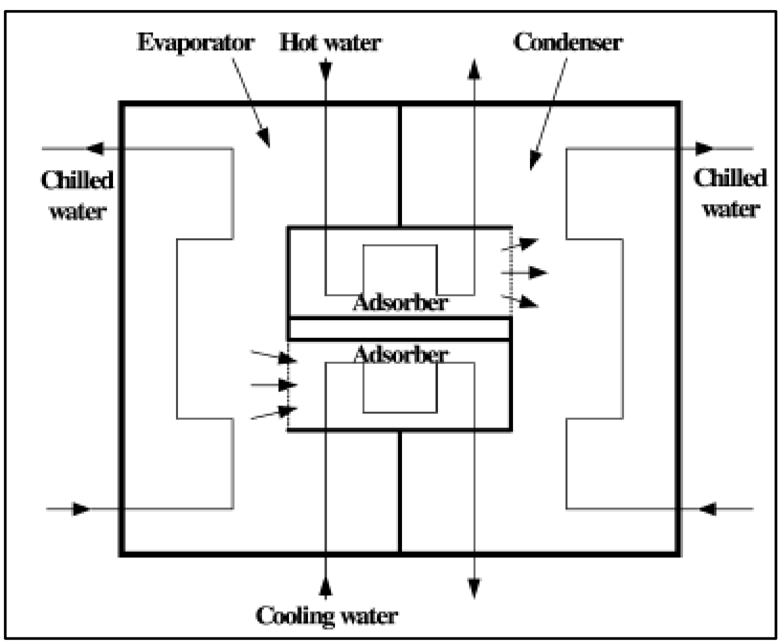

Figure 3.7: The schematic diagram for adsorption chiller [6].

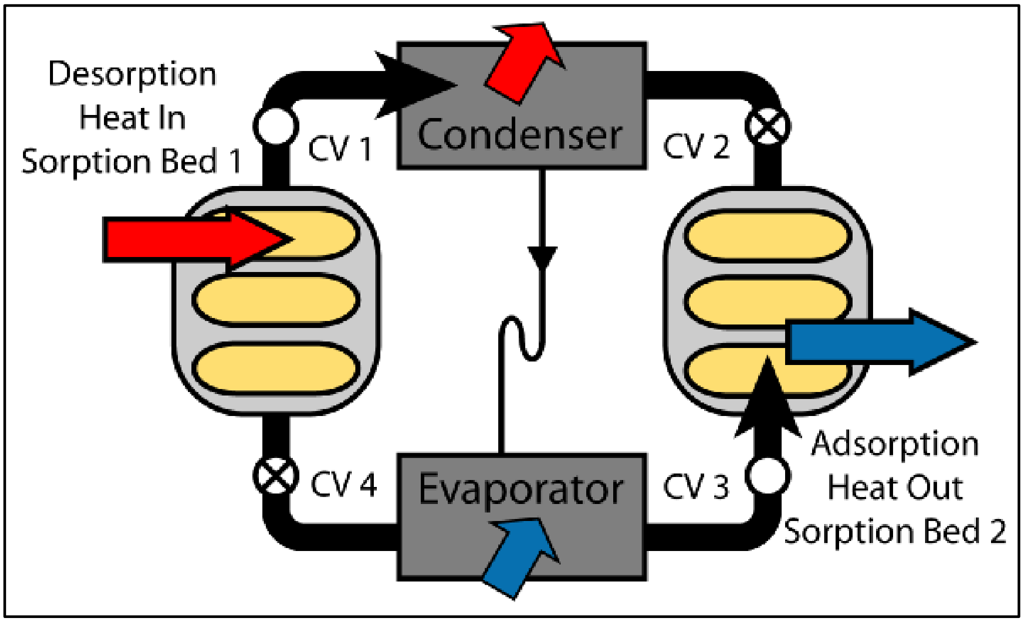

Figure 3.8: example for 2beds adsorption chiller

The figure3.8 shows the structure of compact cooling system of adsorption chiller with a cooling capacity in the 2.5 kW. An adsorption chiller unit was built to study the analysis of its performance of cooling system in tropical region.In the making of adsorption chiller, there is several stages that can be selected like single stage that has 2 beds, double stage that has 4 beds, advanced three-stage and also multi-bed mode. However due to some constraints about the targeted objective the design that has been selected for this project was single stage two beds adsorption chiller. The main components in adsorption chiller are a condenser and an evaporator. The overall size of each bed is (66.7cm x 52.5cm x 23.5cm). Compact light-weight aluminium has been used to carry the silica gel in heat exchanger.

The purpose is to creating a large surface while maintaining low weight and volume. Heat exchanger actually was used for the condenser and evaporator. To perform the process, an electromagnetic valve is used as working chamber to connect the adsorption and desorption beds.

The main performance indices (daily average solar radiation, daily average hot water temperature and daily average COP) of the adsorption cooling system were analyses based on several factors. There are the ambient temperature parameters, structural parameters and operational parameters. Here have the following assumptions:

1) The solar radiant intensity and ambient temperature were assumed to be a fixed value throughout 24 hours per day.

2) The same cycle process of the adsorption chiller and the hot water temperature depend on the ambient temperature and flat plate solar collector efficiency.

3) When the auxiliary component (storage water tank, electrical heater, heat pump) was heated to the set value (60-75) °C, the adsorption chiller was switched on.

4) Once the temperatures of hot water temperature drop less than 55°C, the adsorption chiller were switched off.

5) The inlet temperature of cooling water was 18°C.

6) The working time duration about the night time.

Equation for temperature reduces in order to get the result for coefficient performance for 2.5kW adsorption chiller to cool the residential building.

$$T_{reduce} = \frac{T_{cooling\ ,in} - T_{chilled\ water\ ,in}}{T_{hot\ ,in} - T_{cooling\ ,in}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where the temperature of chilled water, $T_{chilled\ water}$ was assumed to be constant at 18°C.

After the value for reduce temperature, T_{reduce} obtained, the correlation method is used from the others research paper [15] in order to get data for adsorption coefficient of performance, *COP*.

Equation:

$$COP = (139.04x^3 - 150.3x^2 + 51.768x - 5.2085) \ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where the value for x isT_{reduce}..

Heat storage water tank

For small solar heating systems the heat storage water tank is the most important component in order to store the heat. This storage can be considered as stratified water tank as the thermal performance of solar heating systems is influenced by the thermal stratification. Better thermal stratification in the solar tank is important to maintain higher thermal performance of the solar heating system.

In the process of the heat storage water tank, the water is constantly heated by energy that gains from the solar collector. There are divided into two parts of storage water tank which are upper and lower part. Lower part of tank contains low temperature and need longer operation periods for the solar collector and thus increased collector performance. High temperature in upper part of tank will meet the heat demand and this process continuously supply to adsorption chiller with the help of auxiliary component in order to get extra heat demand.

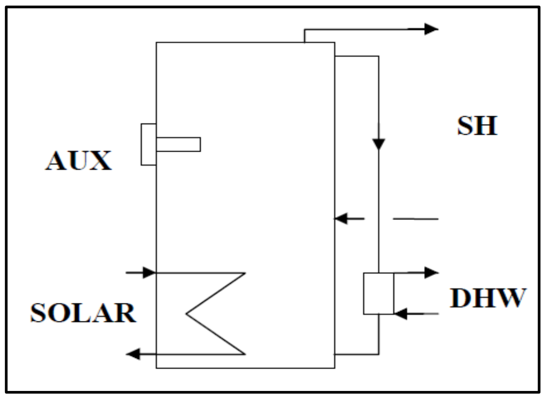

Figure 3.9: Heat storage for solar heating system [14].

Hot water and cooling water tank is supplied by a constant temperature cold water tank. Energy equation takes into the energy gain from the solar plate collectors, energy lost to surroundings and energy consumed by the adsorption chillers. For the cooling storage water tank or cooling tower is very important to the system because the cooling water affects not only the condensation process for condenser but also the adsorption process of the adsorber.

A medium (80-100gallon) storage tank is usually sufficient for small residential house. For active systems, the size of the solar storage tank increases with the size of the collector, typically 1.5 gallons per square foot of collector. This helps prevent the system from overheating when the demand for hot water is low.

A galvanized steel sheet is a sheet of steel that has been galvanized in order to help prevent corrosion. Galvanized steel sheets can be used in a variety of applications including in furniture, cars, or in making tool boxes. The process is done in order to help steel stave off corrosion caused by exposure to other metals in the presence of an electrolyte or to oxygen and water. GI sheet are widely demanded in the industry due to its everlasting high performance. In industrial water, galvanized tanks provide an economical solution to any industrial water application. The volume of the water in the storage water tank is compatible with the size of the storage. This storage can be categorized in medium size that mostly used in any residential house.

$$\eta = \frac{Q_{storage\ ,out}}{Q_{storage\ ,in}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

From the equation 4, the value for heat storage, in obtained when the efficiency of the storage water tank is fixed to 90%. Then, the volume of the storage water tank can be calculated.

$$Q_{storage\ ,in} = V\ x\ \rho\ x\ Cp\ x\ \Delta T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Assume that:

ρ = 1000kg/m³

C_p= 4.18 KJ/Kg.K

ΔT= (T_{in}-T_{out}) = (353-333) K= 20K

From the previous volume of water tank storage, the area for solar plate collector can be calculated. Below are shown two figures about the flow process for the solar plate collector and thermo siphon is one of the flat plate solar collectors that is used in this study.

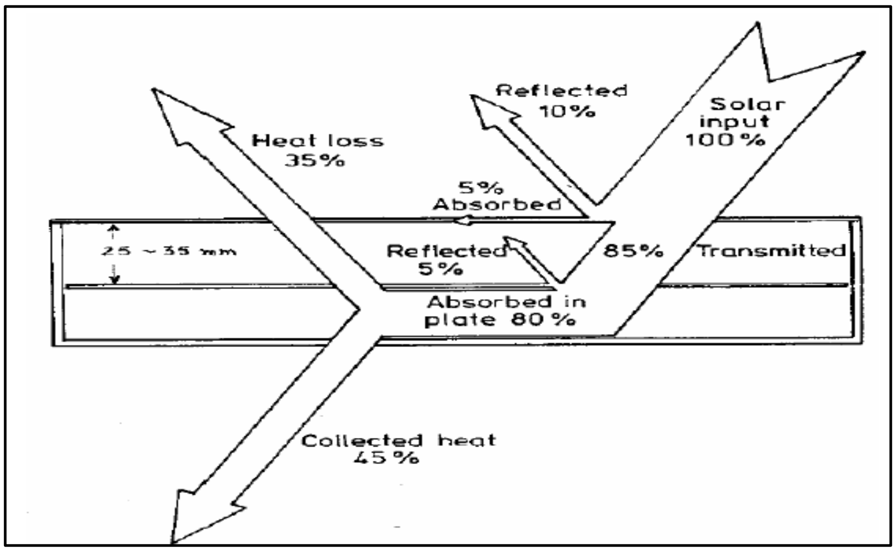

Figure 3.10: Heat flow through flat plate solar collector [12]

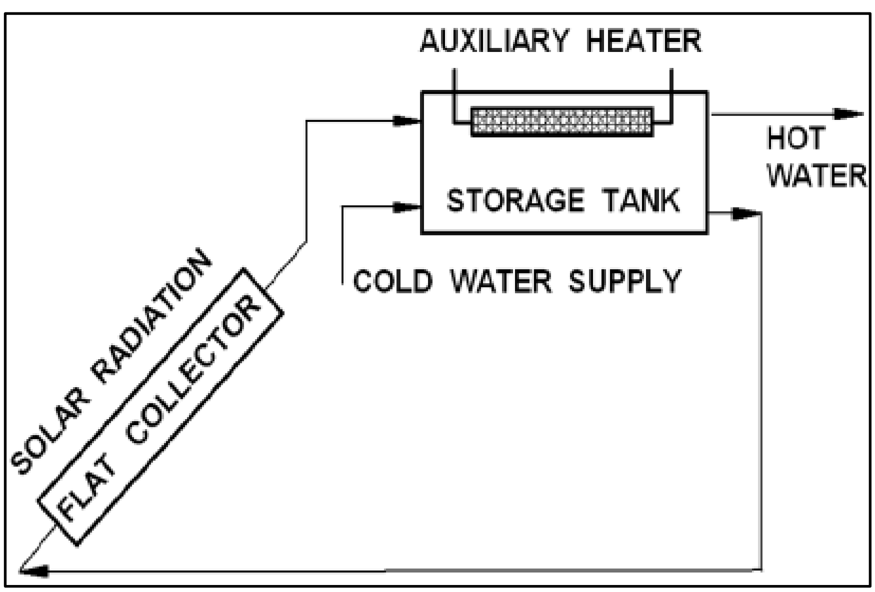

Figure 3.11: Thermo siphon solar plate system [12]

Solar panels are used for heating of water in water tank storage by means the collection of solar irradiation during the daytime and also for cooling of water by means of radiation towards sky during the nighttime. Since the requirements on collectors and radiators operation areopposite to each other, it is very difficult to achieve good performance in both heat collectionand heat dissipation with only by solar plate. Therefore, the best would be to use one paneltype for solar heat collection whis is the standard is flat-plate collectors and to use the other auxiliary component with water tank storage. Then the heat stored from the water tank storage will be transferred into the adsorption chiller.

In a thermo siphon system where the tank is mounted on the roof above the collectors, cold water flows naturally into the collector because it is heavier than hot water. The solar collector is made of materials that absorb heat from the sun very efficiently. The cold water travels through the collector and the heat in the collector heats up the water, which returns to the tank. Hot water floats to the top of the tank and colder water is taken from the bottom and returned to the solar collector. When you use hot water, it is taken from the top of the tank where the water is hottest.Thermosiphon systems still remain as one of the most interesting technologies for exploitation of solar energy. Their remarkable efficiencies, combined with simplicity of construction, autonomy in operation, absence of moving parts and thus the minimization of necessary maintenance, make them an interesting alternative to forced circulation systems [12].

The solar powered adsorption chiller produce the useful cooling effect at the evaporator and delivered chilled water from evaporator. The useful energy received by the solar collectors can be calculated according to instantaneous efficiency of solar collector arrays. The efficiency of solar collector arrays are obtained from thermosiphon solar collector which is 0.68. So, the area of solar plate collector can be calculated.

$$A_{Collector} = \frac{Total\ heat}{Heat\ from\ collector} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Reduce 60% and 30% of original water tank volume

When the volume of water tank storage is reduced to 60% and 30%, the amount of heat collected decrease and it is insufficient to supply the heat to the adsorption chiller. In order to maximize again the heat supply, backup system or auxiliary components are used. In this study, electric water heater (figure 3.3) and natural gas boiler (figure 3.4) are used according to several factors such as cost, performance, and emission produce.

Table 3.1: Volume of storage and solar plate area for each condition

Size of storage	Volume (m^3)	Area of solar collector (m^2)
Original	3.35	27.3
60%	2.01	14.7
30%	1.0	7.3

Mass of emission produce

From the excess of the heat source used like electric and natural gas, there are emission produce which are the carbon dioxide, carbon monoxide and nitrogen oxide. The data for emission cost is referred from distributed vs. centralized generation: The importance of system performance by N.Strachan, University of California Berkeley, USA [20].Table 3.2 shows the mass of the emission produce from the electric and natural gas.

Table 3.2: Mass of emission produce

Types	CO2(g)	CO(g)	Nox(g)
Air-Cond	146.56	13.63	9.34
Water Storage	0	0	0
Electric-60%	58.63	3.94	2.72
Electric-30%	102.69	6.9	4.76
Natural gas-60%	18.85	1.12	2.06
Natural gas-30%	33	1.97	3.61

Cost for electric water heater

STEP 1: $Q_{storage}$=28.14kWh
Voltage=240V

You need to know or convert the unit cost of electricity by kilowatt-hour (kWh).

STEP 2: $1\ unit\ (kWh) = 0.218\ sen$

Estimated monthly operating cost = 30 Days × heat demand× Electricity Cost (kWh)

Total cost for all cases

Each case have different of equipment and heat energy used. The data for energy cost is referred from equipment arrangement planning of a fuel cell energy network optimized for cost minimization Shin'ya Obara, Tomakai National College of Technology, Japan [21]. The total cost can be obtained from the equipment cost and energy cost. From the table below, there are listed the price of the equipment and energy for every cases including for water storage.

Table 3.3: Total cost for all the cases

Energy Source	Equipment Cost (RM)	Energy Cost (RM)	Total Cost (RM)
Water Storage	7755	0	7755
Electric-60%	5185	184	5369
Electric-30%	2500	322.29	2822.29
Natural gas-60%	4735	14.61	4749.61
Natural gas-30%	2355	15.98	2370.98

CHAPTER 4

RESULTS & DISCUSSION

4.1 Introduction

From the data that have been analyzed, the system can be accepted when the solar as heat source is able to cool the residential house with the help of adsorption chiller as cooling agent in this cooling system. The graph pattern shows that the heat source used for the adsorption to cool the house is more than enough compared with cooling load demand for the house needed. In order to get the significant value for the whole temperature system, the average data have been used in this calculation.

4.2 Result for cooling system

The graph below shows that the difference between the ambient solar irradiation and total amount of solar obtained after used the solar plate collectors. The amount of solar plate energy increase, after we consider the efficiency of thermo siphon flat plate which is 0.68 and the size of the plate use is $27m^3$.The results for the total heat gaining is increased compared with the direct global solar irradiation.

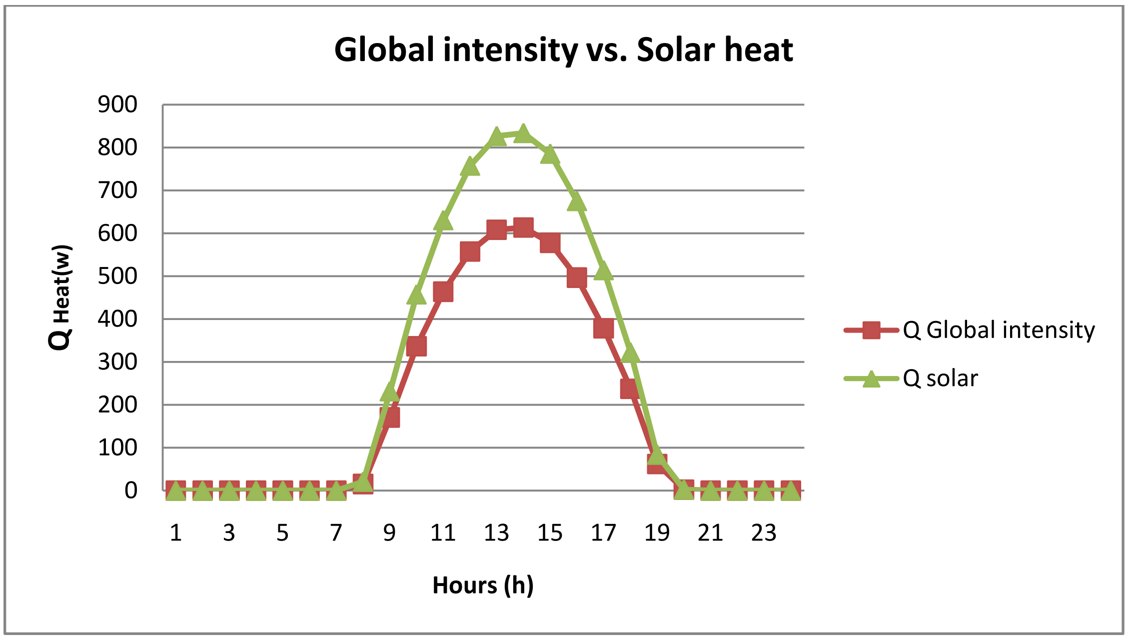

Figure 4.1: Difference of ambient solar and solar plate collector

Figure 4.2 describe about comparison of the heat storage in from the solar plate collector and heat storage out to the adsorption chiller. In the storage, there is heat loss due to heat transfer properties. The total heat in much higher about 77.93 KJ and this heat supply come from the solar collector. For total heat out is lower than heat supply which is 70.14KJ. In the storage, there is heat loss due to heat transfer properties. In this analysis, storage used 90% efficiency in order to minimize the total heat loss. The total heat out in the storage then will supply to the adsorption chiller.

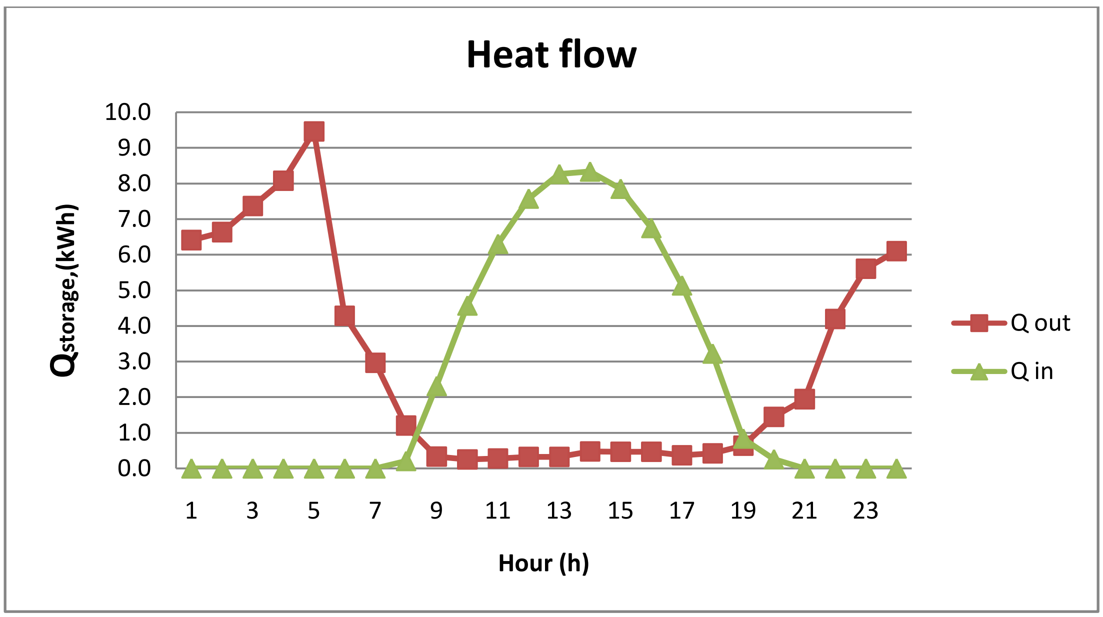

Figure 4.2: Heat flow in the storage water tank

Based on figure 4.3, the graph shows that the result for coefficient performance (COP) of adsorption chiller. Equation for temperature reduces and COP obtained from the correlation equation based on the previous journal. Temperature reduce totally depend on the temperature of water in and out from adsorption chiller. The amounts of temperature reduce increase during the daytime and reduce during the night time.

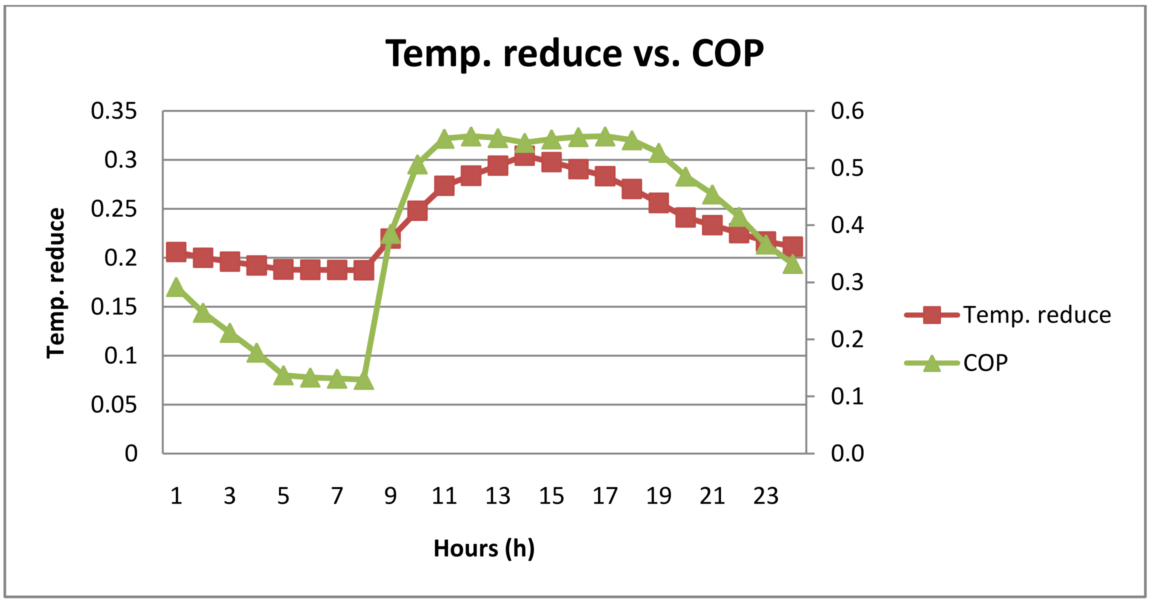

Figure 4.3: Pattern of temperature reduces with COP

The graph shows that the result in the residential house. The cooling load demand of the residential house can be covered by the adsorption chiller in cooling process when the heat supply for the adsorption is higher than house cooling load demand. Total cooling load demand for residential is 18.69kW while it covered with the total value from the adsorption chillers cooling which is 70.14kW. As we can see from the graph the consumption of cooling system is low during the day time because people are away to the workplace, school and so on. It is contrast during the night time when the consumption of cooling load obviously increases.

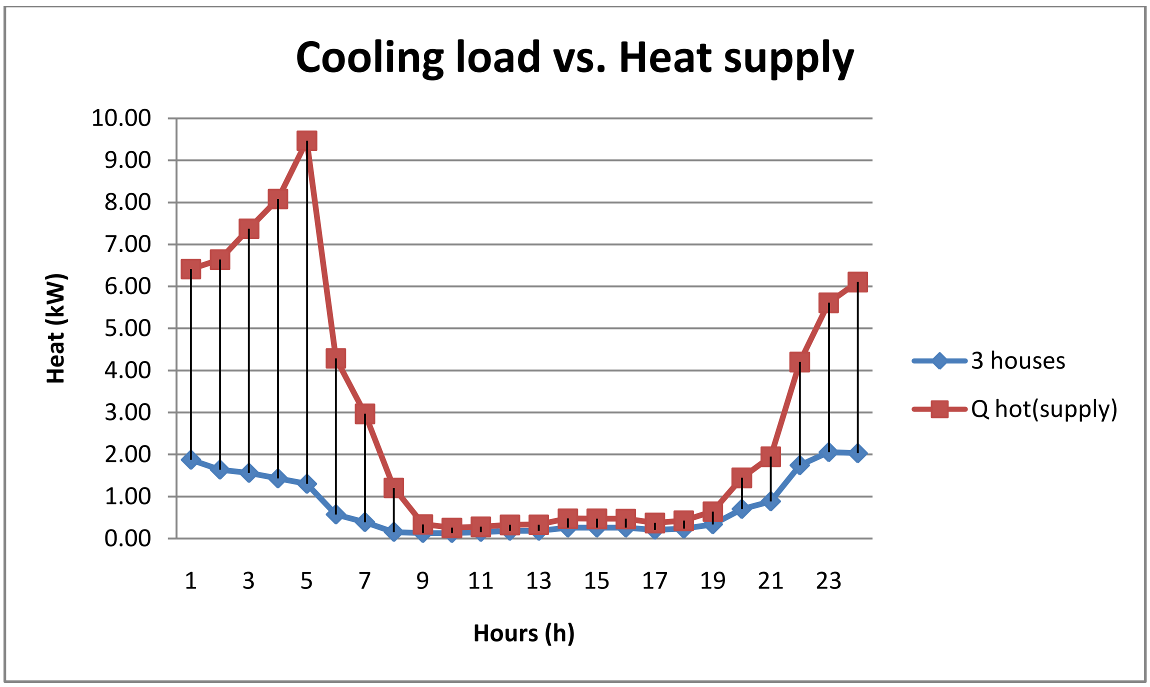

Figure 4.4: Pattern of heat supply and heat demand for 24 hours

Reduce 60% and 30% of water tank volume

When the volume of water tank storage is reduced to 60% and 30%, the amount of heat collected decrease and it is insufficient to supply the heat to the adsorption chiller. In order to maximize again the heat supply, backup system or auxiliary components are used. In this study, electric water heater (figure 3.3) and natural gas boiler (figure 3.4) are used according to several factors such as cost, performance, and emission produce. Differences for each heat demand are shown in table 4.1 and figure 4.5.

Table 4.1: Difference size for storage water tank

Size	$Q_{storage}$	$V_{Storage}$ (m^3)	A_{Solar}(m^2)
Original	77.93kWh	3.35	27.3
60%	46.67 kWh	2.01	14.7
30%	20.90 kWh	1.0	7.3

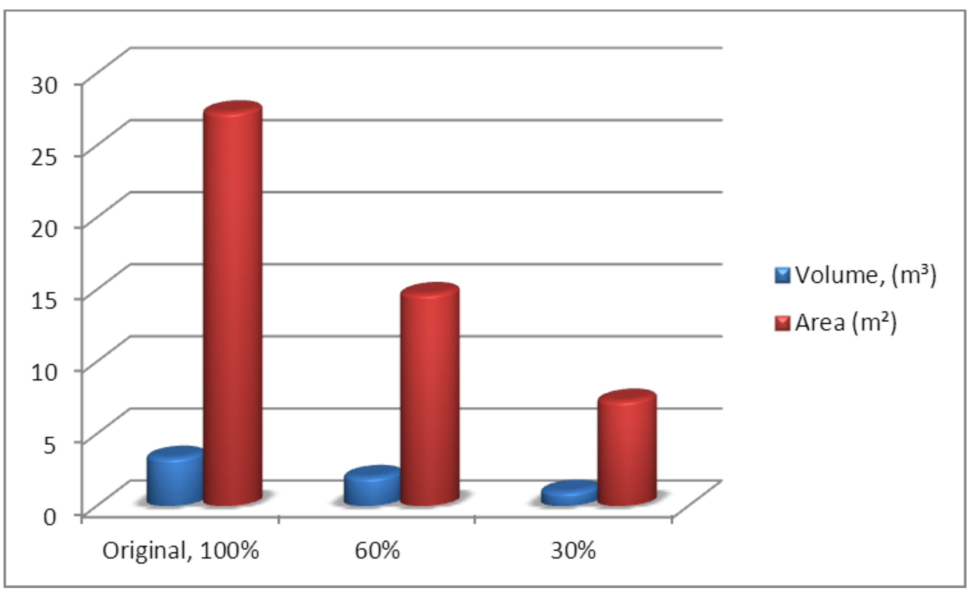

Figure 4.5: Volume of storage and solar plate area for each condition

From the below figure, there are the price for energy cost for every case that consists of electricity, solar and natural gas as their energy source for this cooling system operation. The highest price is conventional air-conditioning about RM333.54 per month followed by electric water heater with 30% reduction of storage water tank which is RM322.29, 60% electric water heater which is RM184, 30% of boiler with natural gas which is RM15.98 and the last one is 60% of boiler with natural gas which is RM14.61.

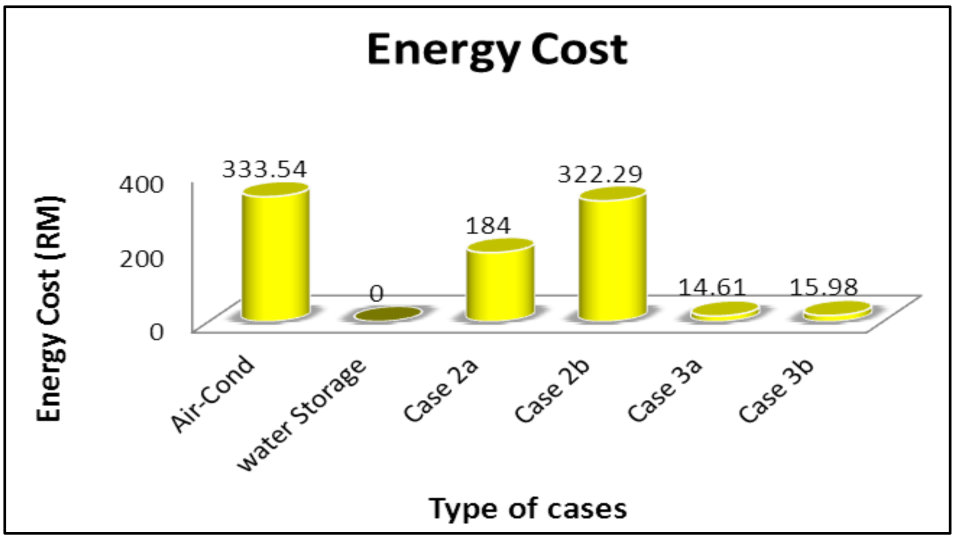

Figure 4.6: Energy cost for each cases

From the figure 4.7, the graph shows the total cost for every case. The total cost is the result from the equipment and energy cost. As example for the equipment cost are the price for storage water tank is different for every volume, area of the solar plate collector, electric water heater and also boiler. We can see from the graph, case 3b is the best total cost for both equipment and energy cost.

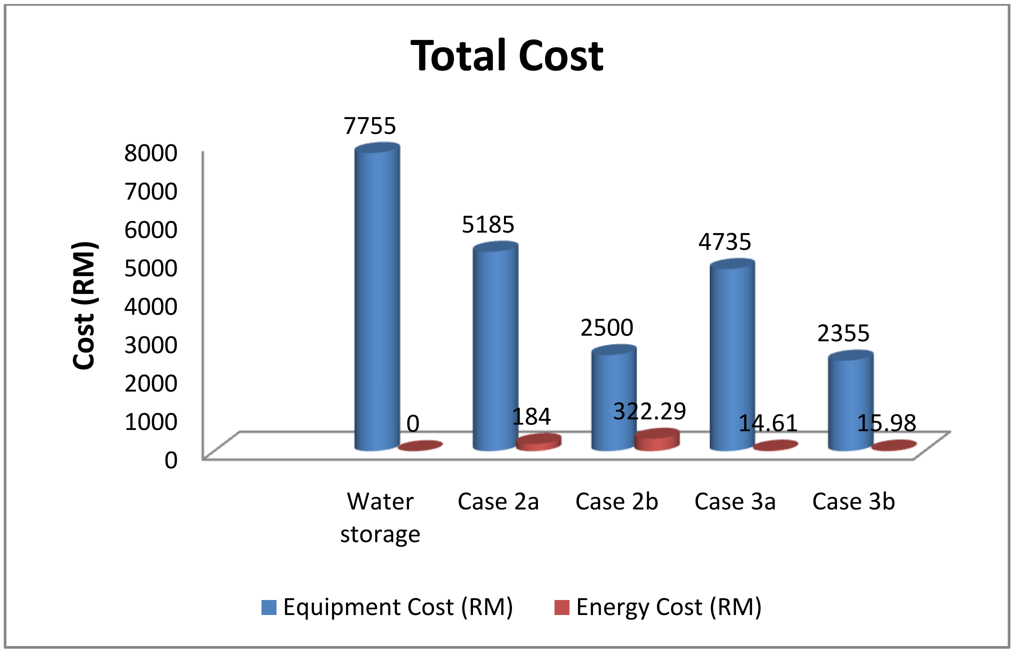

Figure 4.7: Total cost for each case

Figure 4.8, 4.9 and 4.10 show the mass of emission produce for all the cases in the adsorption cooling system. The common types of emission excess from the system are carbon dioxide, carbon monoxide and nitrogen oxide. The pattern for all the emission are same when the highest emission produce is from the air-conditioning which is 146.56 grams followed by the case 2b, case 2a, case 3b, 3a and water storage stated the zero emission produce to the environment.

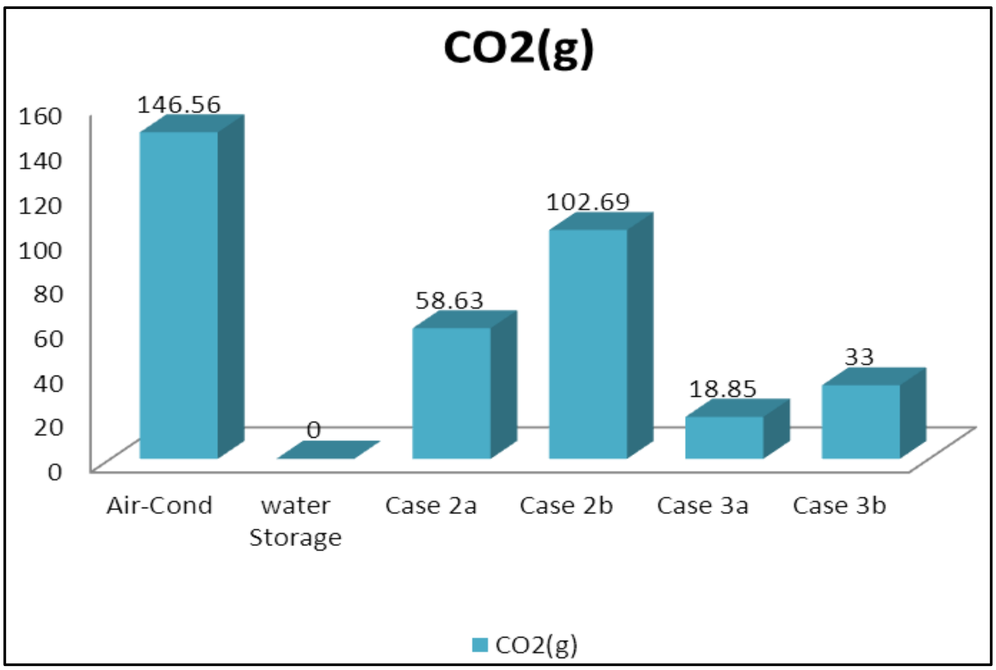

Figure 4.8: Mass of CO_2 emission produce for all cases

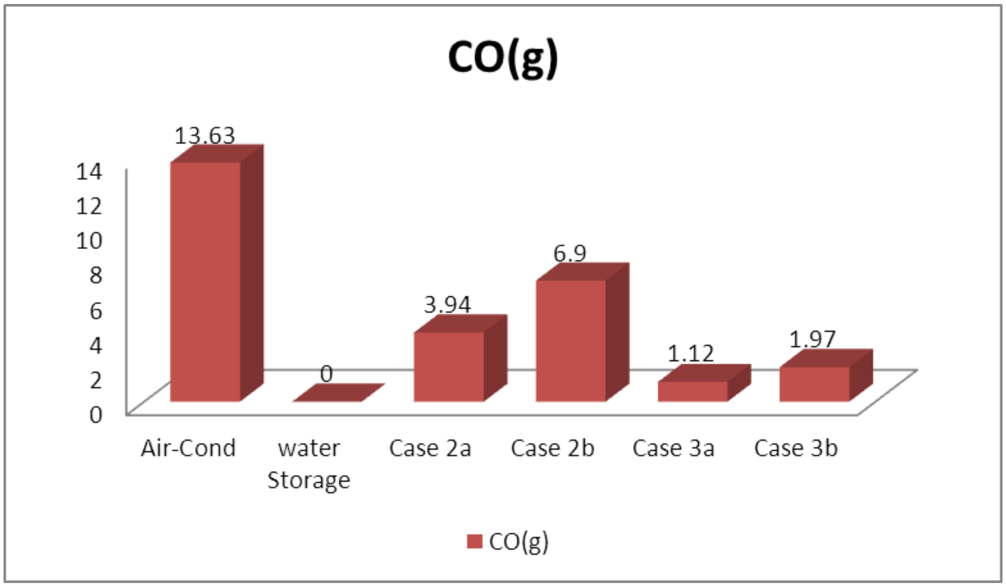

Figure 4.9: Mass of CO emission produce for all cases

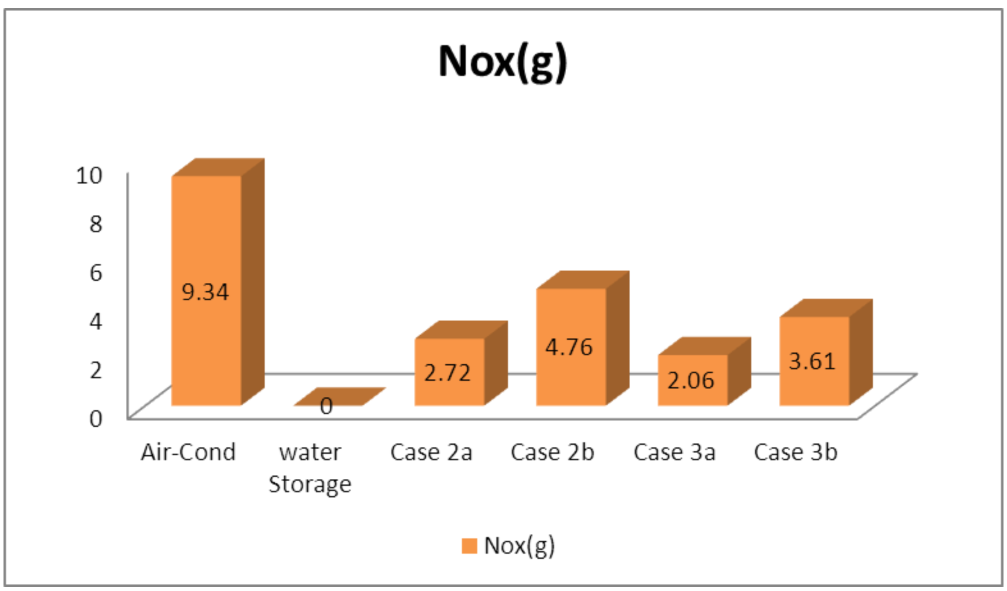

Figure 4.10: Mass of No_x emission produce for all cases

Figure 4.11 shows the result for both total cost and emission produce. Case 1 which is only use water storage that use 3.35m^3 as original volume, Case 2a use electric water heater with 60% reduce from storage water tank, followed by Case 2b use electric water heater with 30% reduce from storage water tank, Case 3a use natural gas boiler with 60% reduce from storage water tank, and followed by Case 3b that use natural gas boiler with 30% reduce from storage water tank.

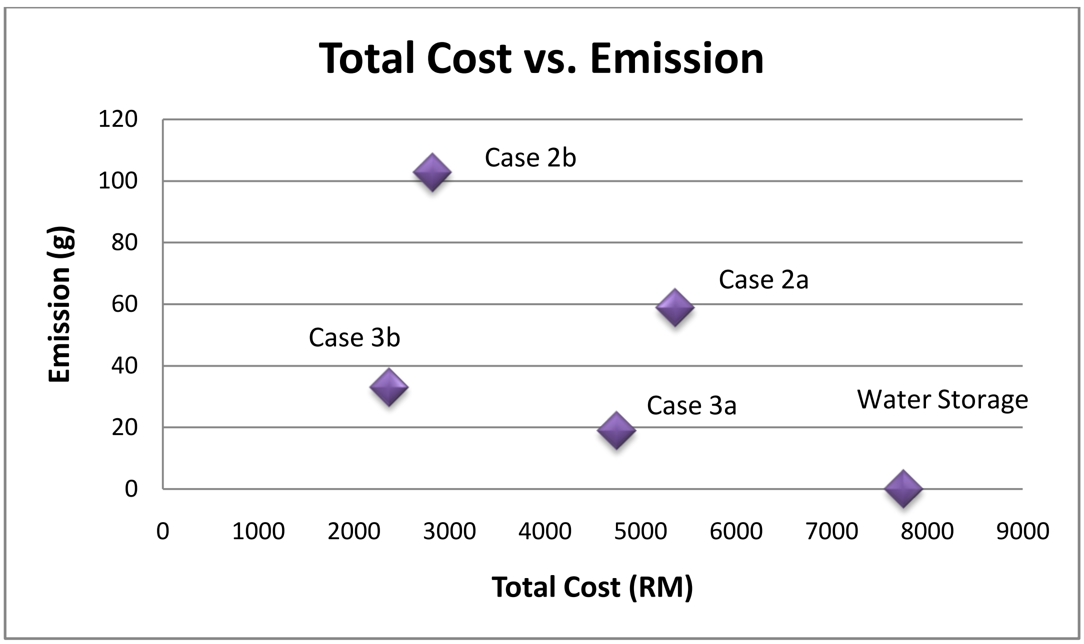

Figure 4.11: Total cost with mass of emission produce for all cases

From the last result in figure 4.11, Case 3b is the best cooling system to be used due to the less total cost and low emission produce to the environment. Only 7.3m^2 for area solar plate collector is used for this case and it can be minimize the equipment cost as the price for solar plate quite expensive nowadays. Other than that, 1m^3 volume for water storage needed in order to store the heat from the solar plate. With this volume of the water storage, it is sufficient to supply the heat to the adsorption chillers during the night time. In term of environmental effect, case 1 or water storage only is emission less as they only used water as a medium to store and supply the heat. Besides that, the cost for the total operating cooling system is the highest compared with the other cases. So the best case between total cost and emission produce is boiler with 30% reduction from the original volume of water storage.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this chapter, the conclusions for overall of the project have been summarized which also includes the problem and future recommendation for the project in future development.

5.2 Conclusion

As a conclusion, this project is considered success as the aim of this project is achieved. The major main goal of this project is to get the best performance of cooling system by adsorption route in tropical region especially in Malaysia. By doing this analysis, there are 3 types of cooling system. The case 3b that used natural gas boiler is the best performance for cooling system in term of cost and less emission produce to the environment.

When there is enough energy, the heat will supply to use in adsorption chiller to cool the residential house. In the case 2 and 3, the cooling system added the auxiliary system to be use with the storage water tank. There are natural gas boiler and electric heater. From the calculation that has been made, the Case 3b is the best cooling system to be used due to the less total cost and low emission produce to the environment. This factor of cooling system is considered according to the cooling load demand in the tropical region.

5.3 Recommendation

The work carried out in this project were focused on the analysis the performance of cooling system by adsorption route in tropical region which constraint on the abundance of solar intensity, solar plate efficiency, storage water tank, adsorption chiller and the residential building as well. But during the study, no further testing or experiment was done to get clearer configuration of the cooling system process. The suggestions for the future works are the following:

1. This project should be developed with hardware experiment in order to get the real result and can be compared with the theoretical result.

2. In addition, for future analysis this research can be used any analysis software to get more accurate condition result and data.

3. More analysis should be done in many angles such as about the solar intensity, cooling system design, measurement methodologies and result representation.

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