# ENERGY BENCHMARKING FOR OFFICE BUILDINGS IN PUTRAJAYA

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## ABSTRACT

Energy consumption in the building sector is one of the major categories of energy consumption in Malaysia, which is rising from year to year in line with the country's economic and social growth. Based on the National Energy Balance (NEB) 2018 released by the Energy Commission, the level of annual electricity consumption in 2018 indicates that the building sector, including domestic and commercial electricity, contributes 49.5% (75.679 GWh) which is the second-highest electricity consumption after the industry sector which indicates 49.8% (76,088 GWh). Energy consumption can be minimised by embracing an efficient energy management as well as investment in terms of technology, systems, or processes. Nevertheless, prior to proceed with all those activities, the first step that need to be done is benchmarking to determine the energy performance of the building. Benchmarking is a method for measuring a building's energy efficiency or performance by comparing its energy use to building with reference building that performs a similar function. A rational and reliable energy benchmark is very useful and informative to give understanding and enhancing building energy performance. Buildings in Putrajaya were chosen in this study case. This study provides a review on the current buildings' energy performance based on the Building Energy Intensity (BEI) where it is used as an indicator. In the meantime, in this study clearly indicates and proved that the significant variable which affected to the energy consumption in office building was the floor area. Analysis on the data of buildings in Putrajaya resulted in an average annual BEI of 125kWh/m²/year. This energy intensity can be using a good energy reference for offices. Besides, it provides recommendation on a new set of office's Building Energy Intensity (BEI) rating.

# ABSTRAK

Penggunaan tenaga dalam sektor bangunan merupakan antara kategori utama penggunaan tenaga di Malaysia, yang semakin meningkat dari tahun ke tahun sejajar dengan pertumbuhan ekonomi dan sosial negara. Berdasarkan Laporan Imbangan Tenaga Kebangsaan 2018 yang dikeluarkan oleh Suruhanjaya Tenaga, tahap penggunaan elektrik tahunan pada 2018 menunjukkan sektor bangunan, termasuk elektrik domestik dan komersial, menyumbang 49.5% (75.679 GWj) yang merupakan tenaga elektrik kedua tertinggi penggunaan selepas sektor industri yang menunjukkan 49.8% (76,088 GWj). Penggunaan tenaga boleh diminimumkan dengan mengamalkan pengurusan tenaga yang cekap serta pelaburan dari segi teknologi, sistem atau proses. Namun begitu, sebelum meneruskan semua aktiviti tersebut, langkah pertama yang perlu dilakukan ialah penanda aras untuk menentukan tahap prestasi tenaga bangunan. Penandaarasan ialah kaedah untuk mengukur kecekapan atau prestasi tenaga bangunan dengan membandingkan penggunaan tenaganya dengan bangunan dengan bangunan rujukan yang menjalankan fungsi yang sama. Penanda aras tenaga yang rasional dan boleh dipercayai sangat berguna untuk meneri maklumat dan pemahaman serta meningkatkan prestasi tenaga bangunan. Bangunan di Putrajaya telah dipilih dalam kes kajian ini. Kajian ini memberikan ulasan tentang prestasi tenaga bangunan semasa berdasarkan Intensiti Tenaga Bangunan di mana ia digunakan sebagai penunjuk. Dalam pada itu, dalam kajian ini jelas menunjukkan dan membuktikan bahawa pembolehubah signifikan yang mempengaruhi penggunaan tenaga di bangunan pejabat ialah keluasan lantai. Analisis terhadap data bangunan di Putrajaya menghasilkan purata BEI tahunan sebanyak 125kWj/$m^2$/setahun. Keamatan tenaga ini boleh digunakan sebagai rujukan tenaga yang baik untuk pejabat. Selain itu, ia memberikan pengesyoran tentang set baharu bagi penilaian Intensiti Tenaga Bangunan Pejabat.

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| | | |
|---|---|---|
| A/C | - | air conditioning |
| ACA | - | Air-Conditioning Area |
| ANN | - | Artificial Neural Network |
| ASEAN | - | Association of South-East Asian Nations |
| BCIS | - | Building Control Information System |
| BEI | - | Building Energy Index |
| BEIL | - | National Building Energy Intensity Labelling |
| BEIL | - | National Building Energy Intensity Labelling |
| CASBEE | - | Comprehensive Assessment System for Built Environment Efficiency |
| CEB | - | Central Electricity Board |
| CDD | - | Cooling Degree Days |
| DEA | - | Data Envelopment |
| EE | - | Energy Efficiency |
| EE&C | - | Energy Efficiency and Conservation |
| EE&C | - | Energy Efficiency and Conservation |
| EEI | - | Energy Efficiency Index |
| EMEER | - | Efficient Management of Electrical Energy Regulations |
| ESM | - | Energy Saving Measures |
| GBI | - | Green Building Index |
| GDC | - | Gas District Cooling |
| GDP | - | Gross Domestic Product |
| GFA | - | Gross Floor Area |
| GHG | - | Greenhouse Gases |
| IEA | - | International Energy Agency |
| KeTSA | - | Ministry of Energy and Resources |
| LEED | - | Leadership in Energy and Environment Design |
| MESI | - | Malaysia Electricity Supply Industry |

| | | |
|---|---|---|
| MGTC | - | Malaysian Green Technology Corporation |
| MIEEIP | - | Malaysian Industrial Energy Efficiency Improvement Project |
| MLRA | - | Multiple Linear Regression Analysis |
| MS | - | Malaysia Standard |
| NABERS | - | The National Australian Built Environment Rating System |
| CASBEE | - | Comprehensive Assessment System for Built Environment Efficiency |
| NABERS | - | The National Australian Built Environment Rating System |
| NAPIC | - | Malaysia Property Market Centre |
| OECD | - | non-Organization for Economic Cooperation and |
| OLS | - | Ordinary Least Square |
| PjC | - | Putrajaya Corporation |
| RE | - | renewable energy |
| $R^2$ | - | coefficient determination |
| SEDA | - | Malaysia Sustainable Energy Development Authority |
| SESB | - | Sabah Electricity Sdn. Bhd. |
| SFA | - | Stochastic Frontier |
| SLRA | - | Single linear regression analysis |
| TNB | - | Tenaga Nasional Berhad |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| GWh | - | Gigawatts hours |
| $CO_2$ | - | Carbon dioxide |
| $GtCO_2$ | - | Gigatonnes of $CO_2$ |
| $kWh/m^2/year$ | - | kilowatt hours per square meter per year |
| kW | - | Kilowatts |
| kWh | - | Kilowatts hours |
| RTH | - | Refrigerant Tonne hour |
| $m^2$ | - | Meter squared |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

According to the current state of energy supply and demand, worldwide energy consumption is expected to increase by about 50% between 2018 and 2050 [1]. In the reference case, most increases in energy consumption are attributed from the non-Organization for Economic Cooperation and Development (OECD), where strong economic growth, increased access to market energy, and rapid population growth have all contributed to rising energy consumption in recent years. Growth in energy consumption in OECD countries is slower than in the rest of the world, owing to slower population and economic growth, improvements in energy efficiency, and a slowdown in the expansion of energy-intensive manufacturing businesses. According to the International Energy Agency, non-OECD countries' energy consumption increased by approximately 70% between 2018 and 2050, compared to a growth of only 15% in OECD countries.

While the developing economies in Asia and the Middle East account for three quarters of total final consumption global growth to 2040. China's reorientation from heavy industries to domestic consumption slows growth in China to just one-fifth of its rates since 2000. By comparing with India, its final consumption is more than doubled by 2040.

The industry is the largest contributor of the end-use sector to overall growth in final demand, with almost 80% of the rise in gas and electricity. Oil represents less than 50 % of demand growth in the transport sector, down from nearly 90 % in the period since 1990.

When it focused by the sectors, global energy demand growth in the building sector would have been approximately 40 % higher without improving performance. It shows that the building sector plays one of an important part to be highlighted in order to lower down the energy demand as well as to enhance the efficient used of energy.

Over the last decade, energy consumption in buildings has risen exponentially because of population growth, increased demand for building functions and indoor environmental quality, and global climate change [2]. According to International Energy Agency, most of the countries' energy consumption comes from buildings, which account for 40% of the total [3].

While comparing to ASEAN, energy consumption in buildings accounted for 28% of total final energy consumption in 2018. Since residential buildings account for most of the energy consumption in buildings, commercial buildings account for less than a quarter of total energy consumption, according to the 6th ASEAN Energy Outlook [4]. Based on current trends, the energy use of buildings is expected to double between 2030 and 2040, reaching a staggering 120% increase in just a decade. This growth may be limited to less than one-third by 2030, and less than half by 2040, due to current national and regional targets. The population, GDP per capita, and urbanisation of the region are all factors that will lead to an increase in demand for services and construction materials. More than 120 million people are expected to join the ranks of the world's population by 2040. Additionally, the warm and humid climate of the ASEAN region contributes to the region's high number of Cooling Degree Days (CDDs). Thus, as incomes rise, air conditioner ownership will increase, but a large portion of the population will still be at risk for heat stress by the year 2040, when air conditioner ownership is expected to reach 60%. [5]

In Malaysia, energy consumption in the building sector is one of the major categories of energy consumption which is rising from year to year in line with the country's economic and social growth. Based on the National Energy Balance 2018

released by the Energy Commission, the level of annual electricity consumption in 2018 indicates that the building sector, including domestic and commercial electricity, contributes 49.5% (75.679 GWh) of the second-highest electricity consumption after the industry sector which indicates 49.8% (76,088 GWh). Government buildings are no exception where the government has to bear the high cost of energy usage which is continuously rising each year in line with the age of buildings and the rise in users and equipment. Increased electricity bills due to inefficient energy use a rise in new buildings and a lack of awareness among building occupants are also factors in the increase in electricity consumption in buildings.

Using the code of practice Malaysia Standard: (MS) 1525 – Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings, the first Malaysian Standard of efficient energy use standard was introduced by the Malaysian government since year 2000, kicking off the country's energy efficiency drive. Within this fiscal year, the government will designate a tax credit to be used to encourage the implementation of energy-efficient programmes. When the governance module is implemented, a significant increase in the number of qualified personnel responsible for the Green Building Index (GBI), which was introduced in 2009, will follow. The concept of a building energy index, or BEI, is introduced by the GBI evaluation tools. When it comes to government buildings (non-residential buildings), GBI implementation looks to them as role models, incorporating excellent energy index programmes into their design and implementation. The GBI also expands the scope of the programme to encompass commercial and industrial structures, in addition to housing.

Realizing the potential savings from the buildings sector, Government has introduced The National Building Energy Intensity Labelling – BEI Labelling for Government buildings effective from the fourth quarter of 2018, starting with all the Ministries and Prime Minister’s Department. This non-regulatory initiative will provide information on the level and performance of a building's energy consumption, create greater awareness and healthy competition among building owners in improving their energy consumption.

This study discussed the initial energy performance of office building in Putrajaya as well as develop an energy benchmark for it. In addition to that, a recommendation for future used of a new set of Building Energy Index (BEI) rating is also proposed for the government's National BEI Labelling initiative.

## 1.2 Research Background

Malaysian Electricity Supply Industry (MESI) has gone through a significant evolution since Egerton's White Paper to establish Central Electricity Board (CEB) in 1949. Since then, the industry which was initially fragmented became integrated in 1970s. Then the electricity industry went through the development phase, consolidation phase and privatization, before the establishment of Malaysian Electricity Industry Reform Initiatives in 2009. Since 2000, Malaysia's final energy elasticity ratios have always been greater than 1.0. The ratio indicates the level of Energy Efficiency (EE) from the techno-economics perspectives and values over 1.0 shows the inefficient use of energy.

EE is an effective mean to address the energy security issue as well as energy-related environmental issues in the country. EE also lead the country to a sustainable energy path. EE can be improvement at demand-side especially on the building sector. Savings on the demand side will reduce the energy losses due to distribution and transmission of power, losses in power generation plants, and the energy use associated with extraction and transportation of fuels.

In energy terms, saving one unit of energy in the demand side will save 3-4 units of primary fuels in term of MmBtu [6]. In addition, investments in energy supply facilities such as power plants and grid can be deferred or postponed. Many EE initiatives took place during this period, such as the Malaysian Industrial Energy Efficiency Improvement Project (MIEEIP) in 1999, followed by the development of MS1525: Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings - Code of Practice (1st rev. 2007, 2nd rev. 2014 and 3rd rev. 2019) and

Efficient Management of Electrical Energy Regulations 2008 (EMEER 2008). On top of this, National Energy Efficiency Action Plan was drafted in 2014 to boost EE in Malaysia. The roadmap of EE initiative that has been implemented in Malaysia illustrated in Figure 1.

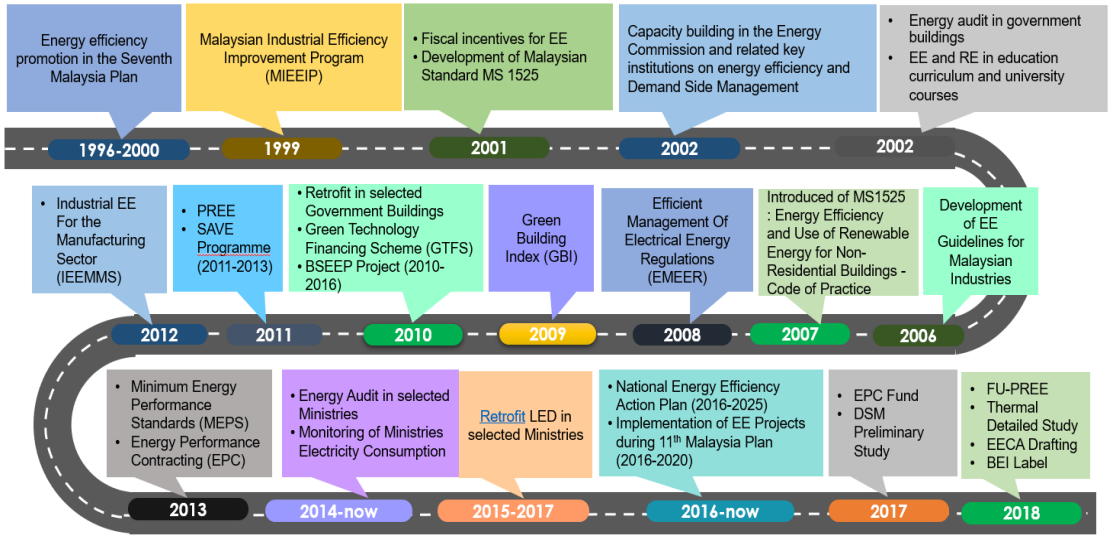


Figure 1 EE Initiatives in Malaysia

Additionally, while EE is one of the five pillars of The New Energy Policy 2010, energy efficiency policies for the building sector are limited and disjointed. Various one-off initiative was attempted during the 10th Malaysia Plan period of 2011 to 2015, but the 11th Malaysia Plan had seen the launch of a larger initiative to provide audit incentives for energy efficiency, with the goal of reducing industrial and commercial electricity consumption by 8% by 2025 compared to the 2015 baseline. The government has committed RM167 million to this effort, but significantly more financial resources, in the vicinity of RM5 billion, will be required to achieve the 8% reduction in electricity consumption. [7].

On the other hand, the renewable energy (RE) took the spotlight with the establishment Renewable Energy Act in 2011. Despite this, the embracing of EE in Malaysia seemed rather slow, due to the absence of the Energy Efficiency and Conservation (EE&C) Act. With the present effort by the ministry to realize this EE&C

Act, it is timely to establish a quantitative parameter to evaluate EE intensity to complement the act, apart from realizing the Building Energy Intensity Labelling which was launched by the government in 2018. This will be the enabler to evaluate the EE intensity for building sector and its sub-categories as a start, before extending the evaluation to other sectors.

In the building sector, one of method to determine and compare the performance with other building in the same category of building is by benchmarking. While most buildings cannot provide sufficient data for a comprehensive energy assessment, a rational and reliable energy benchmark is beneficial for understanding and improving building performance.

Therefore, in this study reviewed and assessed the current energy performance of office buildings in Putrajaya in term of its BEI as well as to develop a rational and reasonable energy benchmark which can be used in operational rating system to evaluate the energy performance of a building accurately and effectively

## 1.3 Problem Statement

A city designated by Malaysia's federal government as one of the nation's pioneering green cities, Putrajaya aims to reduce Greenhouse gas (GHG) emissions in the city by developing EE initiatives as well as renewable energy sources. The energy sector is responsible for the majority of GHG emissions. The Putrajaya statistic shows that the building sector continues to consume the most energy. According to the building types in Putrajaya, 44 % of the floor space is occupied by residents, 30 % by government offices, and 19% by public facilities. The government buildings are second in floor distribution, but when compared to the total energy consumption, they account for a whopping 61% of the total. Putrajaya's growth is expected to have a significant impact on the city's development, but it will also increase Putrajaya's energy demand, which is why this situation is expected to worsen over time. Government allocations for energy costs are also increased as a result. The government has had to increase its allocation to cover these costs to some extent. As a result, demonstrating

new practices in energy efficiency and energy reduction for the building sector in Putrajaya is considered desirable and cost-effective when done by the government. For example, a new initiative that can help the government improve and enhance existing building sector policies on energy efficiency can be introduced in this context. In Putrajaya, for example, there is currently no energy benchmark in place for the building sector. It is possible to get objective and reliable information on energy use and the benefits of improvement through an energy benchmark. Building occupants' awareness of energy efficiency may lead to changes in their behavior. Benchmarking is a critical tool for improving energy efficiency and cannot be ignored. Putrajaya's efforts to improve the energy efficiency of its buildings will begin with this benchmark. There will be a lot more effort required to meet the stated goals. It is necessary to conduct a thorough assessment of the current performance levels of Putrajaya's office buildings before any action can be taken. It is also important to compare and learn from peering countries' studies, which can help us to improve our strategy for achieving our goals.

This study, therefore, focus on reviewing and assessing the current performance of of office building in Putrajaya by using regression analysis to assess its progress and achievements. This analysis be brought to develop a rational and reasonable energy benchmark and provide recommendation on a new set of office's Building Energy Index (BEI) rating for future as a reference point.

## 1.4 Objectives

The objectives of this research are:

1) To review, assess and evaluate the current performance of office building in Putrajaya
2) To develop a rational and reasonable energy benchmark for office building in Putrajaya
3) To provide recommendation on a new set of office's Building Energy Intensity (BEI) rating.

## 1.5 Scope of Study

The following are the scope of work that has been established to achieve the intended objective:

1) Studying and summarising the previous study's literature review related to energy benchmarking that can be used to narrow the gap for this study.
2) Studying and assessing the current energy performance of office building in Putrajaya which included their energy consumption which include electricity and gas district cooling and floor area.
3) Studying the implementation of energy benchmarking in other countries to understand on their methodology and compare it with Malaysia to identify which methodology and implementation would be suitable.
4) Collecting the building data and information pertinent to the energy used from Putrajaya's Building Control Information System (BCIS) and verify it accordingly.
5) Developing a rational and reasonable energy benchmark which particularly suitable for Putrajaya by using the linear regression method approach
6) Recommendation on BEI rating for future.

## 1.6 Significance of Study

This study provides a set of office's Building Energy Index (BEI) rating proposal recommendation that enhanced the existing rating as well as for future utilisation of National Building Energy Intensity (BEI) Labelling Initiative introduced by the Government. This rating came out through the development of the rational and reasonable energy benchmark particularly for the building in Putrajaya. Establishing an energy benchmark helps to create a reference value in order to determine the energy performance of the building. Additional on that most of the building in Putrajaya is government building. Significantly, this study demonstrated that this initiative facilitated and make a Government Lead by Example initiative where there is no

benchmarking in Malaysia currently. Furthermore, it will support and provide a framework for the government to establish a benchmarking policy and to implement it.

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