A CASE STUDY OF OWNERSHIP AND USE OF AIR CONDITIONING IN A TROPICAL URBAN AREA AND ITS IMPACT ON ENERGY CONSUMPTION

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DEPARTMENT OF CHEMICAL ENGINEERING
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THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE MASTER OF SAFETY, HEALTH AND ENVIRONMENT ENGINEERING

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A CASE STUDY OF OWNERSHIP AND USE OF AIR CONDITIONING IN A TROPICAL URBAN AREA AND ITS IMPACT ON ENERGY CONSUMPTION

ABSTRACT

Malaysia, a tropical country had experienced a drastic increase of air conditioner ownership in the past few decades, data from market demand also suggest that the growth would maintain an upward trend in the future. This study aims to review on the trend of households' ownership of air conditioners (AC) and the energy consumption of AC in residential and non-residential area. The selected area of study is Petaling Jaya, a tropical urban environment. Due to the rejection of waste heat from the air conditioner cooling process, it is suggested that there would be an increase in outdoor temperature where air conditioner is in used. This rise of temperature causes a higher average temperature in the urban area. Additionally, it is suggested that this will also increases the usage of air conditioning to maintain the thermal comfort of the indoor environment. This study also recommended alternative cooling methods in an urban area such as a building structure design, ventilation, increase vegetation, green roof and cool roof was recommended.

Keywords: Air Conditioning, Energy Consumption, Tropical, Alternative Cooling Method

SATU KAJIAN KES TENETANG PEMILIKAN DAN PENGGUNAAN PENYAMAN UDARA DI KAWASAN URBAN TROPIKAL DAN IMPAKNYA TERHADAP PENGGUNAAN TENAGA

ABSTRAK

Malaysia, sebuah negara tropika mengalami peningkatan pemilikan penghawa dingin secara drastis dalam beberapa dekade terakhir, data dari permintaan pasar juga menunjukkan bahawa pertumbuhan tersebut akan terus meningkat pada masa depan. Kajian ini bertujuan untuk mengkaji trend pemilikan penghawa dingin isi rumah dan penggunaan tenaga penghawa dingin di kawasan perumahan dan bukan kediaman. Kawasan kajian yang dipilih adalah Petaling Jaya, sebuah persekitaran urban di kawasan tropika. Oleh kerana penolakan sisa haba dari proses penyejukan pendingin udara, disarankan akan terjadi peningkatan suhu luar tempat pendingin udara digunakan. Kenaikan suhu ini menyebabkan suhu purata yang lebih tinggi di kawasan bandar. Selain itu, disarankan bahawa ini juga akan meningkatkan penggunaan penyaman udara untuk menjaga keselesaan termal persekitaran dalaman. Kajian ini juga mengesyorkan kaedah penyejukan alternatif di kawasan perkotaan seperti reka bentuk struktur bangunan, pengudaraan, peningkatan tumbuh-tumbuhan, atap hijau dan atap sejuk.

Kata kunci: Penyaman Udara, Penggunaan Tenaga, Tropika, Kaedah Penyejukan Alternatif

33

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TABLE OF CONTENTS

LIST OF FIGURES

3

CHAPTER 1: INTRODUCTION

1.1. Research Overview

Malaysia as a developing nation had experience rapid urbanization and population growth for the past few decades. For instance, the population of Malaysia had tripled from 10.4 million in the 1970s to 32.68 million in 2019 (Department of Statistics Malaysia, 2019) while the nationwide energy demand in 2017 had increased almost 10 times compared to the energy demand in 1980 (Energy Commission Malaysia, 2019). The energy consumption per household was highly investigated in many developed countries, but there is still a lack in reliable data for a detailed household energy consumption profile, especially in developing nations.

As a Southeast Asia country that is located in the Tropical Region, most of the cities and towns in Malaysia experiences a year-round climate of high temperature (Average minimum temperature of 23.58°C and average maximum temperature of 31.96°C) with abundant rainfall (Mean relative humidity of 71.8% – 87.4%) (MMD, 2016). Based on the population and housing census (Department of Statistics Malaysia, 2000), there are around 85% existing housing in urban areas were built by bricks or bricks and planks. These modern housings unlike the traditional housing in Malaysia that largely made use of natural ventilation, require air-conditioning in order to cope with the hot and humid tropical climate. In fact, there is a drastic increase in the total number of households with air-conditioning in the past few decades. The study from the Malaysian Department of Statistics (Department of Statistics Malaysia, 2010) shows that in 2010, there are 1,416,050 (22.3%) households with air-conditioning compared to 775,000 (16.2%) in 2000 and 229,000 (6.5%) in 1990. According to a study done by Tetsu, air-conditioning was conceived as the second largest contributor (17%) of the total household energy consumption in Malaysia (Tetsu Kubota, 2011). The most common air conditioning systems include window air conditioners, portable air conditioners, wall hung split or multi head split air conditioners and ducted air conditioners.

1.2. Problem Statement

The demand of air conditioners increased from 871,000 units in 2012 and reaches a demand of 1,002,000 units in 2018, approximately 3% increase each year in Malaysia (The Japan Refrigeration and Air Conditioning Industry Association, 2019). Air conditioners keep a building cool inside but release the heat absorbed from inside to the atmosphere (Okwen, 2011). Hence, the waste head that was released to the atmosphere caused an increase in outdoor temperature.

The increasing demand of electricity for indoor cooling by air conditioner cause more fossil fuel burning which cause higher emission of greenhouse gases (Adinna, 2009). The electricity demand is important for the estimation and prediction of electricity consumption in residential area (Aqilah et al., 2019). The air conditioner electricity consumption is important as it has a significant impact on the energy consumption. By considering that the use of air-conditioning systems, while lowering the temperature on the building’s interior, releases waste heat to the exterior, which further increases the heat in the lower part of the urban atmosphere. Thus, this study aims to provide a review of air conditioner usage and the air conditioner electricity consumption in residential and non-residential area in Malaysia.

It is also recognised that under the current condition warmer temperatures lead to more air conditioning; more air conditioning leads to warmer temperatures. Sena et al., 2021 reported that is important to have an energy efficient use in residential area. This is due to the number of air conditioner and the usage of air conditioners on weekdays significantly affected the energy consumption. Hence, it is important to have an electricity saving strategies to overcome the impact of high energy consumption such as emission of carbon dioxide that release from the fuel burning process of energy generation. Hence, this study will attempt to provide some mitigation and alternative measures for cooling the residential area and environment.

1.3. Research Questions:

1. What is the trend of households' ownership of air conditioner household in selected area?
2. What is the electricity consumption in residential and non-residential area?
3. Is there any difference between the air conditioner electricity consumption in residential and non-residential area?
4. What is the mitigation to cooling the residential area and effective way for efficient electricity consumption?

1.4. Objectives of the Study

1. To conduct a systematic review on the trend of households' ownership of air conditioners in a selected tropical urban area.
2. To review the energy usage of air condition according to residential and non-residential sectors.
3. To suggest possible alternatives methods of cooling and energy saving methods in an urban area.

1.5. Scope of the Study

In this study, the target is to identify the number of air conditioner ownership in residential area and the energy consumption of air conditioning. The AC electricity consumption of residential and non-residential from year 2016 to 2019 will be estimated and compared in this study. Petaling Jaya was chosen to be the study area as the population has increased significantly. Population in Petaling Jaya was reported as 200,000 people in 1977 (Lee, 2014) and increasing to 520,698 people in 2019 (Chong et al., 2020). The area of study is an area of 1 km radius around the Malaysian Meteorological Department of Petaling Jaya as there is a well mix development of various built-up sector in the area.

1.6. Significance of study

This study investigates the ownerships of air conditioner and energy consumption by air conditioning in a tropical urban area as well as provide some suggestion on alternative methods of cooling to reduce the urban heat island effect. It is hope that the result of this study will be generate awareness on efficient use of energy in term of choosing a cooling method. In addition, it is hoped that this project will be the beginning of an ongoing body of research into the issue of air conditioning impact on outdoor energy balance in a tropical urban area and the urban heat island mitigation techniques explored in this study may be considered as a reference by policy makers.

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CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

A growing awareness of the irony between more and more evidence for anthropogenic global warming and the increasing favour of mechanical solution to the problem of keeping mankind sufficiently cool has prompted many social scientists to look into thermal comfort. This has mostly been in the context of the regular practices motivated by allegedly harmless devices such as the air conditioner which there are various underlying concerns towards this exercise (Shove, 2003). Firstly, the continuous increasing of atmospheric temperature may induce people to seek shelter even more into thermally neutral shelter that will shield them away from the extreme outdoor temperature that are anticipated to come along with these changes in climate. On the other hand, the increased usage of air conditioning devices, which requires a huge amount of energy themselves, will simply complicate the situation in terms of rising carbon emissions. Certainly, there are many things at risk of being lost here. However, while these efforts have yielded some valuable insights, they have tended to focus on the west and also the northern hemisphere, where there is concern that demand will drastically increase as peak summer temperatures repeatedly exceed the thresholds above which the people are more inclined to pay for the comforts of mechanically cooled air (Chappells & Shove, 2005).

Meanwhile, the other end of the globe in the tropical east, air conditioning is already considered a required feature in almost every vehicle and practically most of the commercial facility. Malaysia, a tropical country, is an ideal example where air conditioning has grown so prevalent in just a few decades that majority Malaysians now benefit from it in some form or another.

2.2. Urbanisation of Klang Valley

Located within the latitudes of 2°35’N to 3°23’N and longitudes 101°17’E to 101°58’E, the Klang Valley region covers around 3200 km^2 in the west coast of the Malay Peninsula (Fig. 1). The urban conglomeration of Klang Valley sits in a valley that is surrounded by hilly terrain that originates from the Titiwangsa mountain range, at the Northeast to East side of the conglomeration. The valley opens at its West facing the Strait of Malacca and also South towards Seremban (Votano, Parham, & Hall, 1998). Most of the forest cover within the valley had been developed into urban land use and it is also regarded as the most populated, flourished, and fastest growing region in Malaysia in comparison to other cities and regions of the nation. Klang Valley consist of two Federal Territories namely Kuala Lumpur and Putrajaya, and five districts of Selangor: Hulu Langat, Sepang, Petaling, Klang, and Gombak.

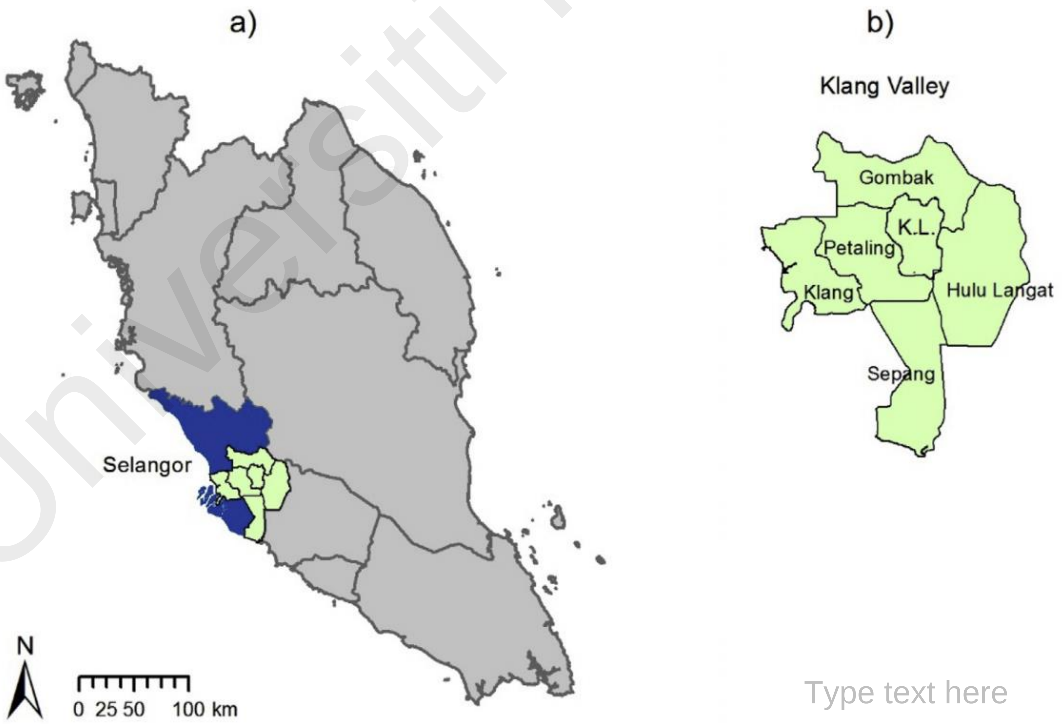

Figure 1: Map of Klang Valley. Note: a) Malay Peninsular; b) Klang Valley

Source: (Chan & Vu, 2017)

During the ‘80s, industrial zones located in Klang Valley had drawn a large number of rural populations to work especially in the industries of electronics manufacture. A rapid development of many new neighbourhood occurs to cater for the increasing inhabitants moving from rural to urban areas. Although new town areas such as Subang Jaya, Bangi, Puchong and Shah Alam are relatively further away from the main city centre, the growth was still rapid during the ‘90s. (Abdullah, 2012).

In the past, Klang Valley was mostly covered by lowland and hill dipterocarp forest, as the urban areas drastically expanded over the years, only fractions of the natural forest remained untouched (Lim, Yaacob, & Jeyaraj, 2000). In a study done by (Chan & Vu, 2017), they divided land type of Klang Valley into 5 different classes, namely Vegetation, Waterbodies, Urban Green Spaces (UGS), High Density Built-up (HDB), and Low Density Built-up (LDB). UGS is defined as any foliage that exists within the urban area. Both built-up classes are classified according to the percentage of developed land inside a 1 km^2 area where developed area that is greater than a 50% threshold will be considered as HDB and LBD for developed area that is less than 50%. Based on the study, Klang Valley’s natural vegetation coverage had decreased drastically from 250,746.03 ha in 1989 to 158,145 ha in 2014, approximately 37% of natural forest had been cleared out. On the other hand, the urban built-up area had increased from 59,792.67 ha to 124,202.52 ha in the same period of time, almost a 52% increase in size. The urbanisation of Klang Valley starts in Kuala Lumpur and expanded by conglomerating smaller towns around it. Majority of the land development urbanised by sacrificing of the foliage and vegetation class. Figure 2 shows the satellite image classification of Klang Valley for 1989, 2001, and 2014 and their respective coverage area for each class based on Chan & Vu (2017) .

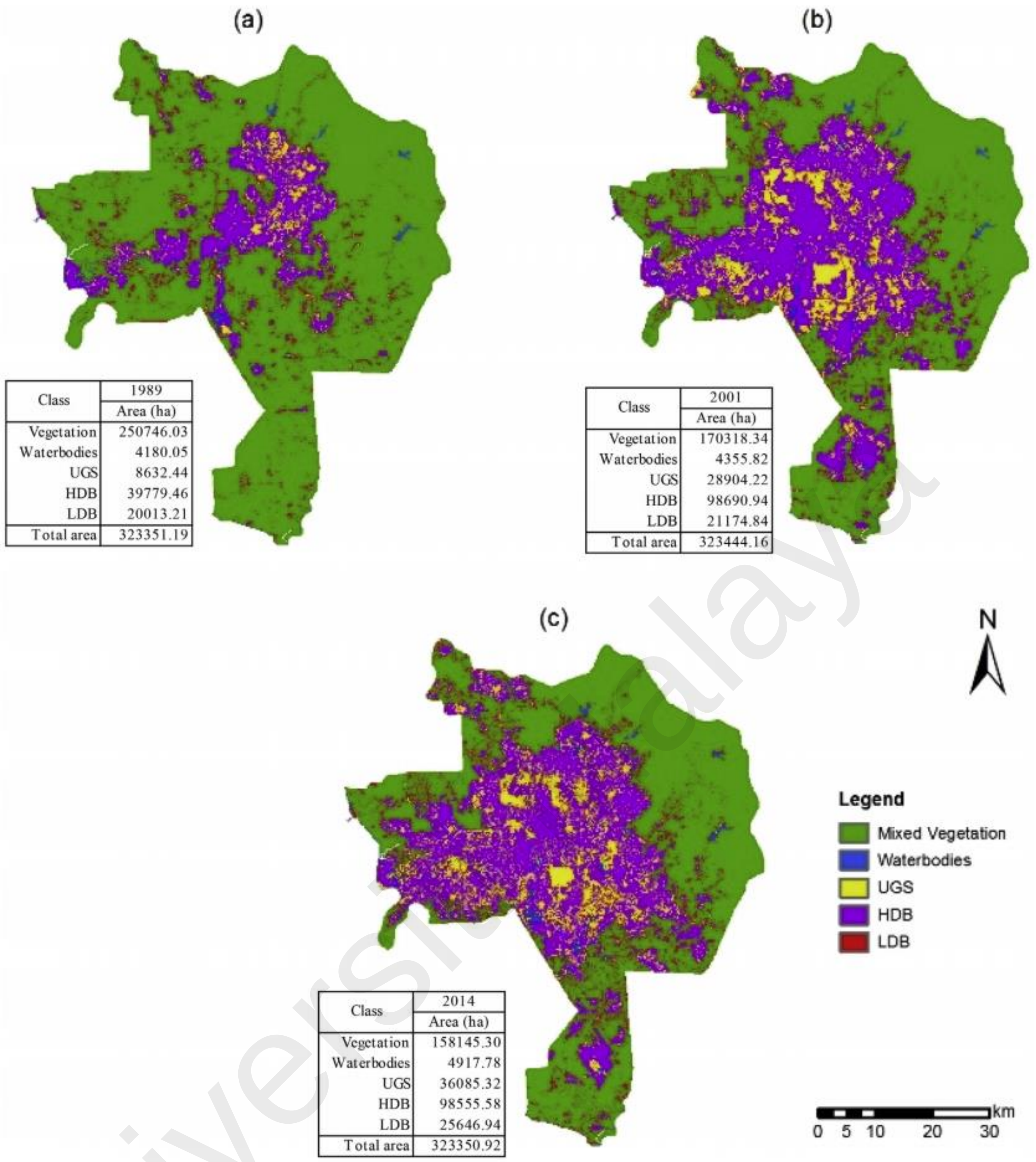

Figure 2: Satellite image classification of Klang Valley for (a) 1989, (b) 2001, (c) 2014 and their respective coverage area for each class.

Source: (Chan & Vu, 2017)

2.2.1. Land Use of Petaling Jaya

After colonization of British in Malaysia, Petaling Jaya (PJ) was the first area to be developed into a town which had an area of 97.2km^2 (Ju, Zaki, & Choi, 2011). As previously reported by Concannon (1955), it was developed comprehensively including commercial, residential, industrial, administrative, and recreational area.

Figure 3: Two images of Petaling Jaya in the late 1960s.

Source: (Lee, 2006)

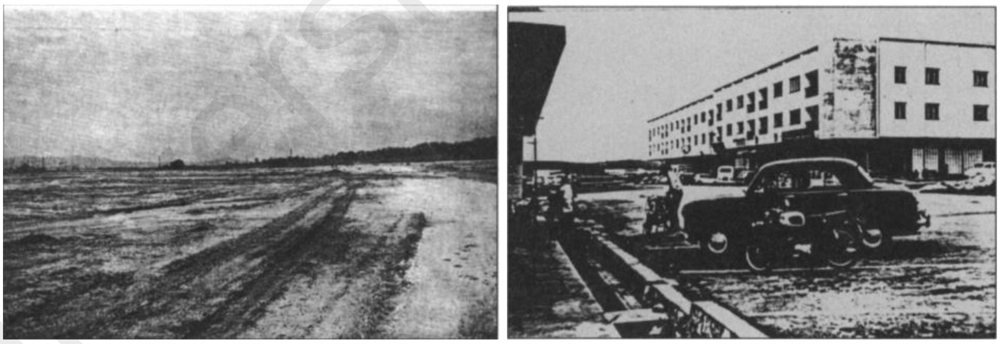

Figure 4: Section 14 of PJ before development (left) and after development (Right)

Source: (Lee, 2006)

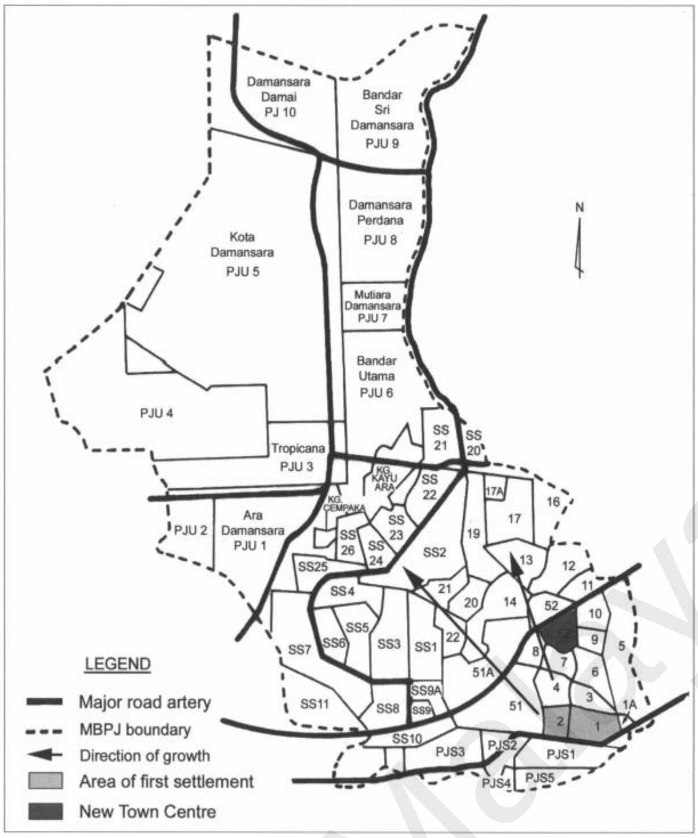

Figure 5: City Boundary of PJ

Source: (Lee, 2006)

When Petaling Jaya was first proposed in the early 1950s, it was primarily for the purpose of resettling Kuala Lumpur's squatters. However, effective design centred on residential neighbourhood units, backed up by a slew of commercial, financial, and administrative benefits, as well as recreational parks and gardens, quickly began to draw the wealthy. Its strategic location, along with easy accessibility, drew a diverse range of businesses.

Following that, the goal of resettling squatters was surpassed by the growing demand for better quality homes from a fast-growing middle class, which turned the city into what it is today (Lee, 2006).

Figure 6: Present day Petaling Jaya

Source: (WWF, 2015)

Aligned with the development of the transportation, specifically Federal Highway made Petaling Jaya to be more compact with people. In order to further investigate the effect of air conditioning, it is vital to understand latest urbanisation of Petaling Jaya. This is because urbanisation plays important role in affecting the quality of environment such as air pollution, water pollution and more (Atash, 2007). A previous study reported that rapid construction such as shopping mall, office and factories in Kuala Lumpur was closely related to air pollution (Ling, Ting, Shaharuddin, Kadaruddin, & Yaakob, 2010). However, it was important to note that the top three usage of land in Petaling Jaya was listed as residential (19.40%), transportation (16.94%) and open space and recreation (9.83%).

Urban planning is one of the most discussed topics as it is closely related to the life of the people in the city. More recent study reported that Petaling Jaya had the fastest built-up lands, aggressively increased 16.5% compared to other studied areas (Halim, et al., 2020). Type text here Besides that, the greenery had been reduced for 16.2% and water bodies decreased by 0.3%. As transportation is essential for the connection between people, Petaling Jaya is linked by Kelana Jaya Line (KJL) which is a light rapid transit (LRT). It showed that the usage for the transport had increased to 2.1 million from 2004 to 2013 (Awanis, Zulkifli, Hamsa, Noor, & Ibrahim, 2017). With that, public transport was integrated to build a more comprehensive transportation facility in Petaling Jaya (Sharifi, Boerboom, Shamsudin, & Veeramuthu, 2006). Although Petaling Jaya's area was mostly developed for residential area and transportation, government was also striving to create sustainable environment for the people (Ju, Zaki, & Choi, 2011). Since the Eighth Malaysian Plan (2000-2005) which focused on green environment development, more open space and greenery were developed in Petaling Jaya.

Figure 7: Image of site study in Petaling Jaya, (N03° 06.612', E101° 42.274').

Source: (Oliver et al., 2014)

2.3. Air Conditioning

Aligned with the urbanization, air conditioner has become a norm, and this had been discussed in 1984 by Arsenault and his colleague (Arsenault, 1984). An air conditioner is defined as a system or process for controlling the temperature, humidity, and sometimes the purity of air in an interior. The primary function of the air conditioner is to maintain conditions that are conducive to human thermal comfort (K. Daou, 2006). Air conditioner was first introduced which aimed to reduce body temperature of malaria and yellow fever victims in the 1830s. During the old days, air conditioner were used in factories involved in production, but in the mid-1920s, the usage of air conditioner had changed to the purpose of commercial usage. This included installation of air conditioner in buildings such as office, hotels and hospitals. However, air conditioner at the time was expensive and was affordable by the rich only. In 1951, affordable air conditioner was introduced and nearly 18% of the household possessed it (Arsenault, 1984). Nowadays, air conditioner in the building is a common observation as studies showed that thermal sensation of people greatly influenced comfortability and person's satisfaction (Chun, Kwok, Mitamura, Miwa, & Tamura, 2008).

To fulfil users experience, more research was conducted to improve the air conditioner's function. A study by Tan and co-researchers focussed on reducing the noise which was produced by air conditioner (Tan, et al., 2018). As technology advances, a more convenient method of controlling air conditioner was introduced. The latest design involved the concept of Internet of Things (IoT) technology (Khaloud, 2020). This innovation enables users to control functioning of air conditioner remotely. With the advancement of the technology, people will experience more comfort in their lifestyle.

2.3.1. Types of air conditioning

There is a wide variation and types of air conditioners in the market. The most common air conditioning systems include window air conditioners, portable air conditioners, wall hung split or multi head split air conditioners and ducted air conditioners.

Table 1: The advantages and disadvantages of different type of air conditioning

Sources: Cielo, 2021; *Pros and cons of a ductless wall mounted air conditioner*, 2010

Types of Air Conditioning	Pros	Cons
Window Air Conditioners Sources: https://www.cielowigle.com/blog/types-of-air-conditioners/	Less cost and cheaper to operate Easy to install Easy to maintain Do not take up floor space	Noisy during operation Obscure the view from window Not all windows support air conditioners
Portable Air Conditioners	Quick and simple to set up Easily moved around the house Effective option for spot cooling	Noisy during operation Cooling larger rooms is a problem Portable units that come with a hose have to be placed near a window and the hose also obstructs the lower part of your window
Ducted Air Conditioners Sources: https://myplumberca.com/pros-and-cons-of-a-ductless-wall-mounted-air-conditioner/	It cools all the rooms connected to ducts at once, thus creating a cooler & regulated environment around	It consumes a lot of energy resulting in higher energy bills. Such units may lose efficiency & effectiveness in case

	the house in minimum time. Humidity is reduced around the house, making the overall environment more comfortable.	a problem arises in the ducts.
Wall Hung Split or Multi Head Split Air Conditioners	Doesn't use up window space It can be installed anywhere easily without a lot of hassle and ductwork. It can control the temperature of each room individually.	Need a professional HVAC technician to advise you on the proper location Larger space requires more units More installation and maintenance cost

Alrashed & Asif (2014) revealed four type of air conditioning system was mainly used in residential buildings in Saudi Arabia: window-type, mini-split, central and evaporative cooler. That apartments and villas employ window-type and mini-split systems, while the traditional houses mainly go for the window-type systems. This research reported that dwellings with mini-split system have about half the annual electricity consumption for dwellings using window-type and central systems.

There is air conditioner with or without inverter in market. The inverter air conditioners were used to reduce the energy consumption (Gosh & Mali, 2017). The inverter can drive the air conditioning system's electrical system in smooth and efficient operation (Almogbel et al., 2020). The inverter air conditioner changes capacity freely by altering revolutions of the compressor (Almogbel et al., 2020). Almogbel et al., 2020 studied on the energy consumption between the inverter and non-inverter air conditioner. This researcher found that there is significance difference of energy consumption between these two types of air conditioners. The energy consumption was 3471 kWh/year and 6230 kWh/year with inverter and non-inverter, respectively. The inverter type of air conditioner has a lower CO_2 emission (Almogbel et al., 2020).

The compressor is the component that consumes a lot of electricity. The difference of inverter and non-inverter air conditioner is the compressor. The compressor in non-inverter type is either on/off. The compressor in inverter type will cut-off once the thermostat detects the desired room temperature and cooling is stopped. The compressor in non-converter type will works at fully capacity and full amount of electricity once it turned on (Almogbel et al., 2020).

2.3.2. Operation of air conditioning

Warm air from the room is drawn into the machine through a grille at the base. The air passes past some chiller pipes, which are carry a coolant fluid. This section of the machine functions similarly to a refrigerator's chiller cabinet. It cools the entering air and eliminates any extra moisture with a dehumidifier. After that, the air passes across a heating element (similar to the one in a fan heater). This section of the unit can be turned all the way up on a cold day to use the HVAC as a heater. The air is blown back into the room through another grille by a fan at the top. The air re-entering the room is significantly cooler when the heating element is turned down, therefore the room progressively cools down.

In the meantime, coolant (a volatile liquid that easily evaporates) circulates through the chiller pipes. It absorbs heat from the air passing through the pipes and evaporates, transforming from a chilly liquid to a heated gas. It transfers the heat from the inside of the room to the exterior of the building, where it dissipates it into the atmosphere. The coolant goes via a compressor unit and some condensing pipes, just like in a refrigerator, before being converted back into a chilled liquid and ready to cycle around the loop again. There are many metal plates in the unit outside the structure that transfer the heat to the atmosphere. To speed up the process, an electric fan blasts air past them. The heat inside the building gradually dissipates into the outside air over time.

Figure 8: The image on the right is a close-up of the black area outlined in the middle photo.

Sources: "How do air conditioners work?," 2020

Figure 9 shows that the schematic diagram of a window-unit air conditioner. An author Wijeysundera, (2015) discussed about the principle of window-unit air conditioner. The author stated inside the conditioned space, the refrigerant evaporator circulates indoor air across a bank of finned tubes conveying cold refrigerant. Heat transfer to the cold refrigerant cools and dehumidifies the air, and moisture collecting in the air is vented to the outside environment. A reciprocating compressor powered by an electric motor compresses the refrigerant. The condenser fan circulates ambient air to cool the heated refrigerant running through a bank of finned tubes in the condenser. To complete the cycle, the liquid refrigerant leaving the condenser expands through the expansion valve.

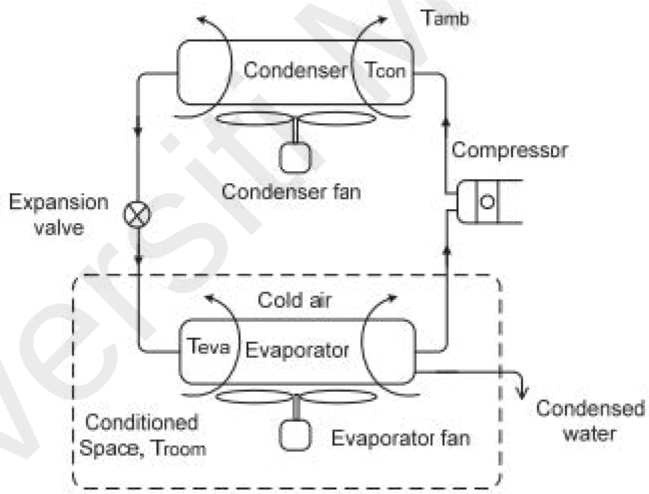

Figure 9: The schematic diagram of a window-unit air conditioner.

Sources: Wijeysundera, (2015)

2.3.3. Household air conditioning habit in Malaysia

Generally, most household residents use air conditioner during night-time. A study done by Hisham, Salim, Hagishima, Yakub, & Saipol (2021) in Kuala Lumpur and Selangor showed that 41% of electricity consumed at night was due to air conditioning compared to only 17% during daytime, which means that there is less usage of air conditioning during daytime. Another study conducted in residential buildings of Kuala Lumpur shows that there is rarely any air conditioning usage during daytime but a rapid increase of usage during night-time (Zaki, Hagishima, Fukami, & Fadhilah, 2017). This phenomenon is also confirmed by another study which states that residents in Malaysia have the tendency to use air conditioning during sleeping hours but not during the day, most of the air conditioning usage occurs in bedrooms rather than living rooms (Zaki, Hanip, Hagishima, Yakub, & Ali, 2018). This shows that the usage of air conditioning is mostly affected by the resident's habitual behaviour rather than outdoor temperature.

People used to sleep with either a standard (single ply blanket) or no blanket at all prior to the invention of air conditioners. In a hot climate like Malaysia, the use of duvet type blankets or comforters has grown commonplace since the introduction of air conditioners. Every department store and large retail retailer in Malaysia now has a section in its home furnishing department that sells comforters.

In Malaysia, a comforter is a blanket made up of two layers of sheets with natural or synthetic insulating material, such as polyester wool, sandwiched between them. The weight of a twin-size comforter ranges from 0.7 to 1.0 kg. The insulating property might range from three to five CLO (Thermal insulation). There is no standard grading for the insulating property of comforters in Malaysia, unlike there is for duvets in the UK.

2.3.4. Ownership of Air Conditioner in Malaysia

Household ownership of air conditioners in Malaysia has increased drastically. Table 2 below shows the total number of households that owns an air conditioner from 1970 to 2020:

Table 2: Total number of households that owns an air conditioner from 1970 to 2020

Year	Population	Household	No. of Household with Air Conditioner	Percentage (%)
2010	28,588,600	6,353,470	1,414,591	22.3
2000	23,274,690	4,801,835	775,358	16.2
1991	18,379,655	3,537,606	253,399	7.1
1990	17,981,730	3,428,142	229,187	6.7
1980	13,745,241	2,503,974	57,340	2.3
1970	10,439,430	1,890,282	13,251	0.7

Source: Population and Housing Census of Malaysia (Department of Statistics Malaysia, 1974, 2000, 2010)

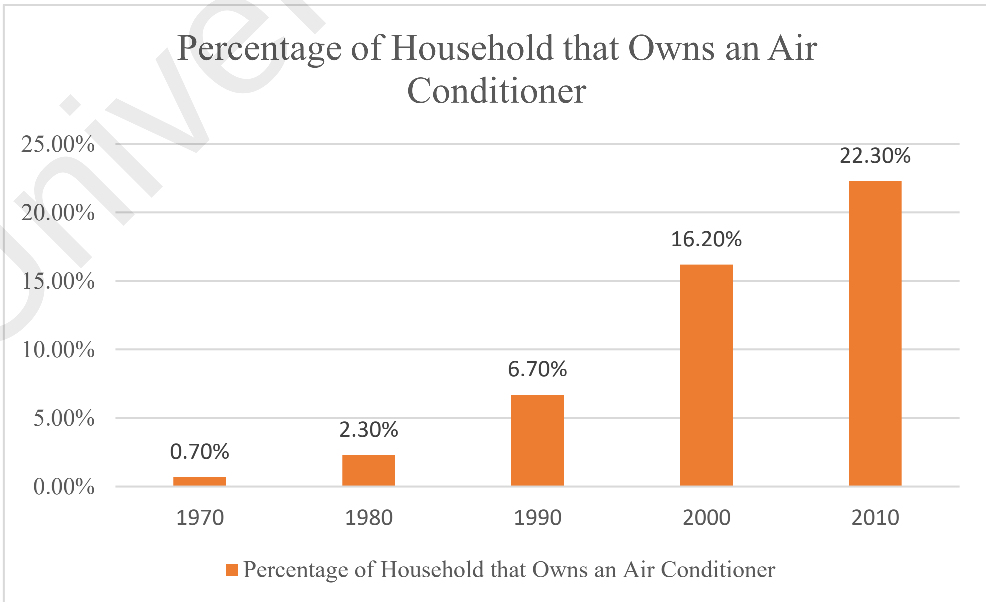

Figure 10: Percentage of Household that Owns an Air Conditioner from 1970 to 2020 in Malaysia

A study done by (Mahlia, Masjuki, Choudhury, & Saidur, 2001) using data from The Economic Planning Unit of the Prime Minister's Department estimated the growth of household air conditioning units until the year 2020. Table 3 below shows the estimated number of household air conditioners starting from 2002 to 2020.

Table 3: Estimated number of household air conditioners from 2002 to 2020

Year	Households	Air-conditioning units (AC)	Percentage of number of AC to number of Households	Annual Residential energy demand (GWh)	Annual national energy demand (GWh)
2002	4,946,941	604,044	12.2%	11,986	66,159
2003	5,093,688	643,586	12.6%	12,927	71,368
2004	5,243,539	684,406	13.1%	13,905	76,779
2005	5,396,495	726,504	13.5%	14,919	82,390
2006	5,552,555	769,879	13.9%	15,969	88,203
2007	5,711,720	814,532	14.3%	17,055	94,217
2008	5,873,989	860,462	14.6%	18,178	100,433
2009	6,039,363	907,670	15.0%	19,337	106,850
2010	6,207,842	956,155	15.4%	20,532	113,468
2011	6,379,425	1,005,918	15.8%	21,764	120,287
2012	6,554,113	1,056,959	16.1%	23,031	127,308
2020	8,063,382	1,511,276	18.7%	34,480	190,721

Source: (Mahlia, Masjuki, Choudhury, & Saidur, 2001)

Based on both tables, we can see that the number of household air conditioners in Malaysia is increasing significantly. The percentage of household with air conditioner in 1970 is only 0.7%. In just two decades, the percentage grown by 10 times to 7.1% in 1991. According to the population and housing census report in 2010, the percentage reaches 22.3%, which outpaced the 15.4% prediction estimated in 2001, and even surpassed the prediction of 18.7% ownership for the year 2020. The potential impact of climate change is not being considered on the use of air conditioners when assessing the predictions given in these studies. It is possible that global warming will raise the figures even further. It is obvious that the use of air conditioner represents a more and more prominent figure on the energy demand in the future.

2.3.5. Overall Demand of Air Conditioner in Malaysia

The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) has published a summary of the expected 2018 air conditioner demand in the world's major countries. JRAIA's Air Conditioning Global Committee obtained data of air conditioner demand that includes the total demand of "Room Air Conditioners" such as window type and small-sized split type air conditioners and also "Commercial Air Conditioners" of houses, buildings, and other structures from major countries around the world starting from 2012 to 2018.

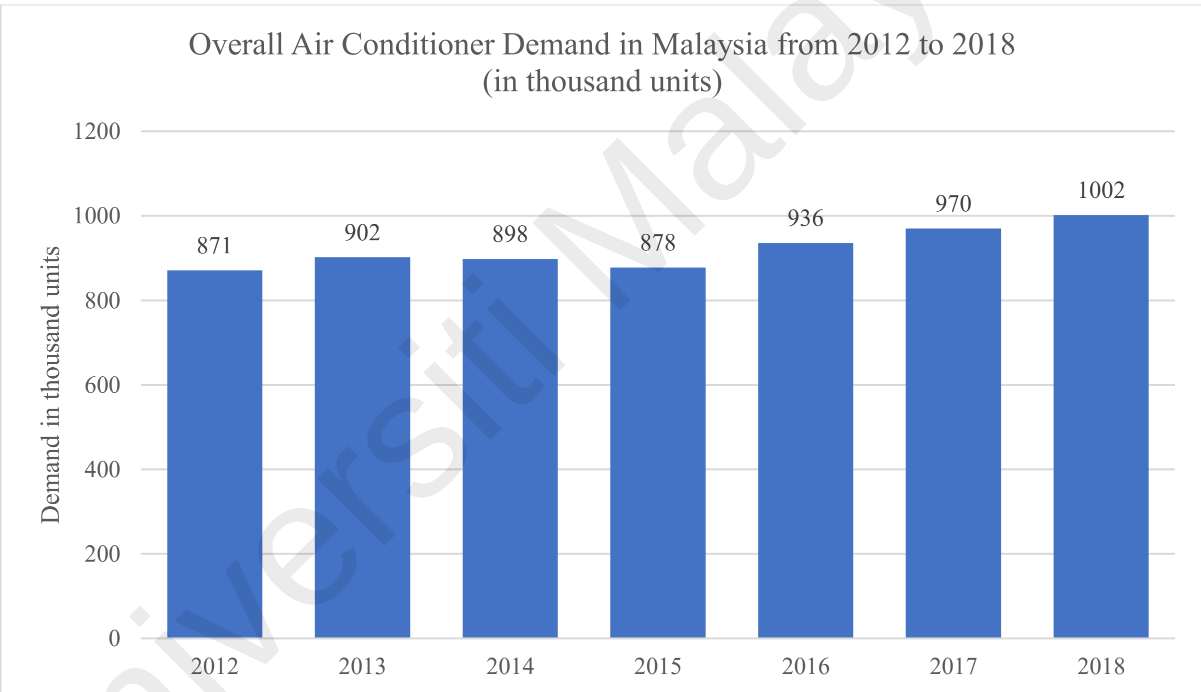

Figure 11: Overall Air Conditioner Demand in Malaysia from 2012 to 2018 (in thousand units)

Source: World Air Conditioner Demand by Region (The Japan Refrigeration and Air Conditioning Industry Association, 2019)

It is clear that overall, the demand shows an up rising trend, starting with 871,000 units in 2012 and reaches a demand of 1,002,000 units in 2018, approximately 3% increase each year. This coincides with the same increasing trend of household AC ownership as mentioned in the previous section.

2.3.6. Influence of Air-Conditioning Waste Heat on Air Temperature

Anthropogenic heat generated by vehicles and buildings has a strong effect to the air temperature of urban areas (Fan & Sailor, 2005). An example is the office areas of big cities where the waste heat produced by air conditioners that is released into the urban environment greatly affects the outdoor temperature. When more people are working in office buildings during weekdays, more waste heat is generated by the air-conditioning system which raises the outdoor air temperature (Fujibe, 1987). (Ohashi, et al., 2007) in their investigation also concluded that air temperature of office districts in Tokyo had increased by 1°–2°C or more due to the waste heat produced by air conditioners during weekdays. This suggested that the cooling load and power consumption in buildings produced waste heat that has a huge effect on outdoor temperature. Study done by (Salamanca, Georgescu, Mahalov, Moustaoui, & Wang, 2014) found out that waste heat generated by air-conditioning system use at night-time could raise 0.5°–1°C of the mean nigh time temperature, demonstrating a strong influence on the studied region. The raise of outdoor air temperature on the other hand not only causes extra energy demand for the air-conditioning system, but it also results in a higher average temperature of urban area, contributing to urban heat island effect.

2.4. Energy consumption

Most of the developing countries are experiencing rapid urbanization and population growth. The energy consumption in these countries has shown tremendous increase over the last few decades. In recent years, consumption of electrical energy has surged, particularly, the demand in developing countries is predicted to drastically increase alongside population and economic growth (Khanna & Rao, 2009). Developed countries such as United States of America and the United Kingdom, residential sector contributes 25% and 30% respectively in electricity consumption (Druckman & Jackson, 2008). On the other hand, residential sector contributed 20.5% of Malaysia's total energy consumption in recent years (Energy Commission Malaysia, 2018). Domestic power consumption has dramatically increased over the past years, resulting in a high demand for electricity to fulfil rising social and economic activities. According to a report published in 1999 by Tenaga National Berhad (TNB), the national energy provider company, Malaysia's domestic power consumption was approximately 2754 kWh/household/year in average. In 2005, a follow-up study was undertaken on urban households throughout the nation which consist of a variety of building types, including single- and double-storey terrace houses, bungalows, and flats. According to the study, the average household electrical energy consumption was estimated to be around 2200 kWh/household/year in 2005 (Tang, 2005).

Nevertheless, according to the International Energy Agency (IEA), urban household consumption is estimated to be 550 kWh/household/year for global average (World Energy Council, 2010). This means that the average household energy consumption of Malaysia is almost 5 times greater than the global average. In spite of that, given the differing methodologies and household sizes used in these publications, a direct comparison could be deceptive. As a result, comparing average household electricity use between various papers is challenging due to the discrepancies in reporting methodologies.

According to (Tang, 2005), by referring to the appliance ownership and also household income, it is forecasted that the average household electrical energy consumption of Malaysia will be 3707 kWh/year in 2010 and 6714 kWh/year in 2020. On the other hand, based on a study done by Noordin, the estimated average value for Malaysia is 3012 kWh/household/year in 2011. By comparing both data, it seems that according to Noordin's study, the average household electrical energy consumption of Malaysia in 2011 was lower than the prediction did by Tang for 2010. In addition, the average household electricity consumption of Malaysia estimated by Noordin is also lower than the world average estimation of World Energy Council (WEC), which is 3500 kWh/household/year. These estimation and data can be used as benchmarks for research findings.

Several research had been conducted on the residential energy consumption to have an accurate prediction of energy demand. In Saudi Arabia, around 52% of the electricity energy produced is utilized in the building while 6% of it was utilized through air conditioning system (Alrashed & Asif, 2014). Residential air conditioning account for over 100 billion kWh of electricity consumption per year in China. Many researchers have carried out the residential energy consumption in China. Lam, (1996) investigated 200 household in different classes of residential units in Hong Kong. The researcher found that the major electricity consuming items was including air conditioner. 400 units AC was observed to obtain the energy consumption in residential area of China thought out the whole year (Wu et al., 2017). Result showed that 27–30 °C temperature range accounts for more than 52% of the cooling time.

The frequency of AC usage increases drastically at night which might consumed up to seven to nine hours per day (Zaki 2017). Hisham et al., 2019 reported that the AC total electricity consumption in Kuala Lumpur and Selangor, Malaysia. The average total daily consumption was 14.5 kWh/day and 3.9 kWh/day for AC total electricity consumption respectively. The AC consumption influenced the total household at about 33% with an average hourly electricity consumption for AC was 0.2kWh/hour. The average hourly electricity of AC (0.1kWh/hour) was inline with a study in Fukushima, Japan which stated 0.1 to 0.2 kWh/hour in summer (Shiraki et al., 2016).

Kubota, 2010 reported the energy consumption for the owner of air conditioning was 1.4 times higher than the non-owner. The researcher suggested that reduction of air conditioning usage would achieve energy-saving in Malaysia. The houses under closed window condition at night will reach 4°C higher than the outdoors due to the high thermal capacity of building structure and the lack of ventilation (Kobuta, 2010). This might due to the unsuitable design of houses which using the brick terraced. Hence, reducing the nocturnal indoor temperature will decline the usage of air conditioning in Malaysia.

2.5. Influence of air-conditioning waste heat on air temperature

The usage of air conditioning in urban areas cooling the insides buildings while release heat to the atmosphere (Munck, et al., 2012). As shown in figure 12, extensive use of air conditioning in an urban area represents one of the key contributors to UHI due to waste heat produced as AC systems rejects heat from indoor to outdoor during the cooling process.

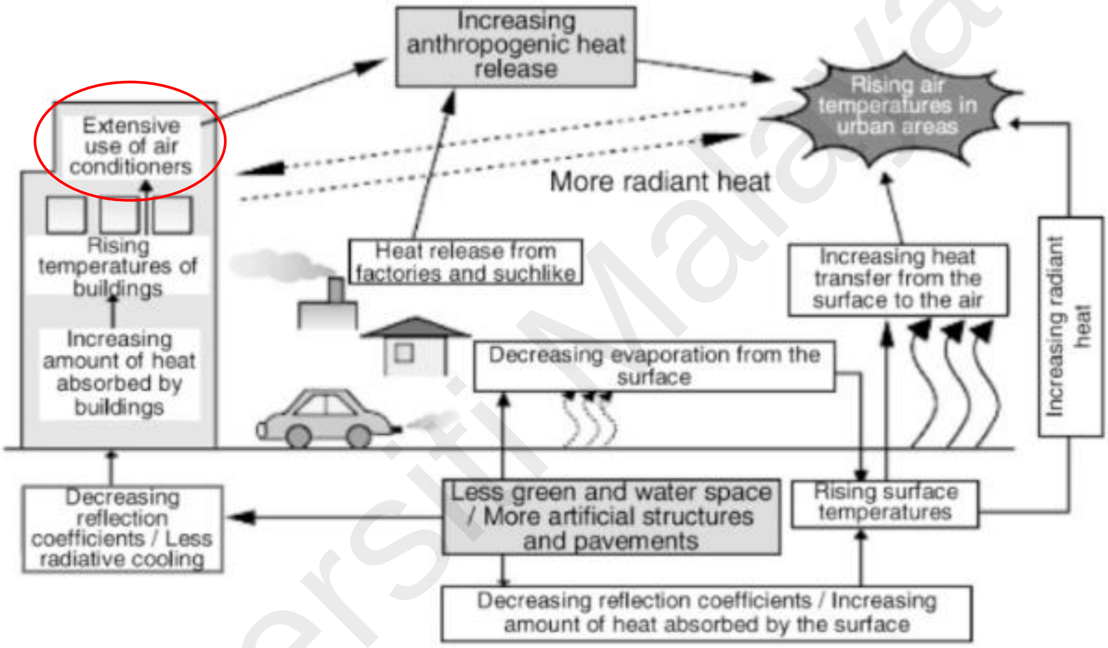

Figure 12: The causes of UHI.

Source: (Yamamoto, 2006)

The interaction of rising temperature due to the increasing temperatures in urban area is expected to have a negative impact on human health, air quality and energy consumption. The need for air conditioning in cities increases as the temperature rises. According to studies, for every 1°F (0.6°C) increase in air temperatures (ranges of 68 to 77°F (20 to 25°C), power demand for air conditioning or cooling increases by 1.5 to 2%, meaning that the community requires roughly 5 to 10% higher electrical demand to cope with the urban heat impact. The demand for air conditioning during increased periods of urban heat islands can overload systems, leading to power disruptions and blackouts. Buildings are frequently cooled by air conditioning. Unfortunately, air conditioning uses a lot of energy and generates a lot of heat in the process of chilling a space. As the temperature rises, so does the demand for air conditioning. The countries with the largest rise in electricity usage are those that have air conditioning in the majority of their buildings. Arifwidodo & Chandrasiri (2015) studied about the development of UHI and its impact on the household energy consumption. This research stated energy consumption is higher in the area with presence of a higher outdoor temperature in an urban area.

2.6. Gap in current work

The usage of air conditioning in Malaysia is increasing yearly from 1970 to 2010 (Table 2). One of the factors that affect the UHI is the energy consumption in the urban area. The high usage of air conditioning led to a higher energy consumption and hence increase the temperature in urban area. There is a need of a comprehensive mitigation on the city's cooling method. However, there are not many studies done regarding the air conditioning and energy consumption of AC in a tropical area. In this study, the relationship between AC electricity consumption within the residential and non-residential zone of Petaling Jaya, Malaysia will be analysed. From the result, some suggestion can be made to improve the cooling city method and reduce the energy consumption in the urban area.

CHAPTER 3: METHODOLOGY

The overall methodology encompasses all of the stages necessary to achieve the research objectives.

3.1. Introduction

The method section outlines the steps that taken to investigate a research problem and why specific procedures, or approaches were used to identify, select, process, and analyze information to better understand the problem, allowing the reader to critically assess a study's overall validity and reliability. The methodology section of a study aimed to answers two key questions: What method was used to gather or generate the data? How was it analyzed? The writing should be clear and concise and always written in the past tense (Kallet, 2004).

3.2. Flow Chart

This flow chart shows the whole procedure of this research.

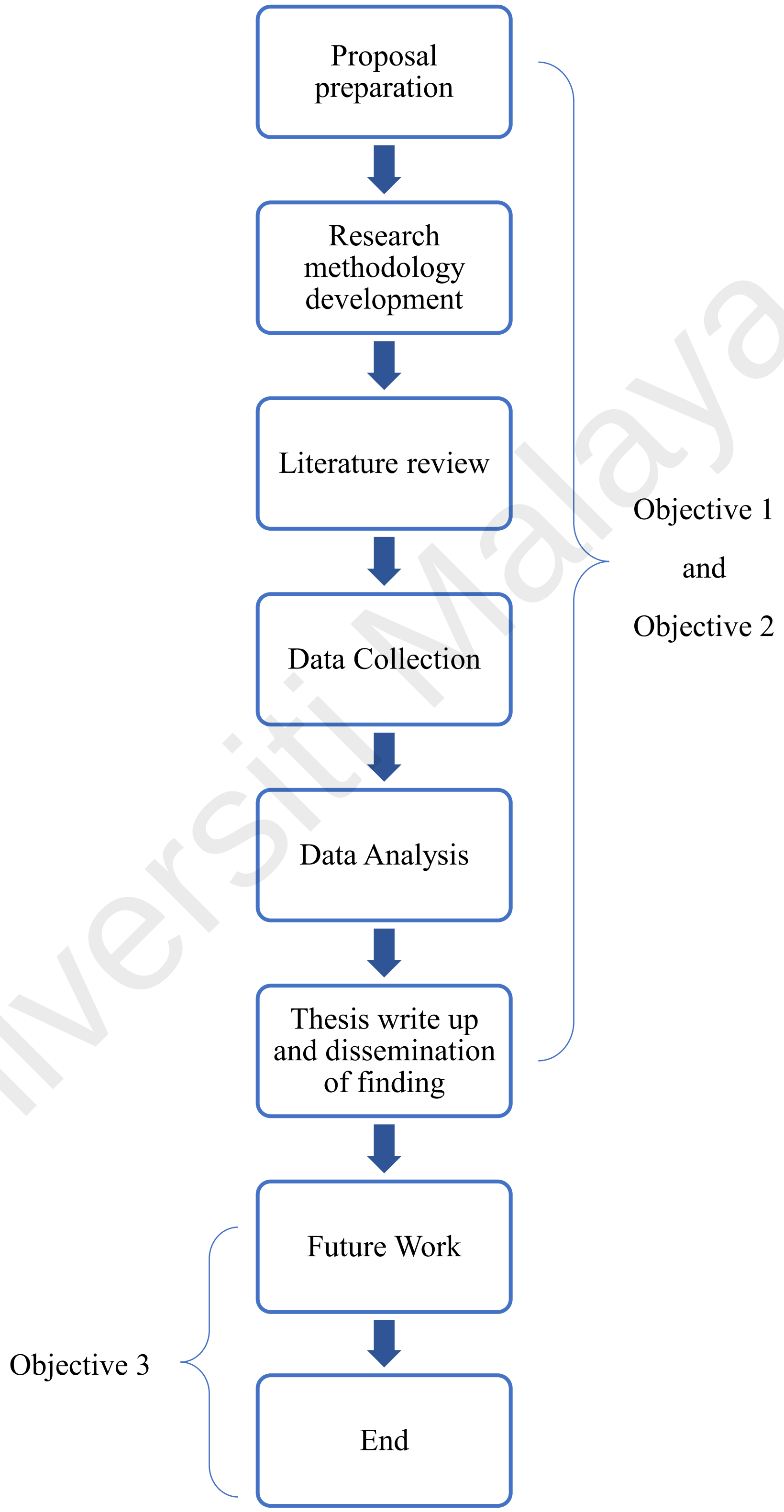

Figure 13: Overall flow chart of research process

3.3. Study Area

This study focuses on an urban area at Petaling Jaya. The studied area represented an area of 1 km radius around the Malaysian Meteorological Department of Petaling Jaya, with a weather station located at it's center to record outdoor temperature. Figure 14 shows the zoning of the studied area. The map was generated with secondary data about the surrounding land use retrieved from Petaling Jaya City Council (MBPJ) and Selangor Planning Information System (SISMAPS version 2, a public access online GIS map). Detailed division of different zoning will be shown in the next section.

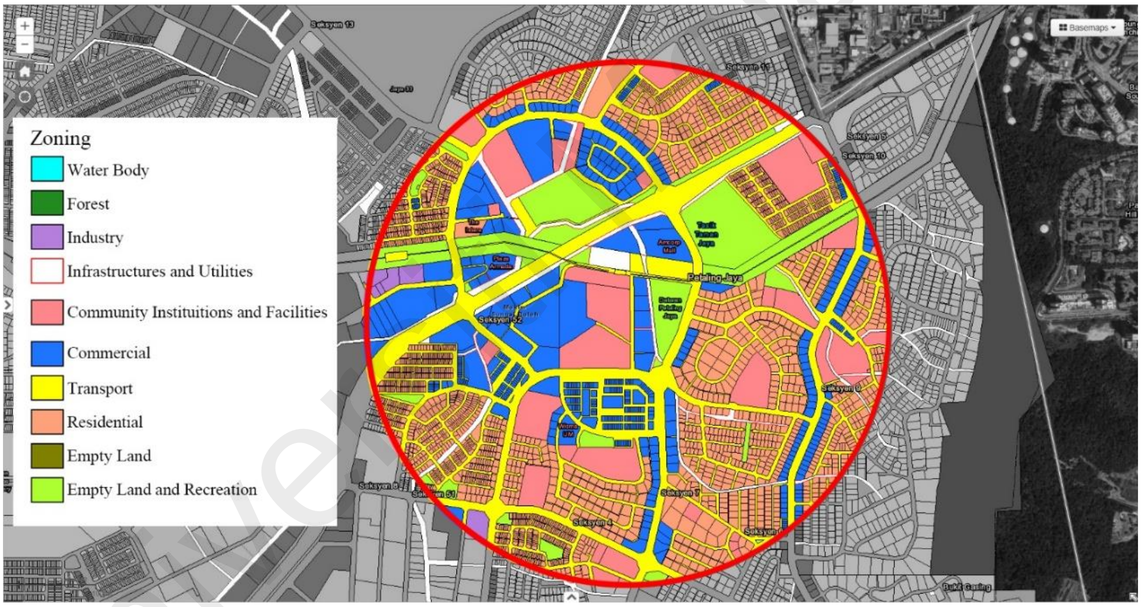

Figure 14: Zoning map of the study area.

Source: (SISMAPS)

3.4. Sampling design

This research obtained secondary data from the previous study. The total number of households that owns an air condition was obtained from internet (Department of Statistics Malaysia, 1974, 2000, 2010). This study is focused on the different AC electricity consumption in residential zone and non-residential zone (commercial sector). The data of estimated electricity consumption per living quarter and commercial establishment of Selangor was obtained from Malaysia Open Data Portal and SME Annual Report (2018 & 2019), respectively. The AC electricity consumption was calculated based on the estimation AC usage in the previous study (Hisham, Zaki, Hagishima, Md, & Yakub, 2019); Malaysia Shopping Malls Association. On the other hand, the data of daily average temperature in Malaysia was obtained from Malaysian Meteorological Department (MMD).

The data of residential and non-residential energy consumption was analysed and tabulated. All data were organized and managed using Microsoft Excel. The Pearson correlation test was carried out by using SPSS software.

3.5. Literature Search

This research also applied a systematic review of the literature on the recommendation of alternative cooling methods and presenting a discussion about finding of studies. This study uses internet search technique to find the relevant literature. A few dominant databases of academic literature were chosen such as Scopus, Science Direct and Research Gate. The combination of the following key words for the literature search such as effect of urban heat island, air temperature changes in urban and rural, usage of air conditioning, land use, AC electricity consumption, residential, institutional, commercial and alternative cooling methods. After listing down the key terms, the universe of literature was collected based on the related key terms. Then, all the literature were screened by reading the abstract to identify the direction of studies.

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Ownership of Household Air Conditioners

The total number of households with air conditioner in Malaysia is shown in Table 4.

Table 4: Total number of households that owns an air conditioner from 1970 to 2010

Year	Population	Household	No. of Household with Air Conditioner	Percentage (%)
2010	28,588,600	6,353,470	1,414,591	22.3
2000	23,274,690	4,801,835	775,358	16.2
1991	18,379,655	3,537,606	253,399	7.1
1990	17,981,730	3,428,142	229,187	6.7
1980	13,745,241	2,503,974	57,340	2.3
1970	10,439,430	1,890,282	13,251	0.7

Source: Population and Housing Census of Malaysia (Department of Statistics Malaysia, 1974, 2000, 2010)

From the table 4, the population, household, and the number of households with air conditioner is increasing from year 1970 to 2010. The household number increase from 2.3% to 6.7% during 1980 to 1990. Increasing of household might be due to the reason of the development of industrial estate in 1980s and 1990s. Many new towns were developed at southeast Johor, Hulu Terengganu, southeast Kelantan and interior Pahang to balance the equitable development and reduce the regional development disparities among regions (Abdullah, 2012). Therefore, the household number increasing according to the land development in Malaysia.

The Pearson correlation test indicate there is strong positive relationship between the number of household and the number of households with air conditioner (Table 5). The higher the number of households, the higher the number of households with air conditioner.

Table 5: Correlation test

Correlations

		Household	No. of Household with Air Conditioner
Household	Pearson Correlation	1	.975**
	Sig. (2-tailed)		.001
	N	6	6
No. of Household with Air Conditioner	Pearson Correlation	.975**	1
	Sig. (2-tailed)	.001	
	N	6	6

**. Correlation is significant at the 0.01 level (2-tailed).

According to the Department of Statistics Malaysia, the number of households with air conditioner is increasing drastically from 7.1% (253,399) to 16.2% (775,358) in year 1991 to 2000. Urbanization is the development process of an area which can cater a large and growing population. The population increase from 2,297,159 (1991) to 3,947,527 (2000) in Selangor (Abdullah, 2012). The rapid increasing population migration of rural to urban area in this period was due to have a higher chance of employment. According to the study of Abdullah (2012), several new towns such as Shah Alam, Puchong, Bangi, and Subang Jaya were developed in Klang Valley to cover high population growth in 1990s. Therefore, the increasing of population will lead to a higher number of household and the number of air conditioner. As discussed in Section 2.2.1, the highest land usage in Petaling Jaya is residential zones (19.40%) and the population of Petaling Jaya had drastically increased from 200,000 in 1977 to 520,628 in 2019, we could assume that this leads to a high ownership of AC in this area. The household energy consumption and AC energy consumption of the study area will be discussed in section 4.2.

Air conditioners is promoted as a solution for reducing the heat related health problems and providing indoor thermal comfort (Anderson & Bell, 2009). The urbanization activities have a significant impact of temperature (Wang et al., 2014). The increase of temperature causes the number of air conditioner ownership to be increase. Based on figures by Malaysian Meteorological Department (MMD), the daily average temperature is increasing from 1981 to 2016 (Figure 15). The increasing temperature indirectly affect the number of ownerships of air conditioner in the household. The demand for air conditioners in such temperature increasing in the tropical area will lead to a higher energy consumption. The relationship of number of air conditioner and energy consumption will be discussed in next section.

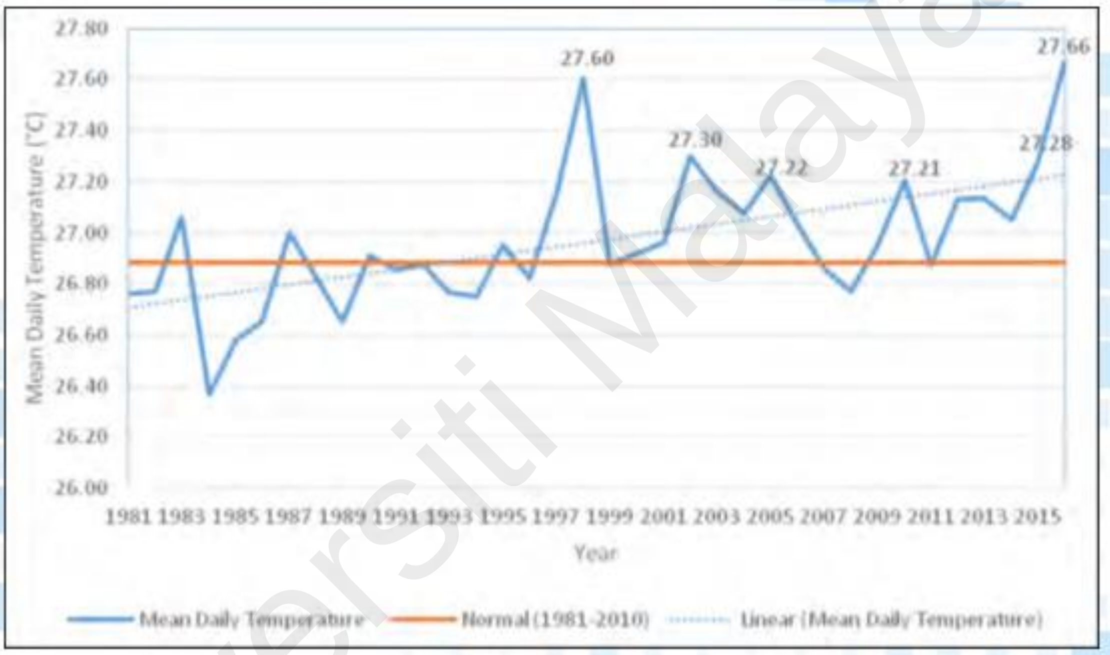

Figure 15: The daily average temperature in Malaysia from 1981 to 2016.

Sources: MMD, 2016

4.2. Energy Usage of Air Conditioners

As mentioned in section 4.1, the increase of number of air conditioner will caused the higher energy consumption in Malaysia. Hence, the air conditioner energy consumption in Petaling Jaya was analyse in this section. To compare the different air conditioner energy consumption, the residential and non-residential sectors in Petaling Jaya were chosen.

4.2.1. Residential Zone

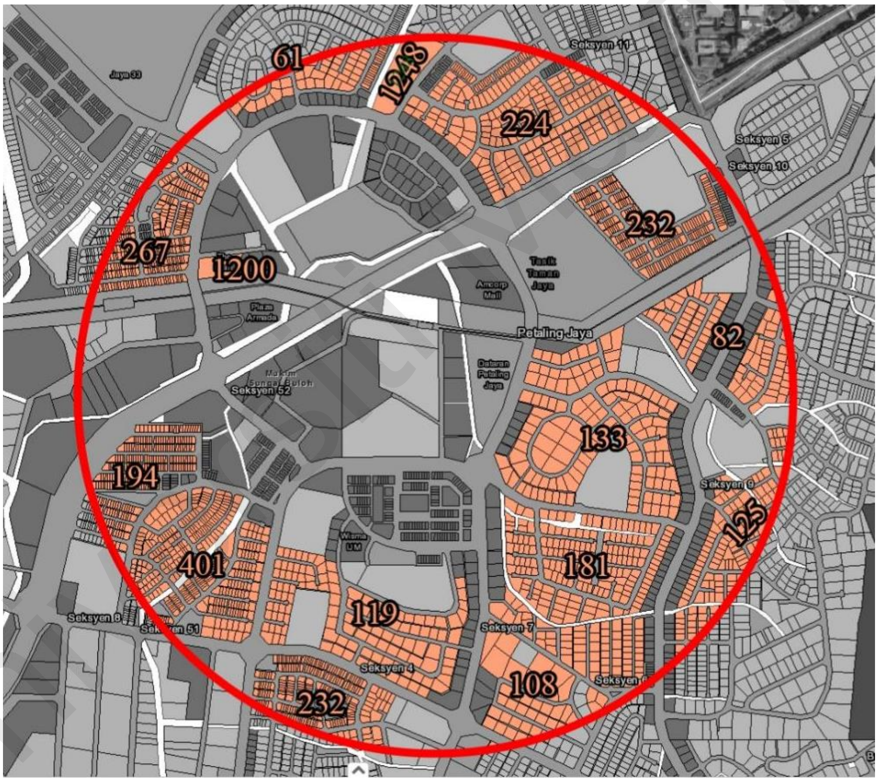

Figure 16: Residential Zoning map of the study area.

Figure 16 shows the residential zone within the studied area. A total of 4807 residential units was recorded, where 2448 units are from two high density residential areas located North and Northwest of the studied area and 2359 units are landed houses surrounding the center part.

4.2.2. Non-residential Zone (Commercial Zone)

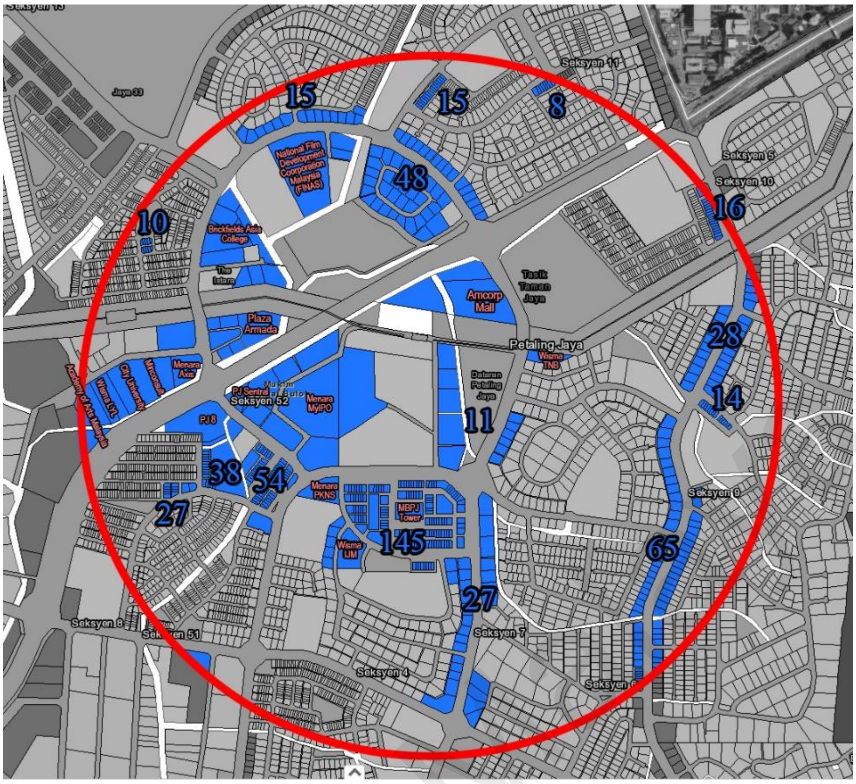

Figure 17: Commercial Zoning map of the study area

Figure 17 shows the commercial zone within the studied area. There are 485 units of shop lots mostly concentrated in the center part of the studied area. Other than that, there are also 12 high density commercial and office areas for example Amcorp Mall, Axis Tower and MyIPO Tower. Interestingly, there are some institutions (namely Brickfield Asia College, City University, Academy of Arts Malaysia, and National Film Development Corporation) are built on commercial zoning.

4.3. Estimated Residential AC Energy Consumption in Study Area

Based on data from Malaysia Open Data Portal, the estimated electricity consumption per living quarter from year 2016 to 2019 is as shown in table 6. The number of living quarters in Selangor is increasing from 1,850,400 (2016) to 1,971,000 (2019). The estimated electricity consumption per living quarter is increasing from 3012 kWh (2016) to 3688 kWh (2019). Hence, it can be said that the higher the number of living quarters, the higher the electricity consumption.

According to the study of (Ahmed et al., 2017), the household daily energy consumption is between 21.9 to 25.8 kWh/day in Putra Jaya and Kajang. The highest electricity usage is air conditioner followed by water heater and electric kettle compared to all the other appliances. Other appliances included electric kettle, electric iron, hair dryer, microwave, washing machine and rice cooker (Ahmed et al., 2017).

Table 6: Estimated Electricity Consumption per living quarter of Selangor (2016-2019)

Year	Number of living Quarters in Selangor	Estimated Residential Electricity Consumption of Selangor (kWh)	Estimated Electricity Consumption Per Living Quater (kWh/Living Quarter)
2016	1,850,400	5,936,674,670	3,012
2017	1,891,200	6,232,361,632	3,227
2018	1,931,500	6,528,048,595	3,452
2019	1,971,000	6,823,735,557	3,688

Source: (data.gov.my)

According to a study done by (Hisham, Zaki, Hagishima, Md, & Yakub, 2019), 30% of household total electricity consumption was consumed by AC. Based on the total 4807 residential unit in the study area, the estimated residential electricity consumption of AC in the study area is shown in table 7 below:

Table 7: Estimated Residential Electricity Consumption of AC in the Study Area

Year	Estimated Electricity Consumption Per Living Quater (kWh/Living Quarter)	Estimated Electricity Consumption of AC Per Living Quater (kWh/Living Quarter)	Estimated Residential Electricity Consumption of AC in Study Area (kWh)
2016	3,012	903.60	4,343,622
2017	3,227	968.01	4,653,217
2018	3,452	1035.54	4,977,844
2019	3,688	1106.31	5,318,044

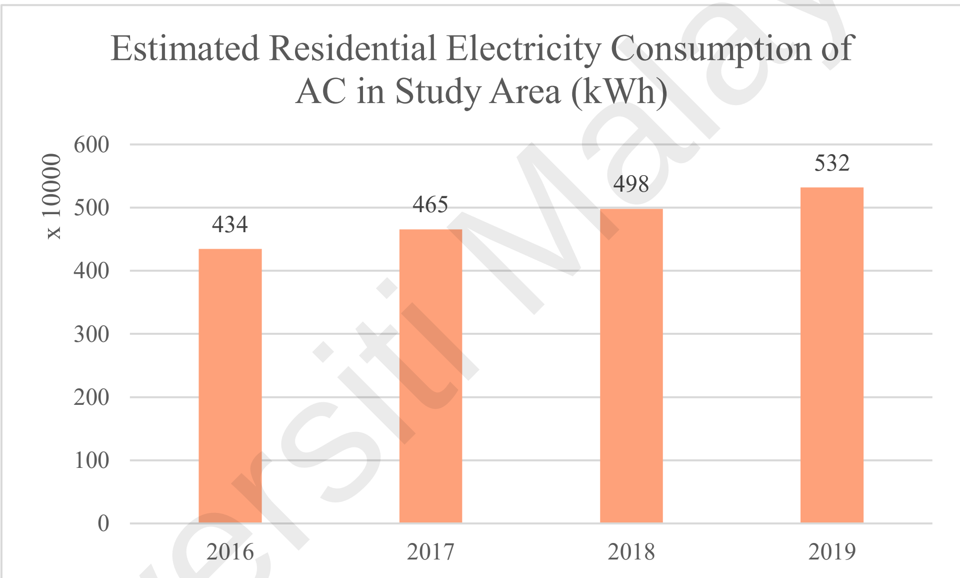

Figure 18: Estimated Residential Electricity Consumption of AC in the Study Area

Based on figure 18, the estimated residential electricity consumption of AC is increasing yearly. The electricity consumption of AC in Petaling Jaya is increasing from 4,343,622 kWh/year to 5,318,044 kWh/year. Electricity consumption in residential is continuously increasing and will continue to grow in the future as more air conditioning will be installed (Mahlia et al., 2001).

4.4. Estimated Commercial AC Energy Consumption in Study Area

Based on data from SME Annual Report (2018 & 2019) and also Malaysia Open Data Portal, the estimated electricity consumption per commercial establishment is as shown in table 5. The number of establishments in Selangor is remain as 179,271 from 2016 to 2019 according to SME Annual Report. The estimated electricity consumption per establishment is increasing from 53,025 kWh (2016) to 59,944 kWh (2019).

According to the study of Abd Hamid, (2016), there are five main factors which are equipment's, outside temperature, building structure, operating hour and people affecting the electricity consumption in commercial buildings. Building structure can affect the electricity consumption if the design of the building consists of extra window shading. The sunlight will get through and this will increase the heat inside the building causing more electricity requires to cool down the indoor temperature (Abd Hamid et al., 2016).

Table 8: Estimated Electricity Consumption per commercial establishment of Selangor

Year	Number of Establishment in Selangor	Estimated Commercial Electricity Consumption (kWh)	Estimated Electricity Consumption Per Establishment (kWh/Establishment)
2019	179,271	10,746,251,875	59,944
2018	179,271	10,332,806,868	57,638
2017	179,271	9,919,361,861	55,332
2016	179,271	9,505,916,853	53,025

Source: SME Annual Report (2018 & 2019), (data.gov.my)

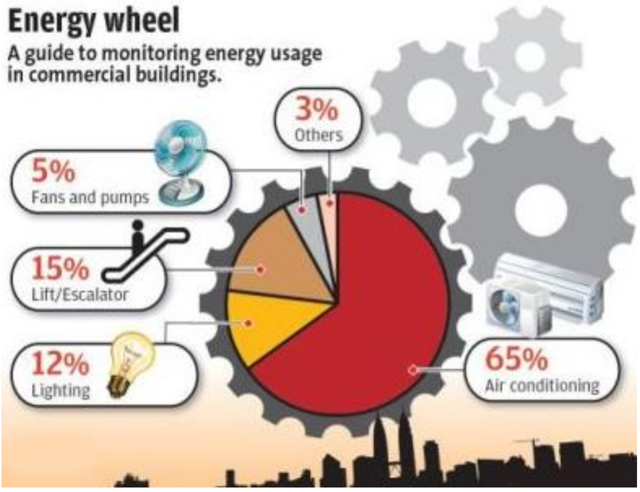

Figure 19: Breakdown of Energy Usage in Commercial Buildings

Source: (Chin, 2013)

According to Malaysia Shopping Malls Association, AC contributes 65% of total energy consumption in commercial buildings. Based on the total commercial establishment of 497 in the study area, the estimated commercial electricity consumption of AC was estimated as shown in Table 6.

Table 9: Estimated Commercial Electricity Consumption of AC in the Study Area

Year	Estimated Electricity Consumption Per Establishment (kWh/Establishment)	Estimated Electricity Consumption of AC Per Establishment (kWh/Establishment)	Estimated Commercial Electricity Consumption of AC in Study Area (kWh)
2019	59,944	38,964	19,364,965
2018	57,638	37,465	18,619,929
2017	55,332	35,966	17,874,892
2016	53,025	34,467	17,129,856

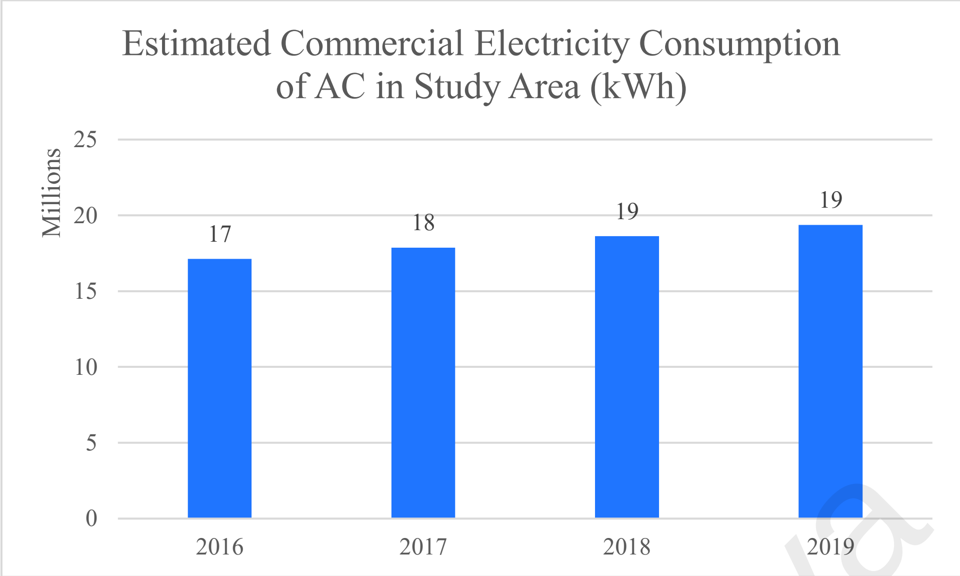

Figure 20: Estimated Commercial Electricity Consumption of AC in the Study Area

Based on figure 20, the estimated commercial electricity consumption of AC is increasing yearly. The electricity consumption of AC in Petaling Jaya is increasing from 17,129,856 kWh/year to 19,364,965 kWh/year. The main energy use in commercial building is the electricity consumption in Malaysia (Abd Hamid, 2016). Temperature is one of the main factors that cause the high energy usage in commercial building as Malaysia is not a four-season country and cooling as thermal comfort. Therefore, it creates a high demand of air conditioner operation in the commercial building.

There are some factors that cause the air conditioning in office building to consume most of the energy. Firstly, the equipment within the air conditioning system such as compressor and supply fans use a lot of electricity to operate (Westphalen, 1999). Secondly, air conditioning system have a longest operation time compared to others in commercial building. The air conditioning system will be operate based on the working hour in the building or some even working throughout the whole day.

However, there are few studies raise the issue of over cooling in office building which causes an energy inefficiency and environmentally hazardous (Azizi et al., 2017). Most of them sets the temperature in between 21 °C to 23 °C which is lower than the recommended temperature settings of many other countries. For example, in China and Singapore, the recommended temperature for commercial buildings is in between 24 °C to 26 °C (Chin, 2013).

Based on the result, the electricity consumption of AC per year in non-residential zone (Figure 20) is higher than the residential zone (Figure 18). This might be due to the difference of operation time in residential and non-residential area. The non-residential area (commercial area) has a longer operation time than the residential area. Hence, more electricity will be consumed. According to the study conducted by Kubota (2010) & Aqilah et al. (2021), the air conditioner was used in bedrooms and only operate during sleeping time at night. An inefficient used on air conditioning cause the high electricity consumption in non-residential area. For example, in UK, there are more 15% of air conditioning system are oversize and cause excessive energy consumption (Sorrella, 2003).

Study done by (Salamanca, Georgescu, Mahalov, Moustaoui, & Wang, 2014) found that waste heat generated by air-conditioning system use at night-time could raise 0.5°–1°C of the mean nigh time temperature, demonstrating a strong influence on the studied region. The raised of outdoor air temperature on the other hand not only causes extra energy demand for the air-conditioning system, but it also results in a higher average temperature of urban area. Energy saving strategy is an essential solution for reducing the CO_2 emission and electricity consumption problems. Hence, the next section will be discussing about some of the methods towards energy saving and alternative cooling methods.

4.5. Energy Saving and Alternative Cooling Methods in an Urban Area

In a tropical urban area, outdoor temperatures could be less comfortable due to overheating of building surfaces. Studies shows that because of the increase in developed areas and decline in greenery, outdoor air temperature rises more easily and increases both indoor and outdoor temperatures (He & Hoyano, 2009) (Taleghani, Tenpierik, Dobbelsteen, & Sailor, 2014). As a result, building inhabitants have to use AC to maintain thermal comfort of their indoor environment. Although AC represents a most straightforward and easy cooling method, it should not be the primary method due to its impact on electricity consumption (Chenari, Carrilho, & Silva, 2016), and also the generation of waste heat that would further increase outdoor temperature (Borge-Diez, Colmenar-Santos, Pérez-Molina, & Castro-Gil, 2013). Therefore, it is important to find out alternative cooling methods to lower the energy consumption in a more effective way. In this section, a few mitigation measures for cooling will be discussed in depth to reduce the use of air conditioner.

An alternative way to reduce the use of AC is apply the night ventilation for the terrace house. A good night ventilation place can reduce the peak indoor temperature by 2.5℃ and nocturnal air temperature by 2.0 ℃ on average compare to daytime ventilation (Kubota et al., 2019). Nocturnal indoor operative temperatures in terraced houses are 2-3℃ higher than outdoor air temperature even under open window condition. Installation of exhaust fan to ventilate the whole house during nighttime would enhance nocturnal structural cooling and therefore reduce indoor air temperature not only at night but also during daytime on the following day. Installation of thermal insulation would reduce the indoor operative temperature significantly. Applying window or wall shading such as roof overhang and strategic shade trees to windows and walls could reduce indoor heat that caused by solar radiation. thus reduce the use of air conditioning system.

Petaling Jaya City Council (MBPJ) is the only local council in Asia that provides assessment rebates to homeowners practicing green living. Deputy mayor Johary Anuar said this at the launch of the 2019 Petaling Jaya Homeowners Low Carbon and Green Initiative assessment rebate scheme at the council. The scheme, which was first introduced in 2011, has in total waived assessment worth RM414,380.48 for 1,240 households in the city up to last year.

According MBPJ Strategic Plan (MBPJ, 2021), government will ensure that all new and existing developments comply with the requirements related to Universal Design and Green Buildings. In the strategic plan, the planting shade trees and provision of "Green roofs" was mentioned for sustainable and green landscape design and also providing of green area. Green roofs provide shade for the building and protect them from solar radiation. It reduces the heat convection to the air above and decrease the energy for cooling (Rakhshandehroo, Arabi, Shahidan, & Kamal, 2015). Several different studies proved that green roof represents one of the effective alternative cooling strategy (Kolokotsa, Santamouris, & Zerefos, 2013); (Santamouris, 2014) (T.Susca, S.R.Gaffin, & Dell'Osso, 2011); (Takebayashi & Moriyama, 2007) (Kolokotsa, Santamouris, & Zerefos, 2013). Additionally, (Osmond & Sharifi, 2017) suggested that the cooling effect produced by plants on green roof could increase the efficiency of photovoltaic panel's energy production.

MBPJ Strategic Plan (MBPJ, 2021) mentioned that planting a shading trees able to improve the energy efficient in Selangor. As stated in the literature review section, vegetation represents a practical method (Ghaffarianhoseini, Berardi, & Ghaffarianhoseini, 2015). A study found out that air temperature was 0.7-1.4°C lower in area with vegetation when compared to area without vegetation (Srivanit & Hokao, 2013). Another study shows that there is approximately 1℃ cooler in average daytime temperature under tree shade when compared to an open space (Yoshida, Hisabayashi, Kashihara, Kinoshita, & Hashida, 2015). Zhang et al., (2010) showed that the higher vegetation cover, the lower the temperature. Therefore, increasing green space represents a mainstream method to counter UHI (Osmond & Sharifi, 2017) effect.

As part of the plan to make Petaling Jaya into a sustainable city by 2030, MBPJ had proposed various initiatives. According to the city council's 2021 – 2025 strategic plan, as stated in strategy 2: Strengthening Environmental Preservation and Conservation Efforts and Green City Sustainability, the city planned to apply the principles of green infrastructure in designing urban landscapes based on different strategies including providing of green areas, planting shade trees (maintaining at least 80,000 trees all year long) and encourages developers to implement vertical landscape and rooftop garden. Green corridors would also be developed throughout the city and MBPJ planned to have an addition of 5 parks in order to increase the vegetation coverage of the city (MBPJ, 2021).

Besides, cool roofs in city able to provide a cooling effect. Cool roofs utilise natural white materials which are highly reflective to reflect most of the incoming solar radiation and thereby decrease the net radiation within the building. (Osmond & Sharifi, 2017) suggested that a well-designed cool roof could reflects up to 75% of the total solar radiation. Therefore, unlike conventional rooftops that tends to absorb a large portion of the solar radiation, cool roofs radiate away most of the energy causing a better cooling effect, and thus decrease the usage of AC (Doulos, Santamouris, & Livada, 2004).

Alternative cooling methods that doesn't utilize AC not only improve thermal comfort, at the same time it also lowers energy demand, making cities more livable. Urban greenery, cool materials, shading, and water are some of the possible measures to reduce outdoor temperatures and enhance a city's sustainability in an increasingly warmer climate (Osmond & Sharifi, 2017).

CHAPTER 5: CONCLUSION AND LIMITATIONS

5.1. Conclusion

Based on the analysis, it can conclude that there is an increase in energy consumption in residential and non-residential area from 2016-2019. This scenario mainly caused by the increasing usage of AC as the ownership of AC shows an upward trend since 1970 from 0.7% to 22.3% in 2010. The percentage is expected to keep growing as supported by the air conditioner demand of Malaysia. Based on literature review findings, as AC usage increases, AC energy demand increases, and the waste heat rejected by AC will cause outdoor temperatures to increase. This in turns would also cause the AC usage to further increase. Finally, alternative cooling methods for an urban area such as a building structure design, ventilation, increase vegetation, green roof and cool roof was recommended. Additionally, featuring the local authority of the study area's strategic planning that incorporate the recommended methods.

5.2. Limitation & Recommendation for Future Work

The limitation of this study is that the data of electricity consumed by AC is only available until 2019. There is only data of electricity consumption by residential and commercial sector available through the online literature in study area. There is a limit in other sectors such as institutional and industry sectors in this study area.

Sampling of data was unable to carry out in the study area due to the Covid -19 pandemic. Difficulty to access a more capable instrument to run an analysis had made this research harder to get more primary data to determine the exact impact of AC of the study area. Future research may consider having a data sampling in the study area in different sectors. The monthly air temperature and monthly AC energy consumption should collect from the different sectors in the study area to increase the sample size of data and improve the accuracy of data.

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