# ANALYSIS OF CAMPUS BUILDING ENERGY OPTIMIZATION BASED ON ENERGYPLUS SOFTWARE SIMULATION

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KUALA LUMPUR

2018

# ANALYSIS OF CAMPUS BUILDING ENERGY OPTIMIZATION BASED ON ENERGYPLUS SOFTWARE SIMULATION

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**RESEARCH REPORT SUBMITTED TO THE FACULTY OF ENGINEERING UNIVERSITY OF MALAYA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF MECHANICAL ENGINEERING**

**2018**

**UNIVERSITY OF MALAYA**

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# ANALYSIS OF CAMPUS BUILDING ENERGY OPTIMIZATION BASED ON ENERGYPLUS SOFTWARE SIMULATION

## ABSTRACT

This research project presents the idea of campus building energy optimization strategies according to the nature of building and occupants' activities. World have been experiencing rapid growth for last few decades and thus cause the energy consumption rise drastically. Therefore, the objectives of this research are to propose the energy optimization approaches: set-point temperature and tinted window for campus building. The approaches were built according to the target building characteristic and focus and thermal consumption only. Energy consumption of the target building was simulated using energy simulation software (EnergyPlus) and the result was compared. The approaches proposed were verified using the software respectively. Simulation result shows that both approaches had successfully reduced the total building energy consumption by reducing HVAC system energy consumption. Set-point temperature reduced the annual energy consumption by 10.05% whereas tinted window would reduce the annual energy consumption by 3.25%. The results proved that the two optimization strategies could effectively reduce the cooling load and total energy consumption of the campus building.

## ANALISIS PENGOPTIMUNAN PENGGUNAAN TENAGA BANGUNAN KAMPUS DENGAN PERISIAN SIMULASI TENAGA ENERGYPLUS


### ABSTRAK

Kajian ini dijalankan untuk mempaparkan idea-idea mengoptimumkan penggunaan tenaga dalam bangunan kampus dengan menurut kepada sifat dan aktiviti-aktiviti penghuni dalam bangunan kampus. Seluruh dunia sedang mengalami pembanguan yang pesat dan mengakibatkan penggunaan tenaga semakin banyak sehingga tahap yang merisaukan. Sebab yang begitu, kajian ini bertujuan untuk mencadangkan strategi-strategi pengoptimuman tenaga: penetapan titik suhu dan tingkap berwarna gelap untuk bangunan kampus. Strategi tersebut dicadangkan menurut kepada ciri-ciri bangunan dan berfokus dalam penggunaan terma sahaja. Pengunaan tenaga dalam banguan sasaran telah disimulasikan dengan menggunakan perisian simulasi tenaga; EnergyPlus and hasil kajian telah dibandingkan. Pendekatan dicadang telah disahkan dengan perisian komputer tersebut. Keputusan simulasi menunjukkan kedua-dua pendekatantersebut berjaya mengurangkan penggunaan tenaga bangunan dengan mengurangkan penggunaan tenaga dalam sistem HVAC. Penetapan titik suhu berjaya mengurangkan penggunaan seluruh tenaga sebanyak 10.05% manakala tingkap berwarna gelap dapat mengurangkan penggunaan seluruh tenaga sebanyak 3.25%. Keputusan ini menunjukkan kedua-dua pendekatan ini dapat mengurangkan muatan penyejukan and penggunaan tenaga bangunan kampus secara efektif.

## ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to all who had guided and support me in completing this research project. This research would not be completed successfully without assistance from them.

Firstly, I would like to thanks my project supervisor, Dr Ong Hwai Chyuan, who had been patient to advice and guide me in this project. He had giving me a helping hand whenever I encounter with problems while completing this research. I am grateful that I have expand my engineering knowledge under supervision from him.

Secondly, special thanks to Mr Azally Bin Makmor from Electrical Department, Department of Development & Asset Maintenance, UM. He had been helpful in providing me the data on the electricity consumption of Engineering Faculty. Also, thanks to Madam Sabrina Nordin from Deputy Dean Office, Engineering Faculty who is kindful to provide me the building information of Block D. Without the information, I would not able to carry out the project smoothly.

Last but not least, highly thankful to my family and my coursemates who help me either directly or indirectly along I completing my research project.

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| ASHRAE | : | American Society of Heating, Refrigerating and Air-Conditioning Engineer |
| DOE | : | Departments of Environment |
| EPBD | : | European Energy Performance of Buildings Directive |
| HVAC | : | Heating, Ventilating, And Air-Conditioning |
| IEA | : | International Energy Agency |
| IWEC | : | International Weather for Energy Calculations |
| ktoe | | Kilotonne of oil equivalent |
| MMD | : | Malaysian Meteorological Department |
| OECD | : | Organization for Economic Cooperation and Development |

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# CHAPTER 1: INTRODUCTION

## 1.1 Project Background

Most of the countries in the world are continuing to experience fast urbanization grow in population in recent years. As results, energy usage among the countries showed a dramatic rise in the past ten years. According to the past research, buildings is the major contributor to energy consumption which use about 40% of the net total world energy (A.S.Bujang, et al., 2016). For case in Malaysia, commercial buildings takes up to a total of nearly half of the electricity produced in the nation and total energy demand is projected to achieve 116 million tonnes of oil equivalent amount during year of 2020 (Hassan, et al., 2014). Along with the high energy demand is the side products like carbon dioxide emission which leads to serious environmental problems

Due to the expected increase in energy demand, energy efficiency becoming more significance. High rate of urbanization with increased buildings and floors which exploit the use of conventional energy source (Khor & Lalchand, 2014). Availability of renewable energy that can be utilised in these buildings is limited therefore the usage of energy must be optimized through energy proficiency and preservation in various aspects (Deb, et al., 2017).

Efficiency of building energy could be evaluated in different ways according to functionality namely HVAC systems, electric motors, building utilities and devices, and also lighting systems, (ZhenHuang, et al., 2006). In either ways of evaluation, the bottom line is to justify for the thermo comfort level for the occupants within the building. Simulation could be done on hourly basis and at peak load to evaluate the energy usage and to see if any improvement could be done on the energy consumption (GrazianoSalvalai, 2012).

### 1.2 Problem Statement

Southeast Asia is one of the region in the world that facing serious issue of energy optimization due to its geological location at the equator (Lau, et al., 2016). Majority of the towns in Southeast Asia are having hot and at the same time quite humid weather all the year round, including Kuala Lumpur which then lead to the larger amount of energy especially in the cooling purpose. The consumption of large amount of electricity have influenced all of us in our daily lives. Many issues arise as the side effect of energy usage mainly due to the large amount of carbon dioxide emission. Along with that, environmental problem occurs namely greenhouse gas effect, climate variation, acidic rain, and the continuous depleting sources of fossil fuels of the world.

Today, nearly 80% of the total world's energy production are coming from fossil fuels as well as nuclear fuels which both will bring not only causes environmental problem, but also safety issue like what nuclear incident happen in Fukushima, Japan (Kubota, 2011). Moreover, fossil fuels used by today technology are non-renewable and are depleting at a rate which is worrying. Therefore, this will heavily affect the world economies when the demands of fuels sources are changing.

Along with the problems outlined, the urge of energy optimization within building is confirmed as it contributes nearly 40% of the total energy consumption (Wei, et al., 2018). Due to the high rate of population growth, quick development of economy and demand of high quality of life, world energy consumption had been increasing. With the world population are continue growing, means the demand of the energy further burdened. High rate of energy consumption will bring only more greenhouse gases which their emissions will cause severe influences on the environment. The projected increment in energy consumption, and also the high percentage of coal in the energy sources, indicate that how significance of the energy efficiency is. Furthermore, rise of amount of urbanization with come along with the increased living room in all sector has forced massive pressure on the present sources of energy (Wei, et al., 2018). Restricted accessibility of the present energy resources and extremely fleeting characteristic of sustainable energy sources have improved the implication of energy saving by parties from all sector.

With the expansion of university within the country, campus building become one of important component in the building sector (Anna, et al., 2012). Therefore, in this research, campus building will be discussed due to its huge energy saving potential. The compared energy consumption result and improved design simulation result to check if the optimization is valid.

## 1.3 Research Objective

Purpose of this research is to study the campus building energy consumption in terms of thermal consideration within the building. It will be done by using energy efficiency approach and evaluate it through energy simulation software. Therefore, the research aims to achieves following objectives:

1. To simulate the building energy consumption by using energy simulation software. This will then act as method to verify the feasibility of energy optimization approaches.
2. To improve building energy efficiency through building thermal design which including set-point temperature approach and window tinting.

## 1.4 Research Scope

The scope of this research project is to achieve the above stated objectives. Formerly, many researches have been done on the similar topic in order to optimize energy consumption within buildings. In this research project, optimization of building energy consumption analysis will be carry out by simulation approach.

The research takes a building in Faculty of Engineering, University of Malaya, namely Block D as a target building in the project which will undergone energy consumption analysis using data and simulation software EnergyPlus. The result obtained from simulation software will be then compared with actual data to validate its accuracy.

After that optimization of the building energy usage will be carry out using setpoint temperature approach and thermal design approach. Analysis is carried out to optimize the energy usage in the building where lecture classes are on-going.

As outcomes of the research, strategies that significantly reduce the building energy consumption are to be proposed as move towards building energy optimization.

## 1.5 Research Project Report Outline

This research project report delivers an overview on the energy consumption in the target building and analysis of the energy optimization within the building using different approaches.

Chapter one in the research project report deliver a general knowledge on the background of current energy outlook worldwide and scenario in Malaysia and deliberate about the difficulties and encounters that confronted. This chapter also emphasis on the urge of this research topic and outcomes that are expecting to be obtained. Generally, the first chapter of the report are delivering the objectives of this research and background information on the research topic.

Chapter two review the reports and outcomes of the past research on the similar topic. This chapter gives very useful applicable information to complete this project. Different sectors that contribute to energy consumption were discussed and being compared. The approaches that being applied by past researches in the similar topic are being discussed. Furthermore, methodology and modelling of building energy simulation method are presented.

Chapter three discussed about the research methodology that being applied in this project. This chapter will illustrate how the simulation of building energy consumption is carried out using the software. Also, the method of how the energy optimization strategies are being verified are also discussed in this chapter.

In chapter four, the results obtained from the project were presented. The comparison of simulation result of the building energy consumption and the actual data is being discussed. Besides, the simulation results of the energy optimization strategies are being analyzed in this chapter.

Chapter five of the thesis conclude the findings from this project to meet the objectives of the project. Also, some recommendations of the future works in the similar fields are also suggested in this chapter.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Global Energy Consumption

The fast rising of global energy consumption has by now elevated concerns from the society. Sources security, depleting and also exhaustion of energy resources had always been issues about the energy sector. Furthermore, severe environmental impacts which including ozone layer depletion, global warming and climate change. The International Energy Agency (IEA) has obtained information that are scary on energy consumption trends. For the past two decades, world primary energy has risen by 50%. Not only that, carbon dioxide emissions is also recorded a rise of 43%, which also equivalent to mean annual increment of about 2%. Researchers had predicted that this phenomenon will continue for the next few decades (Pe´rez-Lombard, et al., 2008).

Energy that are consumed by nations with emerging economies are significant. These countries include Southeast Asia, Middle East, South America and Africa. The energy usage will continue grow at an average annual rate of at least 4% and will overtake developed nations by 2020, for instance, Western Europe, Australia and Japan, which record only average growing rate of 1.5% annually (Oh, et al., 2014).

The scenario in China is more worrying, it took only 20 years to double its energy consumption at an average growing rate of nearly 4%. Serious significances can be obtained from the study of the trend of main world energy demand pointers from 1980 to 2010. In case of China, the population growth rate is always under its nation GDP, resulting in a considerable rise of per capita personal income and global wealth. However, the energy use is noticed to have grown at a higher rate than its population growth, resulting in the increment of tje per capita value over the last three decades. It is interesting to note that carbon dioxide releases have full-fledged at a momentous rate during this dated due to energy use has drastically risen. This also resulting to a proportion increase in final energy usage.

The United State Energy Information Administration's newest report which also known as International Energy Outlook 2017 indicates that world energy use will continue raise by 28% between 2015 and 2040 according to Figure 2-1. This growth is mainly contributed by nations that are not in the Organization for Economic Cooperation and Development (OECD), and particularly in countries where demand is motivated by strong financial growth, mostly from Asia. Non-OECD Asia likes China and India are responsible for more than 60% of the world's total energy usage increment in this period (Qi Jie Kwong, 2018).

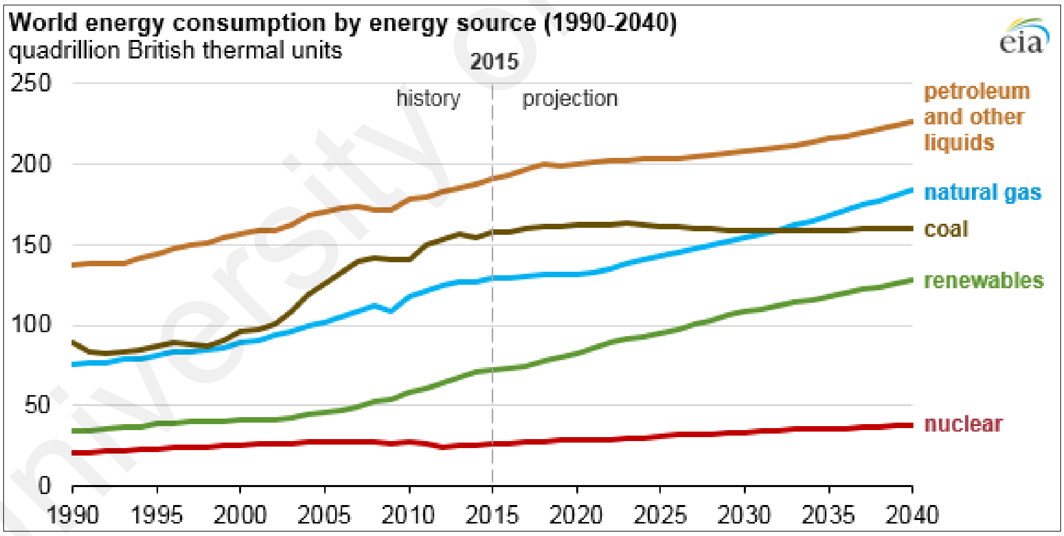


**Figure 2-1: World Energy Consumption 1990-2040**

Globalization and improvement of life quality in most of the world and the rapid growth of communication networks, had been promoting developed nations life style and advance energy needs to consumption trends will exhaust more energy resources and will lead to severe environmental impact. From these it is conclude that, the current energy usage and the style of consumption are definitively unsustainable.

### 2.1.1 World Energy Mix

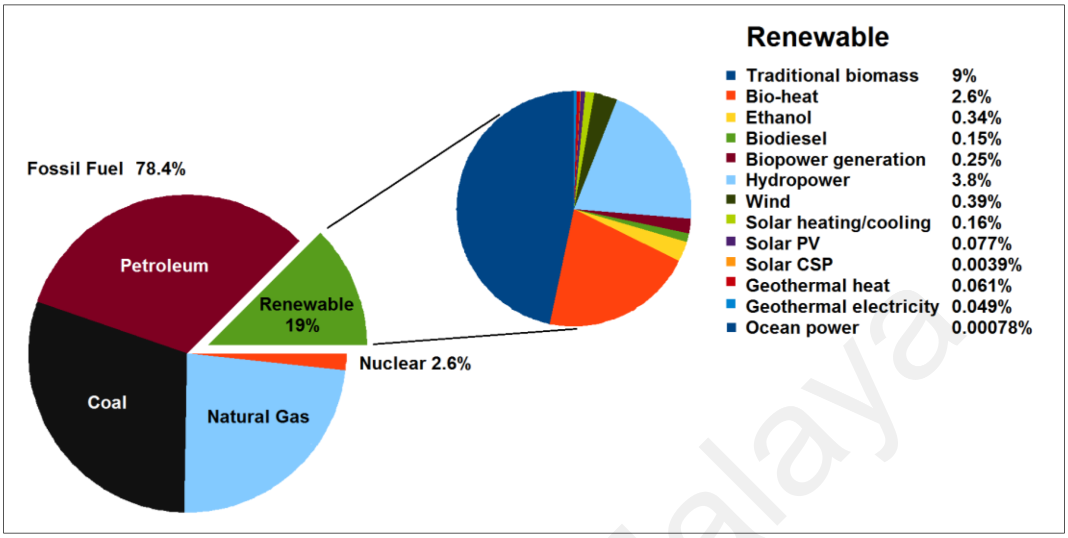


**Figure 2-2: Total Energy Consumed By Source**

In 2016, global primary energy used is recorded at 12.5 million tonnes oil equivalent or 140000 Gigawatt-hours. According to Figure 2-2, 13.6% was used by EU and others are used by rest of world. Among the source of energy, 78.4% was generated by fossil fuels including coal, petroleum and natural (Krartia & Dubey, 2018). Large portion of fossil fuel in energy mix will cause problems especially the carbon emission which critically affect the ecosystem. When the global energy usage is continuing rise as result of the growth of global population. The issues on the energy usage cannot directly be countered, the sustainability of development can somewhat be improved by imply some modify in the energy mix to become more dominant renewables sources. The main forces in this process are national and transnational energy policy and the energy industry together with their requesters.

## 2.2 Malaysia Energy Use

Figure 2-3 shows the gross generation and usage of electricity in the nation of Malaysia during 2016. The electricity consumption is less than the generation with about 18GWh.

The electricity produced in the nation is around 135 GWh and the consumption is around 117GWh (Ali, et al., 2012). The advanced development in Malaysian economy is dependent on the continuous energy supply. Consequently, any shock or deficiency of energy supply within the country will result in an unfavorable scene to the nation's economy.

| REGION | ELECTRICITY GROSS GENERATION | | ELECTRICITY CONSUMPTION | | AVAILABLE CAPACITY | PEAK DEMAND | |
|---|---|---|---|---|---|---|---|
| | GWh | % | GWh | % | MW | MW | % |
| PENINSULAR MALAYSIA | 117,797 | 87.7 | 102,174 | 87.7 | 21,044 | 15,826 | 33.0 |
| SARAWAK | 10,824 | 8.0 | 9,237 | 7.9 | 2,265 | 1,161 | 95.1 |
| SABAH* | 5,754 | 4.3 | 4,943 | 4.3 | 1,091 | 828 | 31.8 |
| TOTAL | 134,375 | 100.0 | 116,354 | 100.0 | 24,400 | | |

**Figure 2-3: Energy Consumption In Malaysia**

The usage of electricity by each of the major sector namely industries, commercial and residential buildings are indicated in Figure 2-4 (Shaikh, et al., 2017). World Green Building Council definite that buildings are the major single major contributor to the world rise in temperature. It accounts for nearly one-third of global carbon dioxide releases. In our nation, buildings, including of commercial buildings and residential building had consume about 15% of total energy consumption and 48% of the nation electricity usage. Tenaga Nasional Berhad highlighted that building structures in the country chomp a entire of 54% of the total electricity in the country. Commercial buildings consume 33% and the residential buildings 21%. A total of 38,645 GWh was consumed by commercial buildings. On the other hand, residential buildings consume a sum of 24,709 GWh.

The Figure 2-4 shows the energy consumption by various sectors in the country (Samaan, et al., 2016). Figure shows that transportation takes the highest portion of energy followed by industrial and building sector.

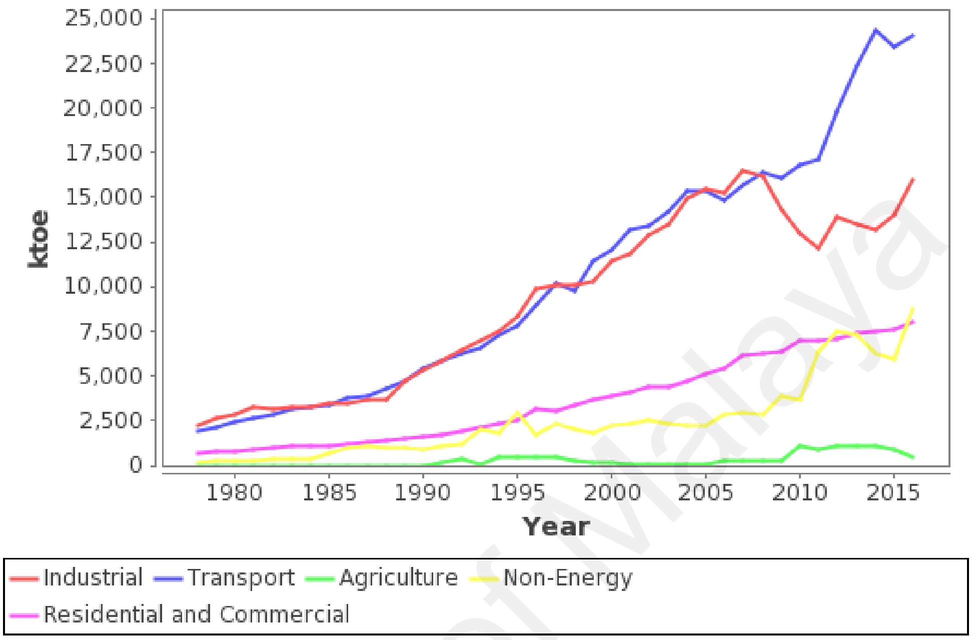


**Figure 2-4: Energy Consumed by Sector In Malaysia**

### 2.2.1 Malaysia Energy Mix

According to the Malaysian Energy Information Hub, at present Malaysia relies heavily on non-renewable energy sources for power generation. From the chart below sources from their database, in the years 2005-2010 in Figure 2-5, natural gas is the primary source of energy followed by crude oil and coal.

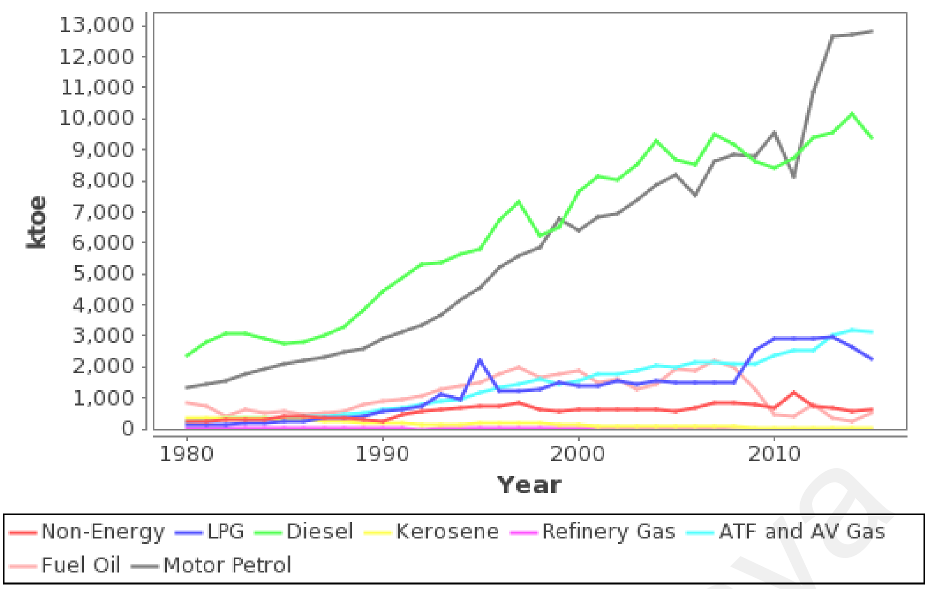


**Figure 2-5: Malaysia Energy Information Hub**

This represents a huge issue for Malaysia. Analyzing the chart provided, non-renewable energy currently dominates the energy usage in this country, while more viable options such as hydropower and biodiesel form a rather meagre sum in comparison with the other major players.

## 2.3 Building Energy Consumption

Figure 2-6 shows that the world energy usage from buildings had been increasing at a rate from 20% to 40% for the past decades and contributed about one third of the greenhouse gas release (Li, et al., 2009). As mentioned above, the case of China which double its energy usage at only 20 years had shocked the world because it came along a lot of consequences. In Figure 2-7, these facts prove that it is a cost-effective store to promote energy efficiency in the building as it is the most practical way to reduce energy usage and carbon dioxide release. Not only that, that will be large saving potential in the economy as outcome from the past studied from many studies on the similar research topic. For example, one of the past researcher have shown that separation of roof establishes the most superiority at closely € 5000 economic benefit during 30 years among various energy saving events for most of the building types (Swan & Ugursal, 2009).

Forecast and cataloguing of energy ingesting in building, as the essential methods communicating to energy efficiency, are meaningfully necessary with the purpose to advance building performance, decrease environmental effect, and estimate economical possible for further energy preservation and renewable energy system. Building energy usage has been primarily analyzed by significant amount of studies during the entire building lifecycle, with different emphases on classifying the sub-component energy use at countless building levels or measuring energy presentation in a comprehensive analysis. This complete set of studies on different levels could assistance us not only optimize the energy use of a particular building through appropriate retrofit or inclusion of state-of-the-art renewable energy technologies, but also discover probable energy lessening opportunities and create better urban-sustainability approaches.

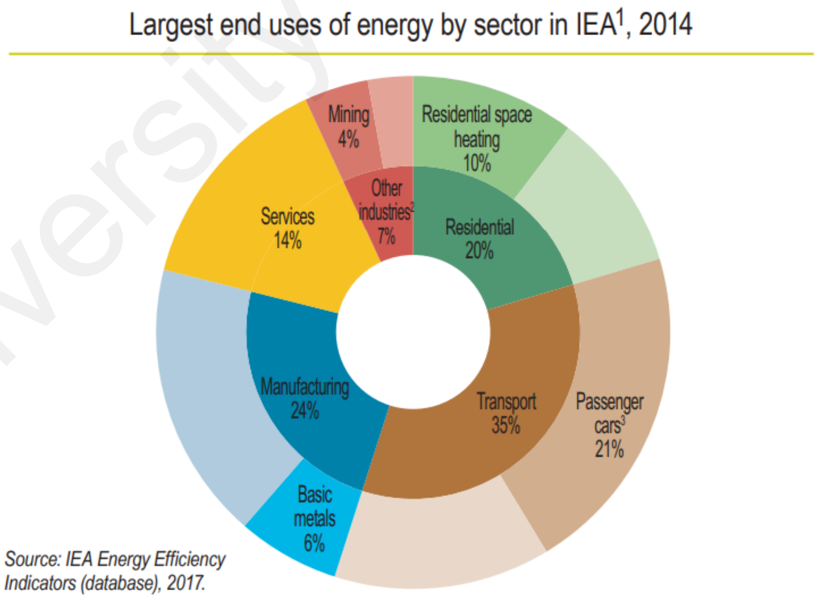


**Figure 2-6: Uses of Energy by Sector in IEA**

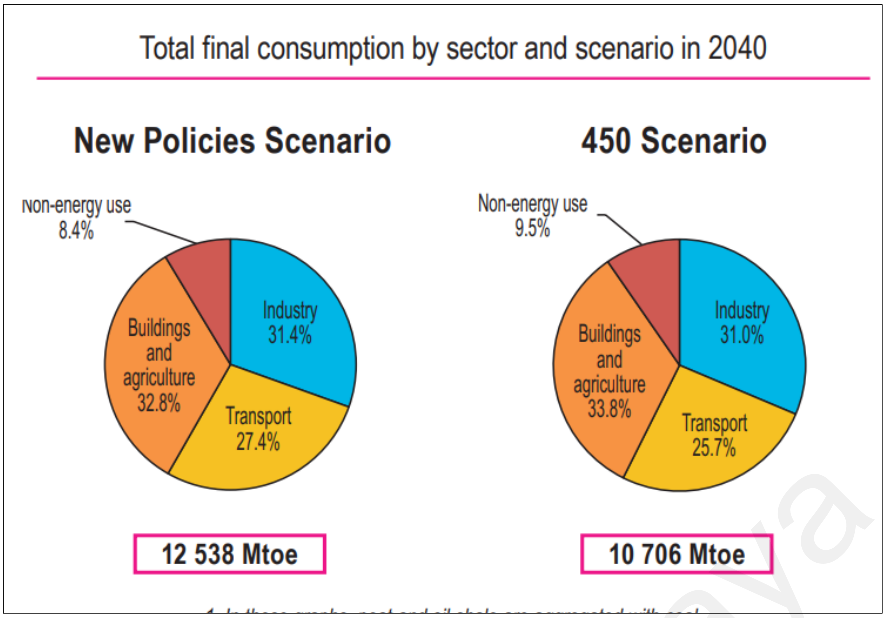


**Figure 2-7: Total Final Consumption by Sector**

### 2.3.1 Building Energy Consumption by Sector

Usage of energy had increased in the commercial sector for the last ten years. In profitable buildings, the yearly energy usage per square meter of the floor area is in excess of 200 kWh. Among all the, air conditioning and lighting appliances are the two most energy used appliances in a building. Rise in building energy usage is driven mostly by the growing of population, houses, and economic activities floor space, which are predictable to rise by nearly 30% by 2035 (Fokaides, et al., 2011).

In order to maintain the thermo comfort level of the occupants, HVAC systems, lighting systems, electric motors are the largest energy usage of appliances in a building. Unconditional classification of energy usage by machine like space heating, chilling, cooking, for both residential and commercial buildings is illustrated in Figure 2-8. From the figure it shows that the biggest four sector of building energy consumer are space heating, lighting, space cooling, and water heating, noted that these consumed around 60% of building energy consumption. Besides that, other sector likes electronics device, kitchen appliances, and ventilation, made up the remaining 40% (Ge, et al., 2018). Energy efficiency and conservation procedures critically should be considered for reduction of the energy requirements especially in big developing nations like China and India. This is because conservation can help to achieve sustainability of energy resources to make sure energy supply is secure therefore ensuring a more productive use of existing resources. It also brings more efficient energy usage and at the same time maintain the thermo comfort levels. Researches had been done and found out a number of approach to reduce electricity consumption therefore upsurge energy efficiency in building. It is projected that original structures can decrease energy usage by around half of the original consumption through proper design and alternatives within the building envelope, HVAC, lighting, water boiling, chilling and office equipments and control systems, (Basrawi, et al., 2013).

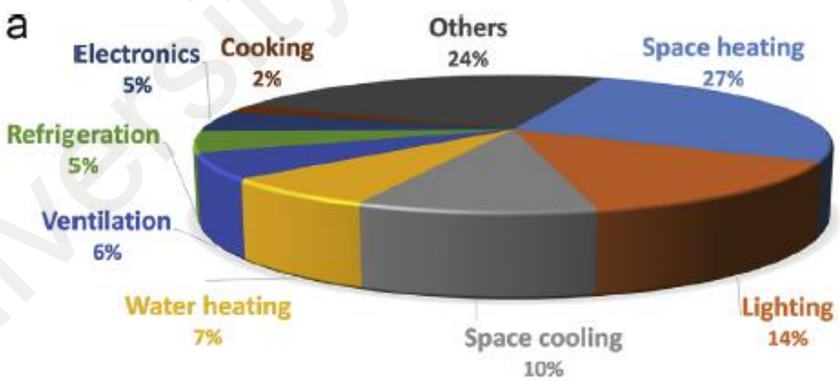


**Figure 2-8: Building Energy Consumption by End Uses**

The energy usage of a building is affected by many factors, for instance are weather conditions, especially the dry-bulb temperature. It also affected by the building construction and thermal property of the construction materials used, the occupant size and their activities, thermos comfort appliances such as lighting, HVAC systems, their presentation and schedules (Saidur, 2009). Due to the complexity of the issue, exact consumption prediction is rather tough. Recently, a big number of methods to prediction, either intricate or simplified, have been planned and functional to a comprehensive range of problems. The researches have been carried out in the term of building design, operation and maintenance, in order to predict the building energy usage

### 2.3.2 Heating, Ventilation and Air Conditioning System

The explosion of large energy consumption and carbon dioxide in the building environment has cause energy efficiency and savings strategies become the major concern In energy policies for most of the countries (Kwok & Lee, 2011). A clear sample is that European Energy Performance of Buildings Directive (EPBD). Among all the sectors, the most important has been contributed a lot to energy consumption is HVAC systems, which is the most important things in order to meet the need for thermal comfort. It is the largest energy consumption sector in a building, both in the residential and commercial sector, which including of heating, ventilation and air conditioning.

Its majority is clear when it is compared with another end uses. For instance, Table 1 shows that it signifies about half the energy consumption more than that for heating of domestic hot water. For residential buildings, it is estimated HVAC consumed energy of around 42-68%.

**Table 1: Energy Consumption by End Uses in Residential Building**

| Energy consumption by end uses in the residential sector | | | | |
|---|---|---|---|---|
| End uses in the residential sector (%) | Spain | UE | USA | UK |
| Space conditioning | 42 | 68 | 53 | 62 |
| Domestic hot water (DHW) | 26 | 14 | 17 | 22 |
| Lighting and appliances | 32 | 18 | 30 | 16 |

At Europe itself, the percentage of HVAC is dominant, where many sources indicates that there is significant increase in the use of air conditioning, especially in southern countries (Spain and Italy) accounts for more than 50% of the Europe countries, making serious supply difficulties during peak load phases (Kardooni, et al., 2018).

In European countries, from the information collected it shows that regional or local levels is insufficient to efficiently plan future energy policies for buildings. It is hard to coordinate methods to address all the end usage of energy. Analysis by sectors made by EIA for residential and commercial buildings are being supported by local authorities so that a comprehensive database of the building stock (type, area, location and age) and energy parameters (consumption, expenditures, fuels, type of usage) could be act as reference for future measure to impose energy efficiency (Chang, et al., 2011).

In a bigger picture, HVAC consumption in developed countries accounts for half the energy use in buildings and one fifth of the total national energy use. Not only that, predictions show that there will be a big growth of energy consumption and conditioned area in the world for the coming 15 years, which will caused the usage of energy at least by half (Defiana & Erwindi, 2015).

### 2.3.3 Lighting Systems

Lighting systems is considered as a significant component of energy consumption for commercial and residential buildings (Zhao & Magoulès, 2012). For example, lighting systems had consumed of around 30% of the electricity in fully air-conditioned building and up to 50% for a non-air-conditioned building. On the other hand, hospitals consumed of about 25% of the total energy just for building lighting. As for now, the power of lighting in a typical building varies from 18–25 W/$m^2$. In current days, lighting systems not only considered for a small portion of the building energy consumption but considered as space load because they dispel significant amount of heat during their operation. Not to mention the heat dissipation can will warm the building environment. Therefore, in cold country, some researchers proposed to use it to recover for cold climatic inhouse condition. IES recommends illuminance levels for visual tasks and surrounding lighted areas. The energy used up by a lighting installation depends upon the power consumption of the luminaries and the total of time for which they are active. Both of these characteristics are significant, as any variables of these will affect the energy efficiency. Data about the consumption of energy of an existing or proposed lightings systems are important so that the option for lighting design will meet cost-effectiveness as measures to improve its energy efficiency (G. S. B. Ganandran, 2014).

### 2.3.4 Nature of Building

The nature of buildings and activities make a huge variant on the building energy consumption. From total energy being used, about 18% of the energy will be determined by its building nature and the activities of the occupants. In most of the developed countries, they found that for 30% of the total energy is used in commercial building while for the rest kind of buildings types take the rest (Mahlia, et al., 2005). Therefore, it is advisable to start the analysis on the topic proposed with the commercial buildings due to its significance of energy usage proportion.

### 2.3.5 Climate

According to English Encarta dictionary, climate is defined as a typical weather in a region. Malaysian Meteorological Department (MMD) had categorized Malaysia weather as high humidity, exacting temperature and plentiful rainfall. In Malaysia, it is very infrequent to have an ample day with complete clear sky even during time of dry weather. It is uncommon to have a rare day without sunlight (Pan, et al., 2018).

Malaysia is located in between latitude 4o 12’ N / 101o 58’ E. This makes Malaysia 8 hours ahead of Greenwich Mean Time. Since the location of its latitude and longitude, it has a difference in temperature ranging from 31°C in the day time, to 21°C after night, with only small change in temperature in all places of the nation. Some investigations showed that ambient temperature plays an important role in energy consumption study especially due to the air conditioning system (Oh, et al., 2018).

Researcher claimed that Malaysia is blessed naturally with sufficient sunlight and high solar radiation. Malaysia having about 6 hours of sunlight in a day, with a daily solar radiation range from 14.90 Mjm-2 to 22 Mjm-2 on an average day during the dry seasons.

Since Malaysia is located in hot-humid tropical region with less powerful wind speeds, it causes low variation of indoor air speed. Air speed within buildings only in between 0.04 m/s and 0.47 m/s, which is quite inadequate for indoor air movement. In Malaysia the major concern on energy efficiency is attentive with following main sectors, which are transportation, industry plants, residential and office building.

Malaysia experienced high humidity and hot climate throughout the year. For occupants to survive this harsh climatic condition, Malaysian traditional houses were used for residential purposes. These houses were popularly known as the Malay house. These houses were built with lightweight materials such as wood and thatches. In addition, very wide openings of windows are made for proper natural ventilation. Nowadays, Malay traditional houses are hardly seen in city areas due to technological advancement. However, many of these building types are still in existence in the rural areas. Majority of the modern houses in Malaysian towns and city areas today are concrete and brick houses.

In Malaysia, buildings are built as clusters, condominium and terraced types with insufficient of air ventilation. Due to this, occupants will need air conditioner to meet their thermo comfort. The major problem of this is that the sustainable development should be well-organized in terms of energy usage, energy wastage lessening and promoting the application of renewable energy.

Malaysia experienced a rapid economic boost and technological growth and development. Subsequently the amount of energy usage has been increased. A research directed by Centre for Environment Technology and Development of Malaysia (CETDEM) designated that air conditions and cooling devices take up to nearly 70% of the total building energy usage. Air conditioner is the largest primary device of energy usage in Malaysian buildings. The economic growth of any country is restrained by Gross Domestic Product. Malaysian GDP is in correlation with the amount of energy consumption within country (Foucquier, et al., 2013).

## 2.4 Green Building

Malaysia has experienced more than 50 years of rapid industrialization, with 5 – 9% annual GDP growth. Along with the exciting GDP growth, there is come with the significant amount of carbon emission due to the industrialization. Thoughtlessly, the progress procedure of the nation is never been sustainable so there is urge for a comprehensive sustainable approach in terms of energy usage (Chlela, et al., 2009). The building energy efficiency is definitely aa major sector towards sustainable energy in order to save the environment. Malaysia authorities has documented the possible benefits and worth of building energy efficiency approaches. These effective measurements are made to ensure economic and environmental sustainability in connection with energy especially in the buildings sector.

Along with that, Malaysia authorities had lead the nation in the energy efficiency actions through setting up of the energy efficient plans and green buildings. These buildings serve as milestone missions to inspire more energy efficient and green buildings to be built in the nation by the private sector. Example of green buildings in Malaysia is Low energy office (LEO), Green tech Malaysia building and Diamond building, which consumes only less than 30% of energy a normal building will take. To encourage the approach, other countries had been introducing policy and index to evaluate the green building since about 20 years ago like "Green Star" in Australia and "Green Mark" in Singapore. Therefore, Malaysia also introduced "Green Building Index" in 2009 to support building energy efficiency in the country.

## 2.5 Building Energy Optimization Method

### 2.5.1 Set-point Temperature

The conservative building heating and cooling load estimation approach is based on the constant design room temperature, which is 18°C in the hot season and 25°C in cold season at a day. Problem from this method is that the building load is different from time to time therefore a fixed temperature design point cannot actually suit for all load for a whole day, which will then results in energy waste. Therefore, the set-point room temperature method was planned to optimize the design load and energy usage for the building energy design especially on the cooling and heating (Fumo, 2014).

It is a energy efficiency method that is based on the exact features of the energy usage of building sets can meaningfully decrease the total energy use and peak load. These specifies that by using this method, the total energy consumption in a building can be significantly reduced and following by the reduction of cost of the HVAC systems. Past researches shows that in respect of load peak cutting, the peak load having two different types and each groups happens at different times, by which the peak load cutting can be achieved, and the total building energy load can be concentrated to save the initial investment.

Past researcher from Shanghai had simulates the energy usage in the campus building and result proved that the strategy of set-point temperature optimization could efficiently reduce the design load and energy consumption of campus building groups.

### 2.5.2 Climate-Adaptive Energy Saving

In countries that having cold and hot seasons, there are two factors that affect energy consumption within a building. One is the high demand for cooling and heating, especially the cooling requirement in a hot weather, another is the irregular energy application, which lies on the occupancy of the building. Climate adaptive is a technical approach to the building which is based on the continuous energy use mode, which needs to be optimized to fit in with local climate characteristics and energy consumption behaviors. For instant, energy saving plans in Shanghai had apply the outer window shading coefficient, the air-tightness of the windows and doors, and the heat transfer performance index of the building, as well as the thermal insulation mode of building's exterior wall (Tong & Zhao, 2013).

There are three noteworthy composes for picked, for example, inside warm protection, outer warm protection and empty protected, in past examinations, the topographies of various warmth conservation method of outside dividers have been talked about a considerable measure. Outer divider protection notices to the innovation of warm protection on the outside surface of one divider, and this compose keeps up indoor temperature to become constant.

By selecting appropriate insulation material and adjusting the thickness of the wall, the purpose of saving energy and heat preservation can be achieved.

## 2.6 Building Energy Simulation

Building Energy Model is a simulation tool which computes the energy and thermal load used inside a building. Building energy software are used in retrofitting of the existing structures based on the building style and HVAC system as well as designing of new buildings. Today, building energy simulation software can help to estimate the right construction resources and thermal design to be implemented within a building. It also specifies unique energy saving methods like advanced window treatment for sun shading as well as energy renewable system (Daniel, et al., 2014).

Two parameters need to be considered while developing building energy model (Wang & Srinivasan, 2017). The first one is the building as a structure. The second one is the occupants that utilize the building and their corresponding activities. These parameters related to building should include the architectural layout, the materials used in building and HVAC gear used in the buildings

### 2.6.1 Simulation Software

Building energy simulation modelling software enable the comprehensive calculation of the energy compulsory to maintain specified building performance loading which are the zone temperature and zone humidity, under the effect of external contributions such as weather, occupant and activities (Ruiz & Romero, 2011). Point by point heat-balance calculations are carried out at discrete time-steps based on the physical properties of the building and mechanical frameworks as well as these energetic outside inputs (climate, inhabitance, lighting, hardware loads etc.). These calculations are by and large performed over the course of a full year period (Harish & ArunKumar, 2016).

#### 2.6.1.1 DOE-2

DOE-2 is a open source software to perform building energy simulation. It provide the hourly energy consumed and energy costing of the building. It requires the input such as climate data, a building geometric and HVAC representation, and electricity rate assembly. It is founded and continuously funded by the U.S. Branch of Energy (DOE), thus the taken after name of the department: DOE.

#### 2.6.1.2 EnergyPlus

EnergyPlus is a progressive building energy simulation software, it is created by the departments which also created DOE-2 (Han, et al., 2015). It joins the similar functionality as DOE-2, creating hourly energy prices of the building with same required input like weather and occupant. It also includes many progressive structures not obtainable in DOE-2, such as multiple zone airflow and wide HVAC requirement competences.

EnergyPlus simulation software purposes to grow and establish software tools which are easily workable and access by public (Crawleya, et al., 2001). It is vital to summary EnergyPlus did not happen to have a graphic interface that permit users to see the building. Because of this third-party software like Sketch Up essential to be utilizes. EnergyPlus is a thermal simulation software tool that lets the analysis of energy within building and the heating and cooling load. It is usually utilized by engineers, architects and researchers to simulate the energy consumption within the buildings.

#### 2.6.1.3 TRNSYS

It is a fleeting simulation software with a linked structure which gears a component-based simulation approach (Beausoleil-Morrison, et al., 2012). Mechanisms perhaps simple systems such as pumps or fans, or complex system like buildings which having more than one thermal zone. This program could be perform in period of the time from minimum intervals of 15 minutes. The plug in available with this software could link the model to more thermal zone, enable the usage of other buildings system such as HVAC, hydrogen system, chilled water and solar collector. It also permits the formation of altering the climate information and other info by altering the simulation outputs (Beausoleil-Morrison, et al., 2014). The mechanisms can be collective among numerous users without consuming to recompile the program thanks to the utilization of DLL expertise. Not only that, this energy simulation program also enables user to join other plug in software such as Matlab and Excel (Daniel, et al., 2014).

#### 2.6.1.4 IDA ICE

IDA ICE (IDA Indoor Climate Energy) is a building energy simulation software that is widely used in construction industry. The program is based on a universal system simulation platform with a segmental system (Soleimani-Mohseni, et al., 2016). The model of thermal zone and other thermal systems are defined in the software using symbolic equations starting with a simulation language Neutral Model Format. In order to utilize the software, user have to describes the acceptances which regulator the correctness of the simulation results, then permitting the separation of arithmetical modeling methods. This software has are having more advantages in the industry. Firstly it could be paired with other plug in so that building modelled could be built in a more accurate way. Besides, the scientific model can be reviewed to examine the variables, limitations and calculations and the investigation replicas are simply achieved (Hilliaho, et al., 2015).

## 2.7 Summary

To conclude this chapter, first the scenario world current energy consumption was discussed as well as the energy consumption in the country. It was found that building averagely took up to 40% of the total energy consumption. Among the end uses within a building, air conditioning is the most energy consuming compared to other end uses likes lighting, ventilation and indoor appliances. Optimization methods of building energy consumption are discussed in this chapter. Building energy simulation software available in the market are also being discussed. Next chapter of the report would present the methodology of the research to fulfill the project scope.

# CHAPTER 3: METHODOLOGY

This research will be conducted mainly using the energy simulation software. First building chosen as case study will undergone energy analysis. After that improvement for energy optimization will be suggested. The approaches for energy optimization will be evaluated using the same software. The result will show the outcome of these energy optimization approaches and determine the validity of these approaches. In a nutshell, the methodology of the research containing the following:

1. Choice of Building
2. Building Characterization
3. Building Modeling
4. Energy Simulation of the Case Study
5. Energy optimization strategy and dynamic simulation
6. Result Analysis

The single campus building model which are having same function as office building model were established according to the national design standard. Besides, the energy consumption simulation result of the target building models was compared with the actual result which obtained from the data manually, and then the simulation parameter will be used for further prediction analysis as shown in Figure 3-1.

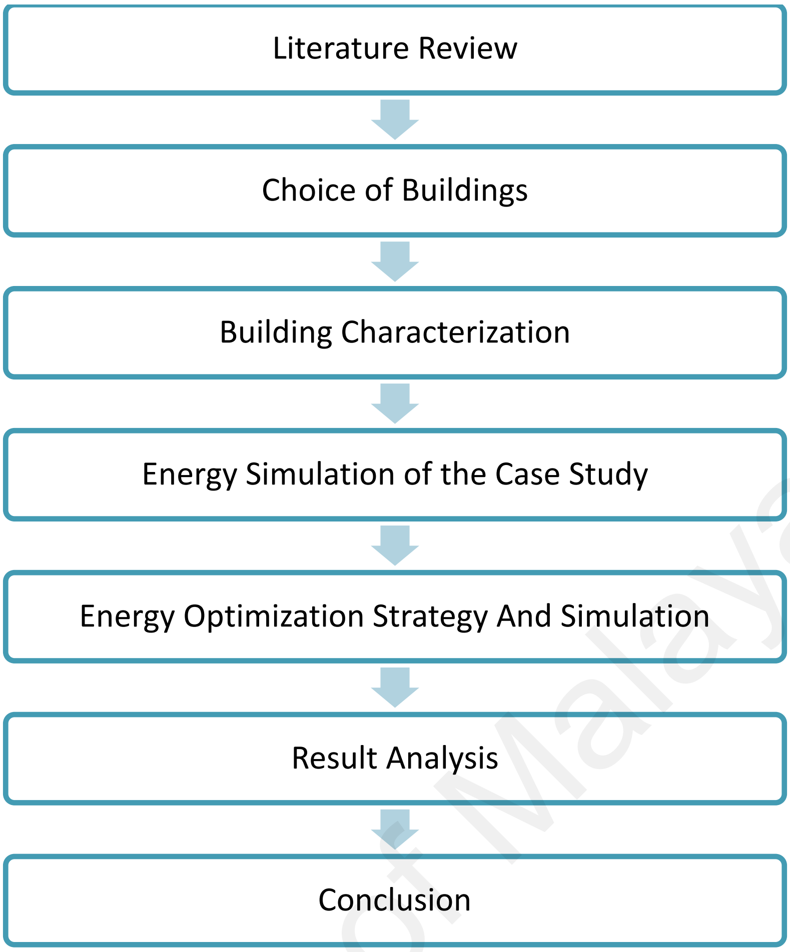


**Figure 3-1: Workflow of Research Project**

## 3.1 Choice of Building

As discussed in previous chapter, type of building is a very important factor that affect the total amount of energy consumed in a building. Also, we know that campus building is one type of building that is highly energy consuming due to its activities likes machine, labs, and research. Therefore, in this research, focus will be one of the block building in Faculty of Engineering, University of Malaya as shown in Figure 3-2 ,so that we can further determine the outcome of the research project.

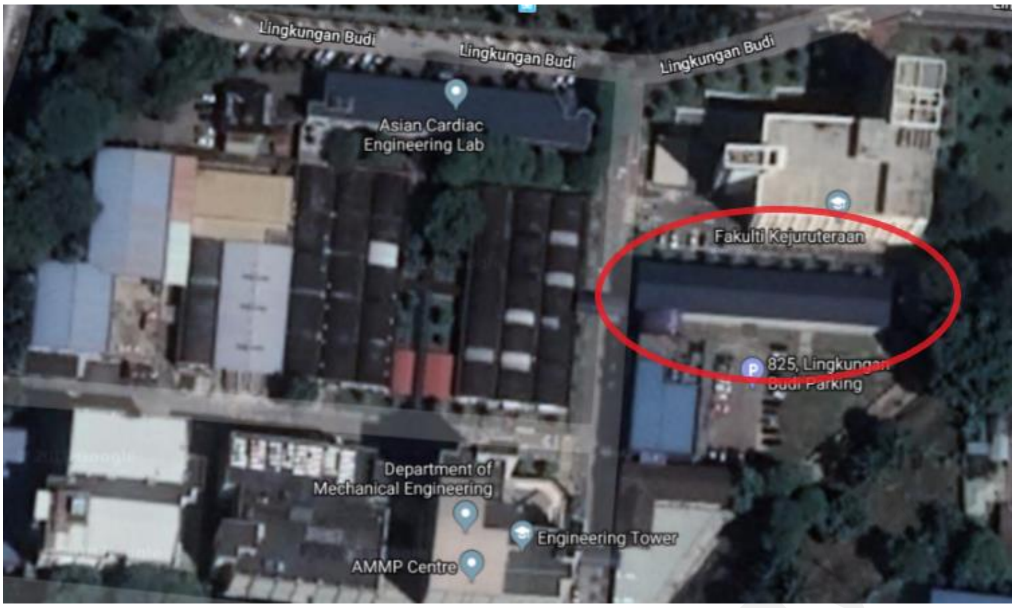


**Figure 3-2: Location of Target Building**

The campus buildings were simplified as office public buildings due to their activities and time of usage. Choice of building is vital to make sure the analysis of the research is appropriate. The prototype building was mainly used for lecture teaching for engineering student including weekdays for undergraduate students and weekends for postgraduate students. In this research, it is to monitoring the building activities likes weekly timing or daily agenda in order to schedule all energy consumption and reduce energy waste while maintaining the occupants comfortable level.

## 3.2 Building Modelling

The building used as prototype in the research is Block D, Faculty of Engineering, University of Malaya. The building model was created to serve as the criterion for determination of the average energy consumption of teaching buildings in the campus. It is a 3-storey high building with all floors are utilized and fully equip with HVAC system.

It is facing south with total construction area is 447m$^2$ and height of 3.2m. The floor plans that show the configuration of the building are as illustrated in Figure 3-3 to Figure 3-5.

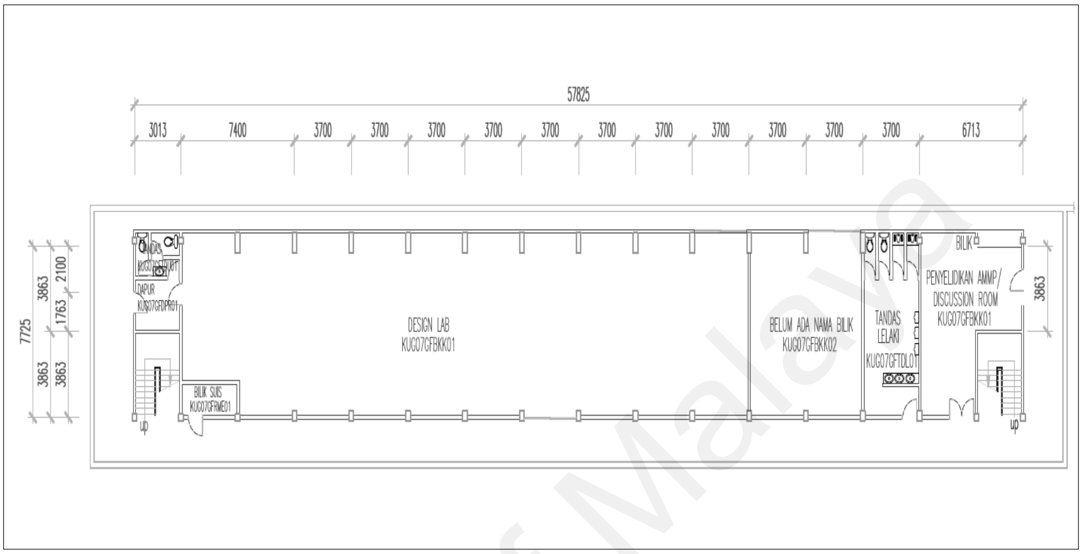


**Figure 3-3: Block D Floor Plan (Ground)**

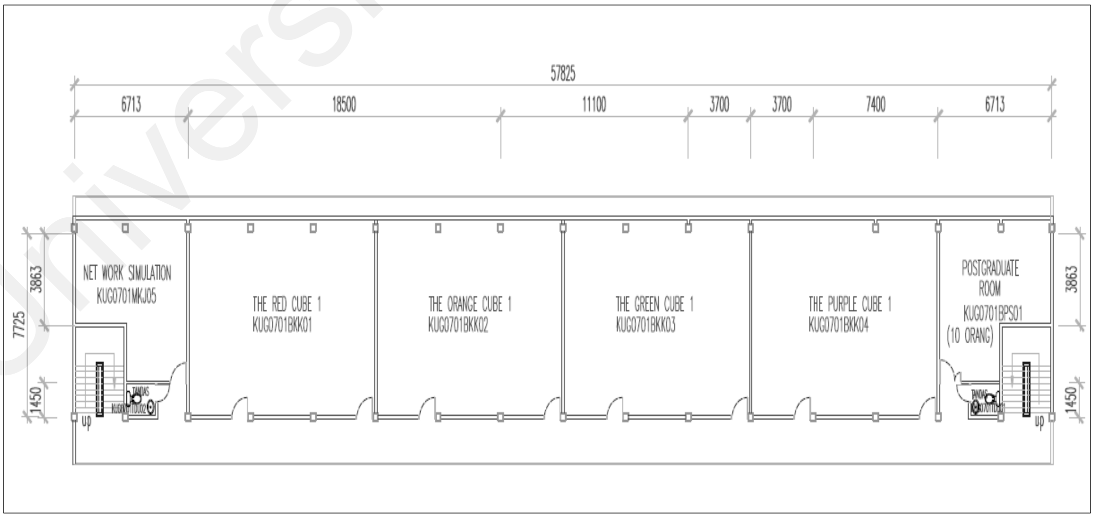


**Figure 3-4: Block D Floor Plan (First Floor)**

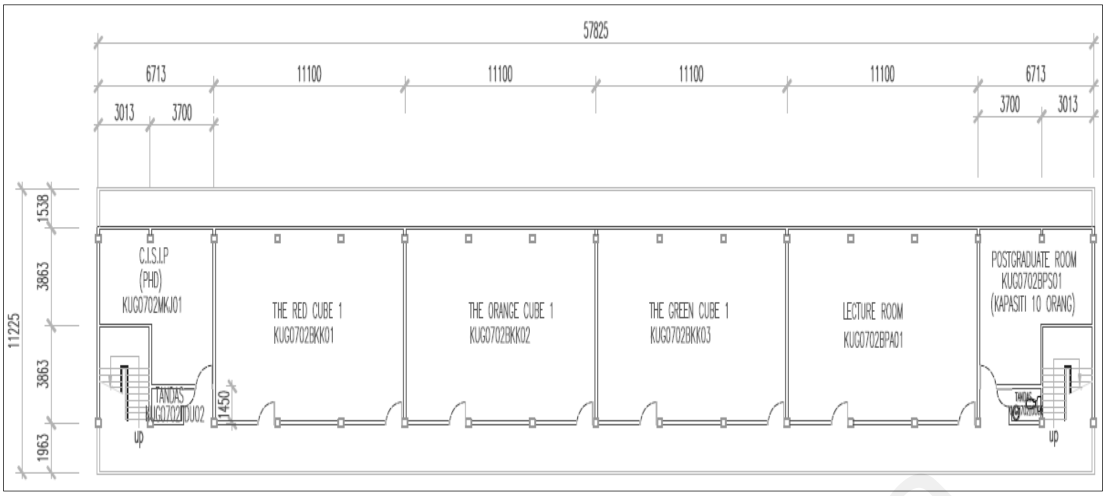


**Figure 3-5: Block D Floor Plan (Second Floor)**

The building needed to be modelled in 3D modelling software before it could be used in the energy simulation software. The 3D modeling used in this project is SketchUp. It is a 3D modeling computer program for a wide range of drawing applications such as architectural, interior design, landscape architecture, civil and mechanical engineering, film and video game design. For thermal simulation, it needed to be paired with OpenStudio plug-in to define the constraints and establish the thermal zones.

As selected simulation software is EnergyPlus 8.9.0, according to Figure 3-6 below, the version of SketchUp chosen is 2017 version and paired with OpenStudion version 2.5.2. The simplified target building was modelled show in Figure 3-7 and Figure 3-8.

| | E+ | Radiance | SketchUp | Ruby | SHA | Released | Gemfile |
|---|---|---|---|---|---|---|---|
| v2.5.2 | 8.9.0 | 5.0.a.12 | 2017 | 2.2.4 | a5af93e7ed | 2018-06-18 | Gemfile |
| v2.5.1 | 8.9.0 | 5.0.a.12 | 2017 | 2.2.4 | 4f268e2854 | 2018-05-02 | Gemfile |
| v2.5.0 | 8.9.0 | 5.0.a.12 | 2017 | 2.2.4 | 366cbe0e3a | 2018-03-30 | Gemfile |
| v2.4.3 | 8.9.0 | 5.0.a.12 | 2017 | 2.2.4 | 29a61f6637 | 2018-03-07 | Gemfile |
| v2.4.1 | 8.8.0 | 5.0.a.12 | 2017 | 2.2.4 | fcd9a4317a | 2018-02-02 | Gemfile |
| v2.4.0 | 8.8.0 | 5.0.a.12 | 2017 | 2.2.4 | f58a3e1808 | 2017-12-12 | Gemfile |
| v2.3.1 | 8.8.0 | 5.0.a.12 | 2017 | 2.2.4 | 9b0fc45840 | 2017-12-04 | Gemfile |
| v2.3.0 | 8.8.0 | 5.0.a.12 | 2017 | 2.2.4 | cf58ee1e38 | 2017-09-29 | Gemfile |

**Figure 3-6: OpenStudio Version Compatibility Matrix**

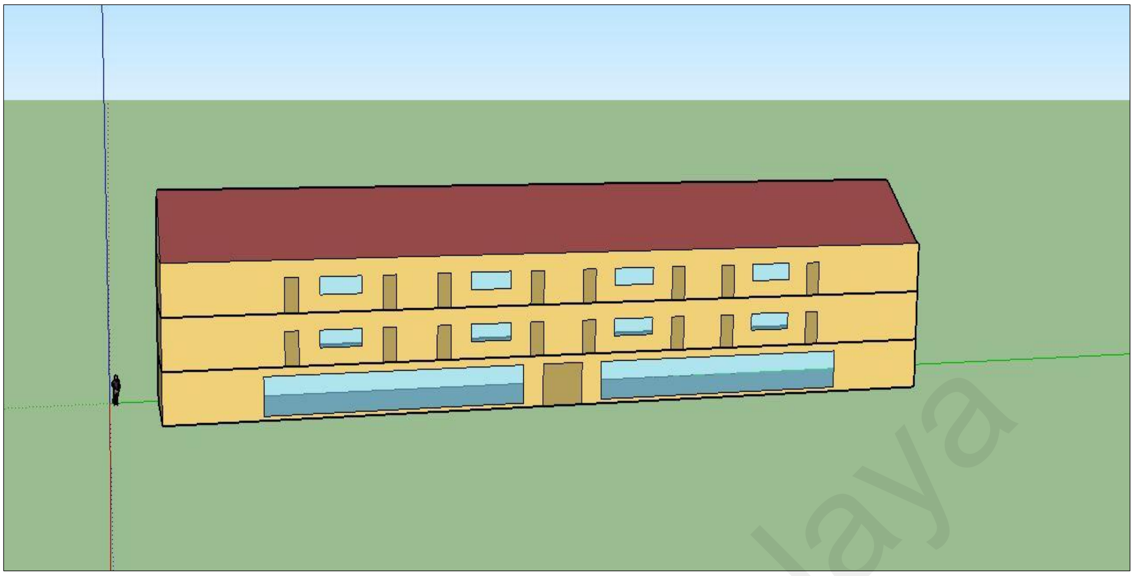

**Figure 3-7: Front of Modelled Building**

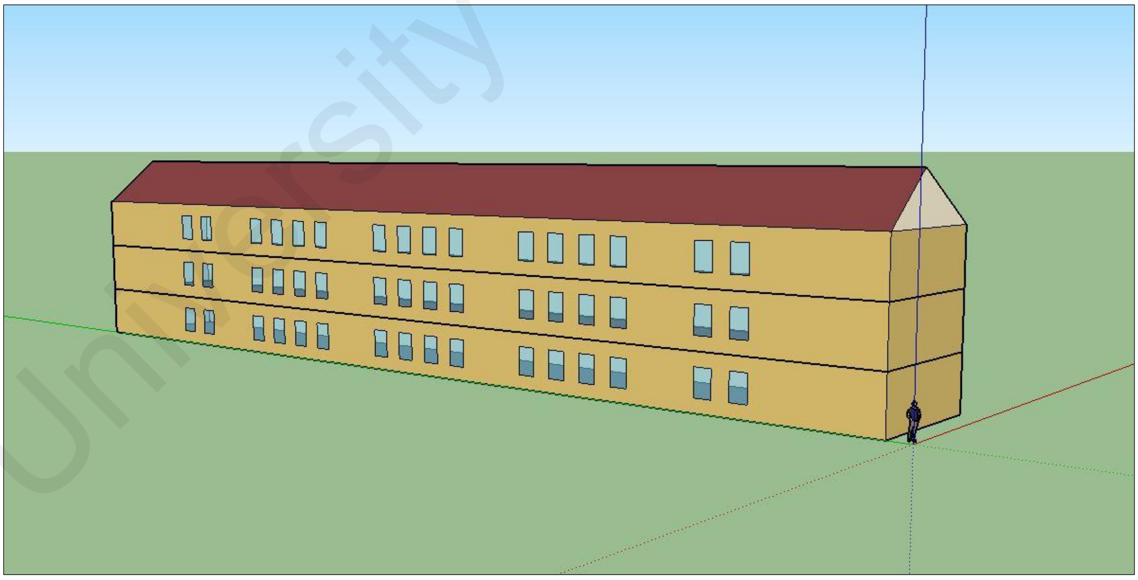

**Figure 3-8: Back of Modelled Building**

## 3.3 Energy Simulation of Case Study

Energy simulation is done using EnergyPlus software. First is to simulate the energy consumption of the target building based on the information collected. Then the result obtained will be compared with the actual data collected to test how accuracy of the simulation is.

### 3.3.1 Settings Up Parameters

In order to make the simulation more accurate and appropriate, there are some parameters that are needed to be concern.

#### 3.3.1.1 Weather

Since the target building is located in Kuala Lumpur, therefore the weather information used for the simulation chosen is Kuala Lumpur – Southwest Pacific region 5. The weather data is collected from International Weather for Energy Calculations (IWEC). The IWEC is one of the ASHRAE project to determine the weather information. The IWEC information files are the weather files suitable for use with building energy simulation programs for more than 200 sites around the world. The weather information of Kuala Lumpur is obtained from the site and being converted in EnergyPlus format.

#### 3.3.1.2 Building Structure Material

The thermal performance parameters for the structure material of the target building model were selected according to European Design Standard for Commercial Buildings (Rosa, et al., 2014).

The settings of the space enclosing structure materials and thermal performance parameters are listed in Table 2.

**Table 2: Parameter Settings of Simulation**

| Building Envelope | Materials | Thickness (mm) | R($m^2$°$CW^{-1}$) | K ($Wm^{-2}$°$C^{-1}$) |
|---|---|---|---|---|
| **Exterior wall** | Lime mortar/ Polystyrene/Concrete blocks/ Cement plaster | 330 | 2.47 | 0.40 |
| **Roof** | Cement plaster/ Lime mortar/ Cement plaster/ Polystyrene/ Concrete blocks | 245 | 2.21 | 0.45 |
| **Floor** | Compacted clay/ Crushed stone concrete/ Cement plaster | 420 | 0.35 | 1.98 |
| **Exterior window** | Glass/ Air/ Polystyrene | 28 | 0.40 | 2.50 |

#### 3.3.1.3 Occupants Activities

As mentioned in the previous chapter, campus building is considered as office building by most of the researchers. Therefore, in this research, target building activities is treated same as typical office building where the time schedule for activities in the building is 9 hours per day from 8am to 5 pm. During this period, lighting system and office equipment will be considered in use for energy simulation. Also, in the simulation, the building is treated as fully air-conditioned for the whole building during this hour, the indoor temperature is always maintained at 24 ℃ for the same period.

### 3.4 Energy Optimization Strategies

As mentioned, this research will have proposed two approaches in terms of thermal design in order to reduce the energy consumption within the buildings. The approaches were analyzed using same simulation software to determine their feasibility.

#### 3.4.1 Set-Point Temperature

Air conditioning had taken up large portion total energy consumption especially is tropical country like Malaysia. Therefore, air-conditioners were wide utilized in the building to achieve the comfortability by maintaining a low indoor air temperature. Under this strategy, the indoor temperature was raised up 2 ˚C to 26 ˚C which to study the effect of temperature rise to the building energy consumption. Simulation result obtained will show the potential energy saving by this approach.

#### 3.4.2 Application of Tinted Film on Window

Target building consist of large area of window. This will cause sunlight directly go through the windows and then warms the indoor air temperature (Molin, et al., 2011). In this approach, all the glass window in Block D will be applied with a tinted film with purpose to reduce direct sunlight from outside and thus achieve the energy efficiency. Simulation result obtained will show the potential energy saving by this approach.

### 3.5 Summary

This chapter have discussed the project methodology to achieve the research scope. Firstly, Block D was chosen as the target building in this research then being modelled using the software SketchUp. The model was then exported to EnergyPlus to be simulated in order to analyze the building energy consumption. Two building energy optimization approaches were utilized namely set-point temperature and window tinting. The results of building energy simulation before and after optimization were being presented and discussed in the next chapter.

# CHAPTER 4: ESULT AND DISCUSSION

## 4.1 Analysis of Building Energy Consumption

Before any energy optimization strategies, overall energy consumed by the building was analyzed using both actual data and simulation results. The total energy consumption was taken under consideration of the period of one year. The annual energy consumption of the building is the compared in terms of actual and simulation results.

### 4.1.1 Actual Data Collected

The data of total annual energy consumed by target building was obtained from the Electrical Department, Department of Development and Asset Maintenance, University of Malaya (JPPHP). Data showing that the total energy consumed by Faculty of Engineering is 6144567 kWh or RM3125986.20 in terms of electricity bill for year 2017. For Block D alone, it consumed 135050 kWh, which is about 2.20% of total energy consumed by the faculty.

### 4.1.2 Simulation Result

From simulation result as showed in Table 3, it is found that the total energy consumed by the target building annually is 142877.70 kWh or 106.64 kWh/m$^2$ per building area. Among all the end uses in Figure 4-1, it is found out that equipment are consuming the most amount of energy which is 48579.13 kWh annually or 34% of the total energy. This phenomenon is in align with the nature of campus building having more numbers of equipment for lecturing purposes such as computers, projectors, and other multimedia learning equipment. From Table 4 also it showed that lighting system consumed about 46191.26 kWh of energy or 32.3% of total energy. This result fulfills the outcomes of the past research that lightings is taking approximately one third of the total energy consumed by a building. Besides, HVAC systems (for cooling purpose) consumed 46929.27 kWh of energy in a year or 32.85% of the total energy. This showed that air-conditioning having a big energy saving potential where lighting and equipment are essential for a campus building while air conditioning level could be adjusted promising the thermal comfort is ensured within the building.

However, comparing this result with the actual energy, the result of total energy consumed from simulation having a minor differ from the actual data collected. The difference is 7827.7kWh or 5.48%. The difference mainly is due to the lacks accurate during the building modelling where some area inside the building may not using any energy for instance like the staircase room. Also, the inconsistency of the occupant in the target building may also affect the accuracy of the simulation results.

**Table 3: Simulation Result for Building Energy Consumption**

| | **Total Energy (kWh)** | **Energy per total Building Area (kWh/m$^2$)** | **Energy Per Conditioned Building Area (kWh/m$^2$)** |
|---|---|---|---|
| **Total Energy** | 142877.70 | 106.64 | 106.64 |
| **Net Energy** | 142877.70 | 106.64 | 106.64 |

**Table 4: Energy Consumption by End Use**

| | Cooling | Lighting | Equipment | Others | Total |
|---|---|---|---|---|---|
| **Electricity (kWh)** | 46929.27 | 46191.26 | 48579.13 | 1178.04 | 142877.70 |

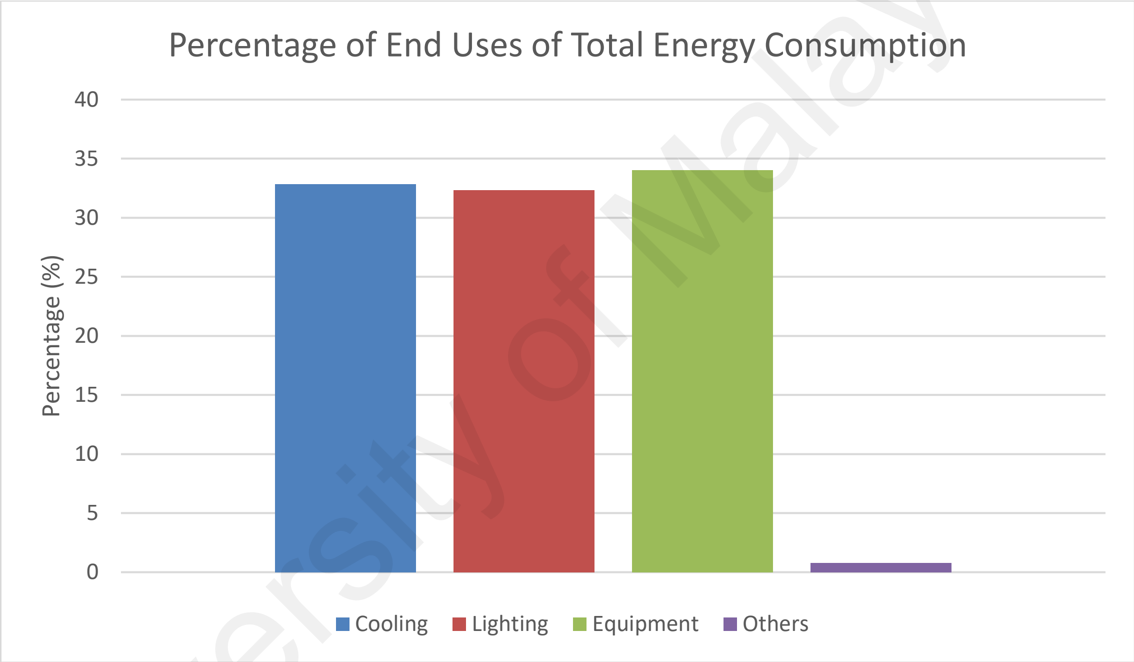


**Figure 4-1: Percentage of End Uses of Total Energy Consumption**

## 4.2 Energy Optimization Strategies

### 4.2.1 Simulation Result for Set-point Temperature

The operating of the air conditioning system should be based on the activities within the buildings at a time. Campus buildings energy consumption are usually affected by the working time of the people in the particular campus. Therefore, there are time where the not all rooms are fully occupied in the buildings. By this, with proper increment of design air temperature during colder weather can effectively reduce the energy consumption by HVAC system in buildings. Therefore, the concept of set-point temperature is proposed, which is setting a different design air temperature during less occupied period (e.g. less lecture class in the late evening) of the building and colder weather. For the ease of simulation and understanding, this project proposed to increase the design air conditioner temperature by 2 ˚C to 26 ˚C and simulation results is obtained as Table 5.

**Table 5: Simulation Result for Set-Point Temperature**

| | Total Energy (kWh) | Energy per total Building Area (kWh/m$^2$) | Energy Per Conditioned Building Area (kWh/m$^2$) |
|---|---|---|---|
| **Total Energy** | 128519.40 | 95.92 | 95.92 |
| **Net Energy** | 128519.40 | 95.92 | 95.92 |

**Table 6: Energy Consumption by End Use for Set-Point Temperature**

| | Cooling | Lighting | Equipment | Others | Total |
|---|---|---|---|---|---|
| **Electricity (kWh)** | 33062.87 | 46191.26 | 48579.13 | 686.14 | 128519.40 |

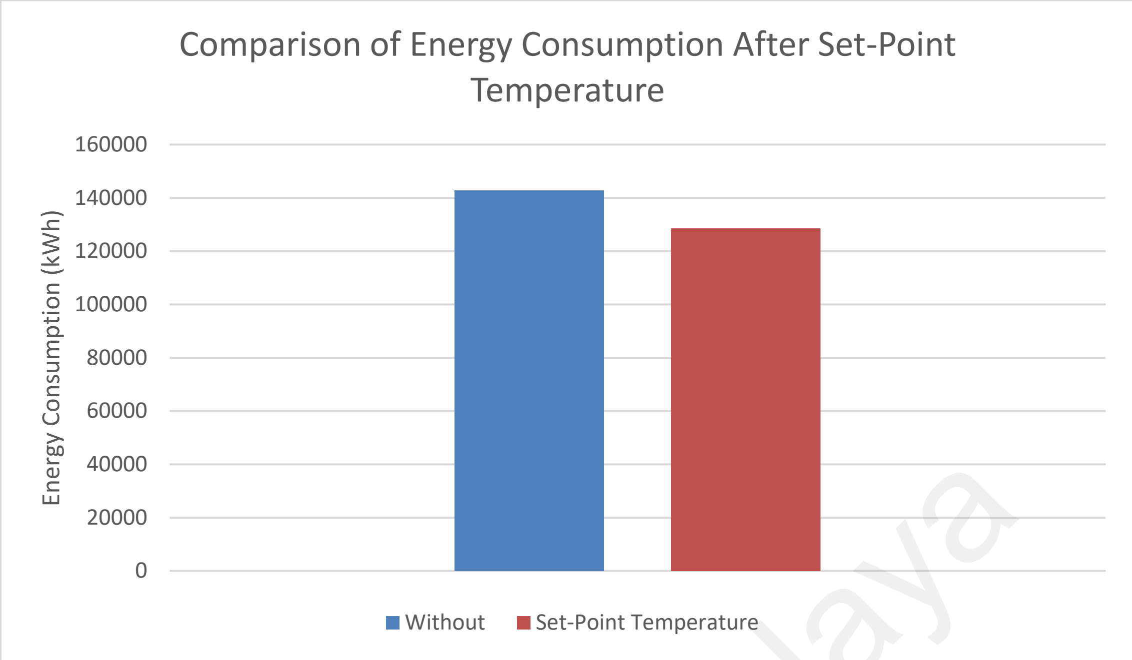


**Figure 4-2: Comparison of Energy Consumption After Optimization (1)**

As from the result, it showed by increasing the air temperature by 2 ˚C, the total annual energy consumed by the target building will become 128519.40 kWh, which is reduced by 14358.3 kWh or 10.05%. Analyzing only the HVAC systems for cooling purpose in Table 6, the energy consumed is reduced from originally 46929.27 kWh to 33062.87 kwh after applying set-point temperature. The reduction in energy consumed is 13866.4 kWh or 29.55% as in Figure 4-2. This result showed that this approached could definitely reduce the energy consumed thus increase the overall energy efficiency in the building. In terms of costing, by applying this approach, the potential saving is about RM7304.64 (10.05%) annually for just a single building. Considering the whole faculty is applying this, the faculty would save a RM365231.98 just to pay for the electricity billing.

### 4.2.2 Simulation Result for Tinted Window

One of the reason that cause the rise in indoor temperature in a building is the direct sunlight that go through the window. Therefore the tint window approach is proposed in this project because the tint films could prevent the sun glare and UV rays from entering the buildings. The tints will deflect light from coming inside which keep the building cooler this reduces energy consumption. The film serves like an insulating system protecting from the staff from extreme temperatures and at the same time saving up on energy and bill expenditures.

The window films is available in variety in the market and do not costly. On top of it, the installation are also very easy and would not cause any disturbance to the environment inside the building. Therefore it is proposed due to it is highly practical and feasible. In this research, tint film proposed is Johnson Window's Film, SUN 70, which has a U factor of 1.01 $w/m^2K$. The simulation results is shown in Table 7 below.

**Table 7: Simulation Result for Window Tinting**

| | Total Energy (kWh) | Energy per total Building Area ($kWh/m^2$) | Energy Per Conditioned Building Area ($kWh/m^2$) |
|---|---|---|---|
| **Total Energy** | 138229.47 | 103.17 | 103.17 |
| **Net Energy** | 138229.47 | 103.17 | 103.17 |

**Table 8: Energy Consumption by End Use for Window Tinting**

| | Cooling | Lighting | Equipment | Others | Total |
|---|---|---|---|---|---|
| **Electricity (kWh)** | 42492.61 | 46191.26 | 48579.13 | 966.47 | 138229.47 |

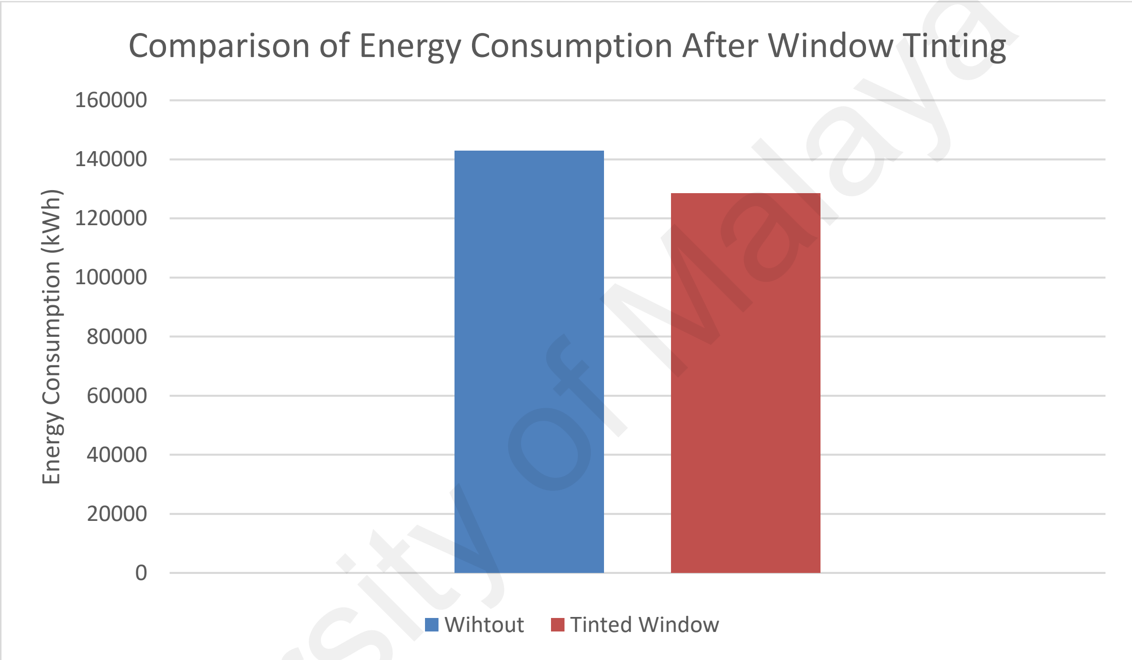


**Figure 4-3: Comparison of Energy Consumption After Optimization (2)**



Result show that the total annual energy consumed by the target building will become 138229.47 kWh, which is reduced by 4648.23 kWh or 3.25% as in Figure 4-3. Analyzing only the HVAC systems for cooling purpose, the energy consumed is reduced from originally 46929.27 kWh to 42492.61 kWh after windows are being tinted. The reduction in energy consumed by HVAC is 4436.66 kWh or 9.45% as shown in Table 8. This result showed that this approached could definitely reduce the energy consumed thus increase the overall energy efficiency in the building. In terms of costing, by applying this approach, the potential saving is about RM2364.74 (3.25%) annually for the target building. Less reduction of building energy consumption by this approach is mainly due to the building nature. It is worth to noted that the building is facing south, and also most of the glass window in the building are facing south as well. This will cause the effect of direct sunlight become less significant and thus the approach becomes less effective. However, for the building which is facing either east or west, it is believed that the approach would have more significant reduction of energy consumption within the building.

## 4.3 Summary

In this chapter the actual energy consumption of target building Block D is 135050 kWh annually based on data collected. When analyzing the building energy consumption using simulation, it shows that the result has a minor difference which is about 5.48%. Results also showed set point temperature and window tinting optimization could reduce the building energy consumption by 10.05% and 3.25% respectively. This show that above optimization methods could significantly reduce the energy consumption if applied to bigger scale of building.

# CHAPTER 5: CONCLUSION

The idea of energy optimization of campus building has been proposed based on the nature of the building which is inconsistent occupancy in the building. Energy optimization approach by introduce set-point temperature and tinted window have been proposed. The feasibility of the approaches are then verified through a specific case analysis, which then creates a new perspective of energy efficiency approach for the campus building.

The research project was realized by utilized the energy simulation software: "EnergyPlus". The comparison between the original building energy consumption simulation result and actual data collected shows that the simulation software is having high degree of accuracy where the variation of result is very low, which is only about 5%.

The energy optimization strategies proposed in this research are focus only towards thermal consumption. Simulation result shows that the above optimization strategies could significantly reduce the annual energy consumption of campus building by 10.05% for set-point temperature and by 3.25% by tinted window. This is done by reducing the energy consumed by the HVAC system of the building which is mainly for indoor cooling purpose.

Noted the target building used as prototype in this research having similar building nature and occupant activities with most of the campus building around the country. Therefore the strategies proposed could be apply to other building as it having huge potential saving on the utility costing as proved in this research.

In a nutshell, the objectives stated in the research are met. First is successfully simulate the building energy consumption by using a software and the result showed that this type of energy simulation have high accuracy. Therefore, the simulation could be utilized in the future in the thermal design of building as it could save the initial investment. Secondly, two approaches proposed by the research are also proved feasible. With these optimization strategies, the operation cost of the building are reduce effectively and on the other hand, the energy sources are also being saved.

## 5.1 Recommendation for Future Works

Upon the conclusion of the project, there are a few recommendations for improvement for future studies on the related topic. Firstly, the target building could be a bigger and more complex building. This is to further prove that by using optimization methods proposed, the building energy could be reduced significantly in order to reduce the energy source used and reduce the energy cost. Secondly, the energy optimization also could be done other that just using thermal consideration. For instant, future research could focus on other system like lighting and office appliances in order to further optimize campus building energy consumption. Last but not least, experimental could be carried by in term of case study where the proposed energy optimization method is installed directly to the building. By this, the difference of the simulation result and actual result could be analyzed and compared in order to verify the accuracy of the simulation software.

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# APPENDIX A

## Specification Sheet of Tinted Film

RESIDENTIAL & COMMERCIAL
FILM SPECIFICATIONS on 1/8" Clear Glass

Johnson Window Films' solar control flat glass films on clear glass reject 99% or more of harmful UV rays.

| | FILM TYPE | COLOR | VISIBLE LIGHT TRANSMISSION | SOLAR ENERGY REJECTION | VISIBLE LIGHT REFLECTANCE Exterior | VISIBLE LIGHT REFLECTANCE Interior | SHADING COEFFICIENT | SOLAR HEAT GAIN COEFFICIENT | HEAT LOAD REDUCTION RATING | U-FACTOR NFRC | SOLAR ABSORPTION | GLARE REDUCTION | FADING REDUCTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLEAR GLASS | clear | 89% | 14% | 8% | 8% | 0.99 | 0.86 | — | 1.04 | 10% | 0% | — |
| SUNLIGHT (SPECTRALLY-SELECTIVE CLEAR SOLAR PROTECTION) | SUN 70 | natural | 67% | 50% | 19% | 17% | 0.58 | 0.50 | ★★★☆☆ | 1.01 | 34% | 25% | 60% |
| NightScape (DUAL REFLECTIVE, NON-SPUTTERED FILMS) | NS 35 | neutral | 36% | 50% | 17% | 11% | 0.57 | 0.50 | ★★★☆☆ | 1.02 | 43% | 60% | 68% |
| | NS 25 | neutral | 24% | 65% | 33% | 16% | 0.40 | 0.35 | ★★★★☆ | .96 | 44% | 73% | 75% |
| | NS 15 | neutral | 14% | 72% | 40% | 11% | 0.33 | 0.28 | ★★★★★ | .95 | 45% | 84% | 79% |
| | NS 07 | neutral | 8% | 73% | 39% | 7% | 0.31 | 0.27 | ★★★★★ | .97 | 48% | 91% | 81% |
| | NS 05 | neutral | 6% | 69% | 12% | 12% | 0.36 | 0.31 | ★★★★☆ | .98 | 61% | 94% | 80% |
| ScenicView (DUAL REFLECTIVE, NON-FADING FILMS) | SV 50 | neutral | 50% | 44% | 16% | 12% | 0.65 | 0.56 | ☆☆☆☆☆ | 1.07 | 40% | 44% | 63% |
| | SV 35 | neutral | 36% | 58% | 26% | 17% | 0.49 | 0.42 | ★★★☆☆ | 1.01 | 46% | 60% | 70% |
| | SV 25 | neutral | 27% | 67% | 38% | 25% | 0.38 | 0.33 | ★★★★☆ | 1.01 | 42% | 70% | 75% |
| | SV 10 | neutral | 8% | 82% | 58% | 25% | 0.21 | 0.18 | ★★★★★ | 1.03 | 41% | 91% | 83% |
| | SV 50 EXT* | neutral | 45% | 50% | 19% | 13% | 0.57 | 0.50 | ★★★☆☆ | 1.04 | 44% | 49% | 66% |
| | SV 25 EXT* | neutral | 29% | 66% | 36% | 23% | 0.39 | 0.34 | ★★★★☆ | 1.04 | 39% | 67% | 74% |
| | SV 10 EXT* | neutral | 9% | 82% | 56% | 24% | 0.21 | 0.18 | ★★★★★ | 1.04 | 36% | 90% | 83% |
| DaylightNatural (NEUTRAL, NON-FADING SPUTTERED FILMS) | DN 60 | neutral | 63% | 30% | 11% | 9% | 0.81 | 0.70 | ☆☆☆☆☆ | 1.10 | 29% | 29% | 56% |
| | DN 50 | neutral | 49% | 39% | 14% | 11% | 0.70 | 0.61 | ☆☆☆☆☆ | 1.10 | 39% | 45% | 62% |
| | DN 35 | neutral | 37% | 45% | 18% | 16% | 0.63 | 0.55 | ☆☆☆☆☆ | 1.10 | 43% | 58% | 67% |
| | DN 20 | neutral | 22% | 60% | 26% | 26% | 0.46 | 0.40 | ★★★★☆ | 1.08 | 52% | 75% | 74% |
| | DN 15 | neutral | 18% | 62% | 19% | 16% | 0.44 | 0.38 | ★★★★☆ | 1.08 | 64% | 80% | 76% |
| | DN 35 EXT* | neutral | 37% | 49% | 16% | 18% | 0.60 | 0.51 | ☆☆☆☆☆ | 1.04 | 48% | 59% | 68% |
| | DN 20 EXT* | neutral | 22% | 63% | 26% | 26% | 0.43 | 0.37 | ★★★★☆ | 1.04 | 54% | 75% | 75% |
| Sunset Bronze (COPPER, NON-FADING SPUTTERED FILMS) | SB 30 | bronze | 33% | 66% | 27% | 24% | 0.39 | 0.34 | ★★★★☆ | .98 | 36% | 63% | 73% |
| | SB 20 | bronze | 20% | 77% | 37% | 34% | 0.26 | 0.23 | ★★★★★ | .97 | 35% | 77% | 79% |

Occupant Comfort Rating 88% (SUN 70)

* Designed for exterior (EXT) use only.

# APPENDIX B

## Simulation Result of Building Energy Consumption Before Optimization

Program Version:**EnergyPlus, Version 8.9.0-40101eaafd, YMD=2018.07.17 17:48**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

Environment: **RUN PERIOD 1 ** KUALA LUMPUR - MYS IWEC Data WMO#=486470**

Simulation Timestamp: **2018-07-17 17:48:17**

---

Report: **Annual Building Utility Performance Summary**

For: **Entire Facility**

Timestamp: **2018-07-17 17:48:17**

**Values gathered over 8760.00 hours**

**Site and Source Energy**

| | Total Energy [kWh] | Energy Per Total Building Area [kWh/m2] | Energy Per Conditioned Building Area [kWh/m2] |
|---|---|---|---|
| Total Site Energy | 142877.70 | 106.64 | 106.64 |
| Net Site Energy | 142877.70 | 106.64 | 106.64 |
| Total Source Energy | 452493.67 | 337.73 | 337.73 |
| Net Source Energy | 452493.67 | 337.73 | 337.73 |

**Site to Source Energy Conversion Factors**

| | Site=>Source Conversion Factor |
|---|---|
| Electricity | 3.167 |
| Natural Gas | 1.084 |
| District Cooling | 1.056 |
| District Heating | 3.613 |
| Steam | 0.300 |
| Gasoline | 1.050 |
| Diesel | 1.050 |
| Coal | 1.050 |
| Fuel Oil #1 | 1.050 |
| Fuel Oil #2 | 1.050 |
| Propane | 1.050 |
| Other Fuel 1 | 1.000 |
| Other Fuel 2 | 1.000 |

**Building Area**

| | Area [m2] |
|---|---|
| Total Building Area | 1339.80 |
| Net Conditioned Building Area | 1339.80 |
| Unconditioned Building Area | 0.00 |

**End Uses**

| | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
|---|---|---|---|---|---|---|
| Heating | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | 46929.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | 46191.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | 48579.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | 1178.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Refrigeration | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| Total End Uses | 142877.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**End Uses By Subcategory**

| | Subcategory | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
|---|---|---|---|---|---|---|---|
| Heating | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | General | 46929.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | General | 46191.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | General | 48579.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | General | 1178.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Refrigeration | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

# APPENDIX C

## Simulation Result of Building Energy Consumption After Optimization (Set-Point Temperature)

Program Version:**EnergyPlus, Version 8.9.0-40101eaafd, YMD=2018.07.17 18:10**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

Environment: **RUN PERIOD 1 ** KUALA LUMPUR - MYS IWEC Data WMO#=486470**

Simulation Timestamp: **2018-07-17 18:10:36**

---

Report: **Annual Building Utility Performance Summary**

For: **Entire Facility**

Timestamp: **2018-07-17 18:10:36**

**Values gathered over 8760.00 hours**

**Site and Source Energy**

| | Total Energy [kWh] | Energy Per Total Building Area [kWh/m2] | Energy Per Conditioned Building Area [kWh/m2] |
|---|---|---|---|
| Total Site Energy | 128519.40 | 95.92 | 95.92 |
| Net Site Energy | 128519.40 | 95.92 | 95.92 |
| Total Source Energy | 407020.93 | 303.79 | 303.79 |
| Net Source Energy | 407020.93 | 303.79 | 303.79 |

**Site to Source Energy Conversion Factors**

| | Site=>Source Conversion Factor |
|---|---|
| Electricity | 3.167 |
| Natural Gas | 1.084 |
| District Cooling | 1.056 |
| District Heating | 3.613 |
| Steam | 0.300 |
| Gasoline | 1.050 |
| Diesel | 1.050 |
| Coal | 1.050 |
| Fuel Oil #1 | 1.050 |
| Fuel Oil #2 | 1.050 |
| Propane | 1.050 |
| Other Fuel 1 | 1.000 |
| Other Fuel 2 | 1.000 |

**Building Area**

| | Area [m2] |
|---|---|
| Total Building Area | 1339.80 |
| Net Conditioned Building Area | 1339.80 |
| Unconditioned Building Area | 0.00 |

**End Uses**

| | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
|---|---|---|---|---|---|---|
| Heating | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | 33062.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | 46191.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | 48579.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | 686.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Refrigeration | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| Total End Uses | 128519.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**End Uses By Subcategory**

| | Subcategory | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
|---|---|---|---|---|---|---|---|
| Heating | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | General | 33062.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | General | 46191.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | General | 48579.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | General | 686.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Refrigeration | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

# APPENDIX D

## Simulation Result of Building Energy Consumption After Optimization (Window Tinting)

Program Version:**EnergyPlus, Version 8.9.0-40101eaafd, YMD=2018.07.18 16:43**

Tabular Output Report in Format: **HTML**

Building: **Building 1**

Environment: **RUN PERIOD 1 ** KUALA LUMPUR - MYS IWEC Data WMO#=486470**

Simulation Timestamp: **2018-07-18 16:43:26**

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Report: **Annual Building Utility Performance Summary**

For: **Entire Facility**

Timestamp: **2018-07-18 16:43:26**

**Values gathered over 8760.00 hours**

**Site and Source Energy**

| | Total Energy [kWh] | Energy Per Total Building Area [kWh/m2] | Energy Per Conditioned Building Area [kWh/m2] |
|---|---|---|---|
| Total Site Energy | 138229.47 | 103.17 | 103.17 |
| Net Site Energy | 138229.47 | 103.17 | 103.17 |
| Total Source Energy | 437772.73 | 326.74 | 326.74 |
| Net Source Energy | 437772.73 | 326.74 | 326.74 |

**Site to Source Energy Conversion Factors**

| | Site=>Source Conversion Factor |
|---|---|
| Electricity | 3.167 |
| Natural Gas | 1.084 |
| District Cooling | 1.056 |
| District Heating | 3.613 |
| Steam | 0.300 |
| Gasoline | 1.050 |
| Diesel | 1.050 |
| Coal | 1.050 |
| Fuel Oil #1 | 1.050 |
| Fuel Oil #2 | 1.050 |
| Propane | 1.050 |
| Other Fuel 1 | 1.000 |
| Other Fuel 2 | 1.000 |

**Building Area**

| | Area [m2] |
|---|---|
| Total Building Area | 1339.80 |
| Net Conditioned Building Area | 1339.80 |
| Unconditioned Building Area | 0.00 |

**End Uses**

| | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
|---|---|---|---|---|---|---|
| Heating | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | 42492.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | 46191.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | 48579.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | 966.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Refrigeration | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| Total End Uses | 138229.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**End Uses By Subcategory**

| | Subcategory | Electricity [kWh] | Natural Gas [kWh] | Additional Fuel [kWh] | District Cooling [kWh] | District Heating [kWh] | Water [m3] |
|---|---|---|---|---|---|---|---|
| Heating | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | General | 42492.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | General | 46191.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | General | 48579.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | General | 966.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Refrigeration | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | General | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |