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Benchmarking Energy Performance of Accommodation Buildings Using Regression and ANNs Models

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ABSTRACT

The accommodation buildings have significant environment and economic impacts in Japan. In the same time, owners and facility managers do great efforts to improve energy performance of accommodation building as respond to new energy policy after great east earthquake in Japan 2011.

The aim of this study is to create an accurate tool to assess the energy use of accommodation building in Kanto area. The study depends on national survey and private data to conduct the current investigation, one of main data source is Database for Energy Consumption of Commercial Buildings (DECC) by Japan Sustainable Building Consortium (JSBC).

The first stage of assessment process is to examine various variables that affect energy consumption of buildings. Therefore, based on this stage some parameters are selected to be the main factors that enable accurate evaluation for energy usage of target buildings.

The second stage of assessment process is to build an appropriate reference that enhances better ability to compare energy performance of selected buildings. A practical benchmark have been developed using statistical approach to find out the impact of selected factors on energy use intensity (EUI) of accommodation buildings in Kanto area.

Third stage, a validation study to examine the accuracy of regression model. It is an important step since the statistical approach is not high accurate approach among other approaches. ANNs model was designed through choosing the best learning method and hidden layers to ensure sufficient accuracy.

Finally, the study applied the previous stages on franchised hotel in Tokyo as a case study to examine the applied methodology of energy assessment.

Study's results point out the benefits of establishing a benchmark for energy performance of accommodation buildings to enable powerful assessment of energy plan and to create practical tool that supports managers to develop their energy management without affecting facility's function.

Keywords: Accommodation Buildings, Artificial Neural Network, Benchmark, Database for Energy Consumption of Commercial Buildings, Energy Performance, Energy Use Intensity, Regression Model

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1. Introduction

1.1. Background:

Man made his first building as a shelter to protect himself against the harsh weather and defense against outside attack. Gradually, man improve his shelters to adapt different aspects such as climate, location and material. He could developed a large spectrum of buildings that meet his needs and adapt with different conditions around the world. As consequence of advanced knowledge, man could improve most of building's component such building structure, energy system, energy flow and control. These improvements increase the performance of buildings in term of functionality or thermal comfort. Generally, the usage of buildings depends on energy through different sources such as electricity, Gas, Coal and liquid fuels which are used to run all of building operation systems such as light, ventilation, cooling, heating and other household equipment. That means without energy buildings can not be used or inhabited.

Because of the pressure on the global environment from energy use, the sufficiency of building design converted into the efficiency of building to emphasis the necessity to reduce energy consumption of buildings. In the same time, ensuring healthy and comfortable condition for all types of users. Advance technologies promise significant achievement to save energy and to integrate renewable energy. On the other hand, new regulation, policy and standards have been issued to change new building to be more sustainable.

Buildings sector is the third consumer of total energy after industry and transportation sectors in most of developed countries. Both of residential and commercial buildings are major need for human activities either as shelter or work place. In this term, increasing population will rise demand for building facilities accompanied with the long time spent inside buildings. Therefore, the energy efficiency in buildings consider an essential issue for energy policy at regional, national and international levels.

The global contribution from buildings towards energy consumption, both residential and commercial sectors, has steadily increased between 20% and 40% in developed countries [1]. Commercial buildings consist of different types of buildings with variety of function or economic activities. Each type has certain intensity of energy use and has certain contribution to national's GDP. Accommodation buildings are the most energy intensive among other buildings categories in many countries. Generally, there are many of factors affect the high-energy consumption, some of which are related to building design and operations, weather condition, and occupancy rate and guest behavior. The accommodation buildings are intensive energy among other commercial buildings and have a high potential to reduce its energy consumption. On other hand, accommodation buildings are a main part of tourism sector beside to transportation and other tourism components. Therefore, many researchers, policy makers and other stockholders employ many efforts to improve energy performance of accommodation buildings.

Different procedures can be applied to enhance less energy usage in accommodation buildings such as passive design or renewable integration.

However, it is necessary to assess the efficiency of these procedures either comparing to other similar buildings or to certain reference. Therefore, the assessment process requires a powerful reference to compare the energy performance of accommodation building; this reference can be developed as benchmark system based on regression model considering most effective variables. Benchmark system is adopted using several approaches. Regression model provides valuable benchmark equation which weighs the impact of variables. However, regression model has low accuracy comparing to other approaches, because of that; ANNs model is used to validate regression results.

In Japan case, the accommodation buildings include western style of hotels, city hotel, business hotels, Traditional hotels (Ryokan) and Inns. The study covers all categories of accommodation buildings regardless the classification, size, age, ownership and functions. In addition, the study performed in regional scale to enhance future work on national scale.

This research evaluates the energy performance of accommodation building within Kanto region in Japan. This area was selected to represent the whole trend of Japanese accommodation buildings. The selection of Kanto region was based on the highest number of survived buildings with high annual primary energy intensity among other regions. Other aspects about choosing the case study will be offer in third chapter. The study reports the importance of building’s physical parameters, operation parameters, energy intensity, and weather and occupancy rate to assess the energy performance of accommodation buildings.

Other variables such as end user behavior, sub-system performance, employee density and the breaking down of energy use will not be included in this investigation. Since to cover all variables and parameters requires very detailed survey, which is not available within this study. It does not focus on macro or micro scale where detailed investigation are required for individual buildings.

Despite of great efforts to improve the energy performance of accommodation buildings in Japan, there is no reference to evaluate the output of these efforts. Therefore, this study seeks to develop a powerful benchmark to enable different stockholder in hospitality sector to assess their energy plan or management. The availability of DECC database have not been used yet to achieve such aim for different categories of commercial buildings.

1.2. Research Objectives and Significant

The main aim of current research is to assess the energy performance of accommodation buildings in Kanto region-Japan. Three sub-objectives are required to achieve the main goals, which are:

- To examine the role of physical variables of building, operation variables and occupancy rate on energy consumption. The correlation between energy consumption and occupancy rate will be investigated deeply because of controversial relation between each other.
- To develop a benchmark system using regression model to compare the energy performance of accommodation buildings with their peers of the same group.
- To design ANNs model by selecting the best learning method and the hidden layers to adopt an accurate ANNs model to validate regression model.

Study's benchmark supports improving the economic performance of buildings by reducing energy cost and improving the reputation of accommodation facility as sustainable building. The reduction of energy consumption will reduce the CO_2 emission and using other natural resources that means better environmental performance. The research has social contribution through increasing awareness about energy saving, providing sustainable facilities that sustain quality level with less energy and natural resources.

Nowadays the improving of energy performance of commercial buildings is an urgent issue because of its contribution in energy usage and environmental impact. The accommodation category is one of energy intensity category in Japan. Therefore, it is an essential to evaluate the energy performance and to investigate the main variables which affect the energy use. In addition, it is necessary to develop a reference to evaluate the energy performance of energy management off accommodation buildings.

According to the above, the current research aims to assess the energy performance of accommodation buildings in Japan, few studies was done to cover accommodation buildings that most studies focused on office buildings.

The study aims to present the first reference/ benchmark in Japan which can be used to assess the energy use of accommodation buildings. Therefore, this study will be a yardstick for owners, managers and other organization' bodies to assess the performance of existence accommodation buildings as shown in figure (1-1). The regression model used to find out the benchmark equation. However, ANNs model was used to validate the regression model. A precise design was adopted for ANNs model by selecting learning method and hidden layer, this step ensures accurate outputs of ANNs model.

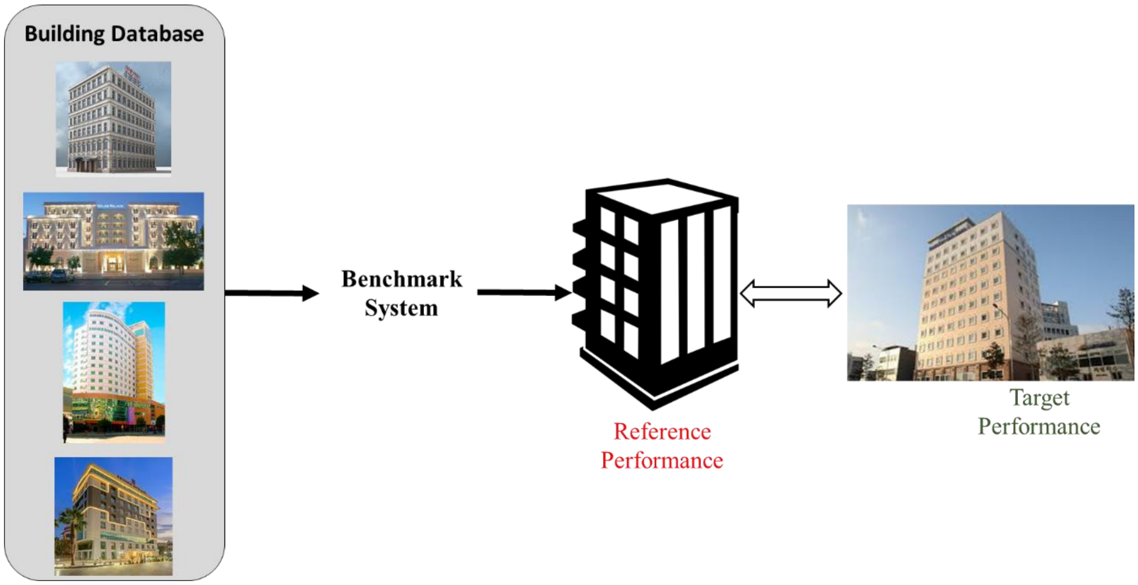

Figure 1-1: Benchmark Concept of Accommodation Building

Finally, this study can be extended to include the whole Japan after performing some climate/ weather correction for future studies. Moreover, it can be deployed to include various categories of commercial buildings with consider different variable due to the function of building

1.3. Research Framework:

The research is framed into six main stages: data acquisition and preparation, energy modeling using regression model, model design of ANNs, comparison study and case study implementation. As shown in Figure 1-1. The figure illustrates the detailed stages of current work; the data collection is the start point of benchmarking process where the DECC is the main source of data to develop proposed benchmark of energy performance.

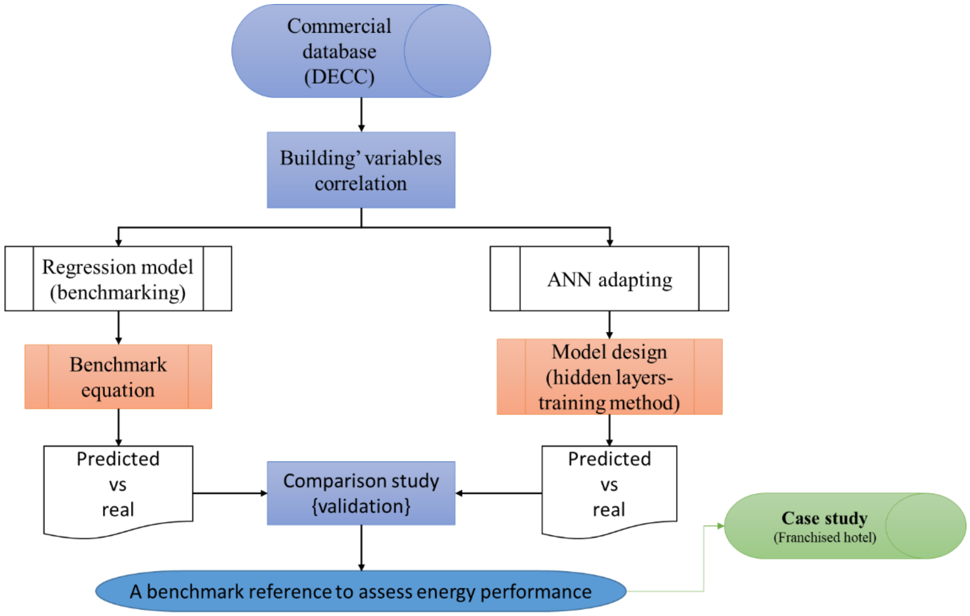

Figure 1-2: Research Framework

This thesis consists of six chapters. An outline of each chapter is given as follows.

Chapter 1 presents an introductory text to the whole research work. Firstly, it presents the background of the study, with focus on energy use in accommodation buildings. Then, the tourism industry in Japan is introduced. Other issues related to research such as Objective, significant and others are introduced in this chapter. At the end, organization of the thesis is outlined, so that the reader knows what to expect in the following chapters.

In Chapter 2, previous research work related to the current study will be reviewed. It includes various aspects of energy use of buildings and its environmental impact, energy use of commercial buildings, accommodation building as intensive energy. The relation between the occupancy and energy consumption. Finally, the effect of weather condition on energy consumption.

In Chapter 3, examines the various factors affect energy performance of accommodation buildings. In addition, the correlation between energy consumption and outdoor weather conditions is included. A descriptive analysis applied to correlate the energy use with occupancy rate and outdoor air temperature. The analysis covers different forms of energy use, such as electricity, gas, and oil fuels.

In Chapter 4, introduces the benchmarking system of DECC by using regression method. A regression model was used to find out the benchmark equation of selected samples of DECC. The impact of target variables was calculated and the relation between real and predicted values was illustrated in graphs. Artificial Neural Network (ANN) model was implied to validate the benchmark results by regression model. ANN uses the same samples of regression model and same input variables.

Chapter 5 presents a discussion regarding previous four chapters and research's finding. The chapter summarizes the energy us in accommodation buildings and the procedures of developing benchmark of energy consumption. The reliability of benchmark have been introduced them to sum up chapter with research's contributions.

Lastly, the study is concluded in Chapter 6, which summarizes the research objectives, research design and also the main results of data analysis. Contributions made by the study will be presented; agreements as well as disagreements with previous research work will be noted. In addition, the chapter also will be discussed the limitations of this study and suggestions for further research.

2. Literature Review

This chapter reviews previous research work related to the current study. It includes various aspects of energy use in buildings and its environmental impact, improving the energy performance of buildings, energy use of commercial buildings, accommodation building as intensive energy, energy-use in accommodation buildings, the occupancy and energy consumption, the effect of weather condition on energy consumption and finally benchmark system in details. Japan’s Energy Sector and Building Management Systems

2.1. Japan’s Energy Sector and Building Management Systems

Building is a basic human activity and is an essential component of sustainable development. The multiple functions of the accommodation sector require different types of energy usage. Therefore, energy in various forms (e.g., electricity, diesel, and LPG) are often required in a building. Furthermore, one energy form is sometimes used for multiple tasks; for example, electricity is used for lighting, air conditioning, and many other functions. The fuel variety can depend on the climate zone in which the building is located. Typically, gas and oil are used more for heating in cold climates, whereas electricity may be required more for cooling in tropical or hot climates.

As a major sub-sector of the tourism industry, the hotel sector accounts for a significant amount of the overall resource consumption in the world's largest export industry, as well as for a substantial portion of the environmental impacts it generates[2]. The percentages of different fuels depend on accommodation type and class. For instance, the accommodation sector in

Vietnam uses various proportions of electricity. Resorts and 4-star hotels have a relatively low percentages of electricity use at 66% and 76%, respectively, whereas 2- and 3-star hotels depend nearly entirely on electricity, accounting for over 90% of total energy consumption[3].

The accommodation industry is considered the most environmentally harmful portion of the hospitality sector because of its considerable consumption of natural resources and production of waste[4]. Most environmental damage influences the air, water, and soil because of the extreme consumption of non-recyclable goods, water, and energy for heating, ventilation, and air conditioning [7]. For instance, two groups of hotels in Europe discharged approximately 160-200 kg of CO_2 per m^2 of room floor area per year, produced 1 kg of waste per guest per night, and used 170-440 liters of water per guest per night [8]. Buildings are responsible for a considerable amount of greenhouse gas emissions, energy and raw material use, waste, and changes in land use dynamics [9].

Furthermore, the growing number of tourists worldwide has increased occupancy rates and the consumption of energy and resources, thereby creating an increased ecological footprint for accommodation buildings [10]. This trend has an obvious effect on the environment when compared with other commercial buildings of similar size because of high energy and resource consumption [11]. In other words, the environmental footprint of accommodation buildings is typically larger than those of other buildings of similar size [12]. Notably, the rapid growth of energy use worldwide has raised concerns regarding supply difficulties, the exhaustion of energy resources, and severe environmental impacts [13].

This extensive consumption of natural resources and the resulting environmental impacts have prompted the accommodation sector to enhance sustainable tourism practices [14]. In addition, this problem requires more attention to environmental issues, policies, and daily routine practices [15].

There are social and environmental problems related to the increasing of energy use. Some of them are not obviously, but we have to survive its effects in the end. More of social/ Culture impacts can be recognized from accommodation sector that can not be measured easily such as the cross-cultural exchange. Therefore, more studies are required to investigate the contributions of accommodation sector in either city or countryside.

Japan imports 91.3 percent of its energy supply. After oil crises of the 1970s, Japan has taken actions to promote energy conservation, find alternatives to petroleum, and secure supply of petroleum. However, after the Great East Japan Earthquake, the percentage of fossil fuels has been increasing, as a substitute for nuclear power as fuel for power generation[13]. Nowadays, despite the actions for decreasing the dependence of energy imports, Japan still considers as one of the most volatile countries in the world. Therefore, different organizations and government-bodies, public institutions, economic agents and researchers concern about energy security [14].

Japan's final energy consumption has trended downward since fiscal 2005. In fiscal 2012, the total primary energy supply in Japan was 21,710 petajoules. While energy consumption in the industrial sector has remained level, there were sharp increases in energy consumption in the commercial and residential sector and in the transport sector. In the commercial and residential sector, energy consumption by the commercial sector in particular has risen in recent years[13].

There are two Japanese governmental programs which intend to enhance energy management by firms. One is regulation on firms by Energy Conservation Law, and the other one is free-of-charge energy audit programs by governmental subsidiary organizations. Energy efficiency policy has an important role to remove market barriers to energy efficiency.

There are three approaches in such policy intervention. One is regulation. This approach includes technology standards, performance standards, and management standards. The last type, which is also called enforced self-regulation or management-based regulation, is a way of regulation which requires firms to have some kind of management systems, and the firms determine the details of the management systems by themselves [15]. Japanese Energy Conservation Law on firms is a good example of management-based regulation. The second approach is providing information and education, such as guidelines, manuals and training. Energy audit programs in Japan belong to this category.

The law was established in 1980 and has been amended in 1993, 1998, 2002, 2005, and 2008. Every time it was adapted the regulatory requirements have became stricter in scope and obligations. It covers large facilities consuming more than 1,500 kilo litters in crude oil equivalent per year (approximates 3,000 t-CO_2 per year) are regulated. The regulated firms sum up to more than 14,000 facilities and their energy consumption consist of 90% in industrial sector, and 10% in commercial sector[16].

The energy conservation standards for housing and building were first established in 1980 as a part of the revised Energy Conservation Act. These energy conservation standards are called the “Standard of Judgment” in the Act. The “Standard of Judgment” is a set of regulatory reference standard and the construction clients of housing and building that fall in the designated group under the Act are recommended to use in implementing their energy conservation obligation as mandated by the Energy Conservation Act. The key obligation includes an annual report on energy conservation measures which shall be submitted by regulated construction clients of housing and building to the government. Since the inception, there were several revisions of the standards regarding this sector in 1992, 1999, and 2012. In the Basic Energy Plan published in 2014, the government plans to strengthen these standards for building and housing towards 2020 in a step by step approach[17].

The direct contribution of Travel & Tourism was 2.4% of total GDP in 2014, and is assumed to rise 2.8% of total GDP in 2025. The total contribution of Travel & Tourism to GDP was 7.5% in 2014, and is forecasted to rise 8.1% in 2025. In addition, Travel & Tourism directly supported 1,152,500 jobs (1.8% of total employment). The growth is expected to rise by 2.2% of total employment in 2025. Travel & Tourism investment in 2014 was JPY3,341.8 bn, or 3.1% of total investment. It should rise to JPY4,018.1bn in 2025 (3.2% of total) [18]. In Japan, the increase in commercial sector energy consumption is almost fully caused by the increase in the total floor area of commercial buildings [19]. Energy consumption of the hotel sector in Japan has been specified as one of the large energy consumers among commercial buildings about 3,421MJ/m2 annual load [20].

Generally, Japanese accommodation facilities can be divided into hotels, traditional inns, family-run guesthouses, pensions and membership resort clubs. Japanese-style inns and guesthouses continued to decline, but hotels grew in scale and number according to JETRO, 2007. Japanese accommodation buildings consist of hotels that simulate the western culture and Ryokan that preserve the traditional culture of Japan[20].

2.2. Methods for Improving Building Energy Management

Energy is one of the most difficult fields to manage especially when it comes to building sector due to many factors that can influence on energy performance as in accommodation sector. There is no specific strategy to follow; many energy agencies and governmental officers have established general guides and tools to help building managers to adjust them for their own needs.

Many management studies dominated the competitiveness of a country firms from the performance of its facilities. At the national level, it is reflected in the performance of the economy, while at the operational level, it is viewed in terms of the market share secured by an enterprise[21]. On top of saving utilities bills, how to link the energy management to business advantages is an area under investigation. For example, the Ecolabel, Green Hotel, etc. are an excellent market tools to promote the hotel's image to the existing and potential customers, in additional to the benefits of reducing energy costs and improvement of environmental quality standards[21].

As the energy performance becomes part of the hotel management measures, in the hospitality industry, it is already quite common to used key performance indicators for assessing its business operations. However, energy benchmarking will only become a major force in the supply chain when it becomes a selection criterion for guests, through travel policy changes either for major stockholders/ governments or through inclusion in the facility quality star rating system. Education and information is the key to achieve this.

2.2.1. Indicators of Energy Performance

The energy performance in buildings is affected by various factors, such as ambient weather conditions, building structure and characteristics, the operation of sub-level components like lighting and condition systems, occupancy and their behavior [22]. The physical parameters of the building affect the resource consumption in accommodation buildings. These parameters include size, building design, geographical and climatic location, type of energy, type and amount of available local resources and energy and water use regulations and cost [6]. Due to accommodation buildings function and operation, it consumes large amount of energy [23][24]. Moreover, the round-the-clock operations drives to excessive use of energy in accommodation buildings [25].

In the built environment, an Energy Use Index (EUI) is widely used to represent the overall energy performance of a building, using its performance to be compared against another, as in benchmarking processes. In general, the indicators are commonly expressed in kWh/m^2/year or MJ/m^2/year, also It can be $kgCO_2/m^2/year$ which expresses an overall CO_2 emission per unit floor area [26]. By normalizing various Factors of energy use, the EUI can be used to compare energy performance between buildings to highlight the inefficiency of a building or its services.

Floor area is the most widely used denominator; there is a large variation in conventions for measuring floor areas such as the Treated Floor Area (TFA) used by building services engineers; Net Internal Area (NIA) or Net lettable Area (NLA) widely used in commercial properties; and Gross Internal Area (GIA) commonly used by design and building teams Bordass (2006). In addition, there are other types of indicators used in certain types of buildings in which other characteristics of buildings or businesses are considered to represent energy use better than the floor area. For example, number of meals served in hotel buildings in Singapore (kWh/room) [27], the number of persons (household) in a residential building in Brunei Darussalam (kWh/person) [28], it can be the number of pupils in a school, or the numbers of bedrooms in a hotel.

These indicators were however deemed insufficient as performance indicators for motivating energy efficiency of buildings through comparison of energy performance, due to a lack of understanding of how effectively a building will be used once it is occupied. In accommodation buildings, The benchmark are measured by energy use intesity (EUI) which is typically expressed in the unite of building consumption per floor area per year, per guest per year or per guest night [29][30].

Saving energy is one of the most important global challenges in nowadays. In the meantime, environmental concerns drive this trend much further. In order to reduce greenhouse gas (GHG) emissions, which are considered to be reason of global warming and sources of pollution, the Kyoto protocol set specific targets for reduction of CO_2 emissions. This situation has encouraged two important initiatives. First, efforts on producing electricity with higher efficiency; Second, on using electricity with higher efficiency and more efficient use of energy not only reduces the consumption of electricity, but also lowers the consumption of primary energy sources.

Buildings, whether residential or commercial, mainly use energy to attain comfort for their residents. Although comfort includes visual and ergonomic, the main concern is about thermal. Air conditioning used to maintain comfort nowadays but utilities high energy. In order to reduce energy utilization of buildings, several passive techniques are introduced in attaining thermal comfort [31].

Passive cooling systems depend on non-mechanical methods to achieve the thermal comfort inside building and reduce the impact of buildings on the environment. Passive cooling techniques can save energy in buildings by decreasing the required cooling load [32]. Earth-Air Heat Exchanger (EAHE) is a passive cooling technology that uses the earth as a heat sink. This technology can be applied into conditioning system through three primary methods: direct, indirect, and isolated method.

EAHE system takes advantage of the high thermal inertia of the soil where at sufficient depth the ground temperature is lower than the outside temperature in summer. The fresh air is drawn inside the EAHE system to cool it before carry it out inside the building. EAHE system can supply conditioned fresh air to air-conditioning units which could reduce value percentage of electricity consumption in the building [33].

Earth-Air Heat Exchangers have been defined as “a system of pipes that utilize the earth near constant temperature in order to cool or heat air or other fluids that move through the pipes. It can be used as a passive cooling or heating system for residential, commercial, industrial or agricultural applications” [34].

In certain areas or applications, EAHE system can be used as alternative system to conventional air condition system that could possibly reduce energy consumption [35] [33] [36][37].

The using of EAHE system becomes common as a passive technique in buildings to reduce the required cooling or heating demand. But this implementation requires large surface of area for their installation and using of large diameter tubes to reduce the pressure drop [38]. EAHE system is used as a passive technique from long time ago for heating and cooling usage [39].

Other passive solutions will improve the energy performance of accommodation buildings and decrease the environmental impact of using fusel fuel energy.

2.2.2. Modeling Energy Consumption of Building

The energy system of a building is affected by many factors, such as the weather conditions, building structure and properties, and occupants and their behavior [21]. Due to the complexity of the energy systems of buildings and the necessity to obtain accurate predictions of usage, many approaches have been proposed to solve this complicated issue, including elaborate and simple methods. These methods are used in different applications, such as designing new buildings and operations or retrofitting existing buildings. Many works related to energy modeling and the prediction of building energy consumption use different methods, including engineering, statistical analysis and artificial intelligence methods [22]. Additionally, many software programs, such as Energy Plus, have been developed to assess energy consumption in buildings [23] [24]. Although these tools are accurate, they have some limitations related to using detailed parameters as inputs and require a high level of experience to ensure effective use [25].

Statistical models, such as regression models, have been widely used for building energy assessment [26]. These models correlate energy consumption with effective variables and depend on historical data. Although these methods are easy to implement, they are generally less accurate than complex methods.

Artificial intelligence (AI) methods are widely used to solve linear and nonlinear problems involving complex applications. Artificial neural networks (ANNs) and support vector machines (SVMs) are the most widely used models applied in building energy prediction [27][46]. AI methods have high accuracy in term of result outputs, but it require high detailed date and high skills to run the analyzing process.

Energy performance assessment schemes and methods are developed mainly for two goals: energy classification and energy performance diagnosis. Energy classification provides constant or authorized means to illustrate a building’s relative energy efficiency and carbon emissions to both the owners and the public to encourage ongoing efficiency and conservation gains. Energy performance diagnosis aims at detecting faults and describing the causes of poor performance in buildings, and accordingly providing specific energy efficient measures to improve energy performance.

2.2.3. Benchmarking System

Benchmarking system in building sector for energy consumption is a process to investigate the energy performance of buildings with its own history or peer buildings, this action is an essential step to evaluate the efficiency of all applied energy plans and energy management in selected buildings. So that the goal of improving performance and saving energy of buildings can be fulfilled. In this section, previous research will be reviewed in order to demonstrate the purpose and the process of building energy benchmarking; then, previous research regarding benchmarking using regression analysis and ANNs will be summarized.

2.3.Accommodation Buildings and Energy Consumption

It is necessary to understand the properties of accommodation buildings to be able to evaluate the energy consumption. Up to facility's function, different forms of energy can be used to meet the energy demand.

2.3.1. The Characteristics of Accommodation Buildings

Generally, accommodation building as a system consists of several sections depending on the services provided. The basic section is guest room, it occupies between 65 and 80 % or more of the total building space [47][48]. A full service building uses 70 to 80 % of its space for guest rooms and corridors. The size of guest rooms varies in area, from about 20 m² for a typical European hotel to over 76 m² in deluxe hotels and suites [47].

Guest rooms are one of the main sources of hotel revenue [49]. The guests mainly spend their time in their guest rooms. For this reason, hotels put considerable resources into providing a pleasant and comfortable atmosphere in the guest rooms. Public zones are another large area that makes up an accommodation building. These areas are the lobby, food and beverage outlets (bars, restaurant, dining hall), hallways, staircases, conference rooms, meeting rooms, health and sport facilities (gym, swimming pool, dressing rooms, massage rooms) and public washrooms [49]. A hotel as a facility provides different services to its customers. Basic services are lodging and food and beverages but it can accommodate all kinds of other activities, such as entertainment, training events, cultural activities, exhibitions, conferences, education, etc.

Accommodation buildings are divided into two basic types, which are: full-service and limited-service hotels, depending on the number of services provided. Full-service hotels offer full service around the clock, seven days a week. Such an operation demands intensive use of energy/water/consumables for lodging, kitchen, restaurant, conference and recreation/relaxation premises, etc., which also generates significant waste.

Studies in many countries detected that accommodation buildings are one of the most energy intensive building categories. A study carried out on 158 Hellenic hotels to estimate the energy saving potential. Where he found the annual average total energy consumption in those hotels was 273kWh/m^2. On other hand, the annual energy consumption in office and school buildings was only 187kWh/m^2 and 92kWh/m^2 respectively [50].

In Europe, a study of energy consumption in 184 Hilton and Scandic Hotels conducted and mean energy use indicators of 364 kWh/m^2 and 285 kWh/m^2 were reported for both hotel groups [6]. An investigation of the energy performance of 19 Ottawa hotels in Canada, reported the average energy use intensity to be 612kWh/m^2 [51]. Another study carried out in 36 hotels in Hong Kong reported the mean energy use intensity to be 542kWh/m^2 [52].

As mentioned before, the multifunction of accommodation sector, it requires different needs of energy use. Therefore, energy in various forms (e.g. electricity, diesel, and LPG) is often required in a building [53]. further, one energy form is sometimes used for multiple tasks, for example, electricity for lighting, air conditioning as well as many other functions. The variety of fuel depends on the climate zone it is located in. typically, gas and oil used more in cold climate for heating, while electricity may require more for cooling in tropical or hot climate.

In Ottawa hotels, three different types of energy used. Electricity and gas represented 36% and 51.1% of the total energy consumption respectively, with the rest provided by steam [51]. The percentage of total energy consumption supplied by electrical is much higher in Hong Kong hotels, 73% of the total [54]. A study of hotels in New Zealand had a similar result with that reported in Hong Kong, which shows that electricity provided more than 70 % of the total energy requirements [48].

The percentage of different fuels depends on accommodation type and class. For instance, accommodation sector in Vietnam has different proportion of electricity use. In resort and 4-star hotels has relatively low rate of electricity use 66% and 76% respectively, whereas the 2 and 3- star hotels depend nearly fully on electricity. It accounts over 90% of total energy consumption [3]. A possible reason is determined by government's energy policy and regulations on estate development.

2.3.2. Occupancy and Accommodation Energy Consumption

As a general anticipation, many would expect that a building's energy consumption is affected by its occupancy rate, but most studies have not proven a clear correlation between energy consumption and occupancy rate. For instance, a study of energy use intensity against the annual mean occupancy rate of 16 Hong Kong hotels was conducted, and no clear relationship could be addressed [52]. In New Zealand's B&B and backpacker, Correlations between energy consumption and occupancy rate were plotted to be statistically significant, though the R^2 were generally low [48].

However, some studies found statistical relationship between energy consumption and occupancy rate in individual hotels. In Hong Kong, a regression model assumed to correlate a hotel's monthly total electricity consumption with outdoor air temperature and number of guests. In that case, the high R^2 of 0.93 shows a strong correlation [52]. An exponential relationship between monthly electricity consumption and number of guests in a five-star Cyprus hotel specified by [55]. The regression model supposed accordingly fits the data very well, with an R^2 of 0.95.

It is possible to consider the occupancy rate for citizens and foreigner in Japanese case because the behavior of both cases are not similar. In Turkey, the occupancy rate among citizens and foreigners are different from city to another[12]. This separation can help to understand the energy use in accommodation buildings

Finally, the improving of energy performance of accommodation facilities will enhance good price for gusts that means increasing the occupancy rate in more efficient buildings.

2.3.3. Weather Conditions/ Energy Use of Accommodation Buildings

Buildings experience different weather conditions depending on the climate zones where they are located. To maintain the same level of indoor comfort, those in very cold or hot climates usually need more energy intensive than other buildings in more temperate climates. In some cases, the same building also goes through very different weather conditions; in subtropical regions, for instance, a building may have both cold winters and hot summers, hence heating and cooling in two seasons.

In Hong Kong hotels, a study showed very good correspond between monthly electricity use and the match monthly mean outdoor air temperature [54]. A study in Swedish hotels reported confused results. Some hotels indicated significant negative correlation between electricity use and temperature, other hotels showed no significant correlation [56].

Weather will affect energy consumption by changing how consumers react to weather condition[57].

Recently, researchers focus on sustainability; how climate change will affect tourism and how destinations can be adapted. Therefore, significant attention is paid to hospitality sector as a contributor to greenhouse gas emission and how to mitigate it.

2.4. Approach for Developing a Benchmark System

Benchmarking have been used widely in industrial sector to evaluate the performance of different manufacturing process through production line. The concept is used in other sectors and fields such as business, marketing and energy field. The benchmarking process verifies based on the applied scope and the aim of the benchmark system, different approaches and techniques can be used to perform benchmark study.

There are two fundamentally different approaches that are used to analysis or design systems in engineering disciplines: top-down and bottom-up. A top-down approach refers to the way in which a system is designed by first formulating an overview without details of the sub-systems. The bottom-up approach on the other hand refers to ways in which whole-building energy benchmarks are built up by aggregating system-level information. For example, benchmarks for accommodation would be derived by first estimating the energy performance of individual systems, such as the ventilation or condition systems. These system-level consumption figures would then be aggregated together into a single EUI representing the hypothetical performance of a whole building. The system would then be refined further, subject to the availability of more detailed information. A bottom-up approach on the other hand would involve specification of lower-level system information that would then be used to build up a more precise overview.

In the field of benchmarking, the top-down approach can be referred to ways in which energy benchmarks are derived based on building-level energy performance figures. These benchmarks are usually expressed as energy use intensities (EUI) and indicate how other buildings with similar demand use energy.

2.4.1. Defining A benchmark System

In the Cambridge dictionary, benchmark is defined as “to measure the quality of something by comparing it with something else of an accepted standard”[58]. The practical definition of benchmarking as developed at Xerox. In the built environment, often benchmarking is applied as part of an energy management practice in existing buildings to evaluate and improve their energy efficiency according to CIBSE 2012[59].

Building energy performance is a term to refer the quantity of energy consumed in a building, which can be introduced by one or more indicators [60]. For example, a widely used indicator is the annual building energy use per gross floor area, which has the unit of KBtu/yr-ft^2. Generally, building energy performance assessment can be divided into two categories: energy classification and performance diagnosis. Energy classification is defined as “providing uniform means to communicate a building’s relative energy efficiency and carbon emissions to both the owners and the public to encourage ongoing efficiency and conservation gains” [61]. The concepts of benchmarking, rating and labeling all under this category.

Building energy benchmarking is a simple, straightforward and low-cost method to inform decision makers of a facility’s energy performance score by comparing a whole-building energy performance of the assessed building against reference benchmarks. Therefore, the objectives of building energy benchmarking can be summarized as: 1) introducing a reference to assess the relative energy performance of the target buildings. 2) alerting concerned stockholders to poor energy performers. 3) indicating the need for energy management to decision-makers, such as building owners, architects, engineers, and energy managers; and 4) providing a pre-retrofit baseline, so that it could be possible to estimate energy savings of installed conservation measures (ECMs) during the retrofit.

Building energy benchmarking belongs to a sub-category of building energy performance assessment. Building energy performance is a term to refer the quantity of energy used in a building, which can be represented by one or more numeric indicators [60]. Building energy performance assessment can be generally classified into two categories: energy classification and performance diagnosis. Energy classification is defined as "providing uniform means to communicate a building's relative energy efficiency and carbon emissions to both the owners and the public to encourage ongoing efficiency and conservation gains" [61]. The concepts of benchmarking, rating and labeling all belong to this category.

Building energy benchmarking is a simple, straightforward and low-cost method to inform decision makers of a facility's relative energy performance level by comparing entire of building energy performance of the assessed building(s) against reference benchmarks [62].

2.4.2. Process of Developing Benchmark

The building energy benchmarking process consists of four stages, shown in Figure 2-1 [1]. First, the building energy database needs to be established in order to collect and archive the building energy information. Then, energy usage of the assessed building(s) should be calculated, and an indicator of the building energy performance should be selected and quantified as well. Third, conduct a comparative analysis in order to define best practice examples, as well as the worst case scenario. Last, cost-effective ECMs will be recommended.

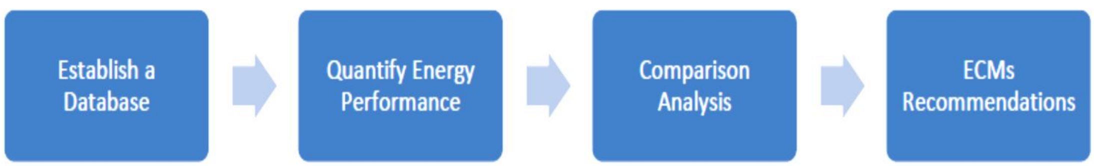

Figure 2-1: Building Energy Benchmarking Process

The first step in a benchmarking process is to collect building energy related information with a representative sample of buildings. It is difficult and time-consuming to collect such amount of data including not only energy consumption, but also variables having influence on energy performance, such as number of occupancy, activity type, system specifications, temperature set points, site information, etc.

In the second step, energy consumption needs to be quantified first in order to obtain the energy performance indicator. The next step is comparative analysis, which is the core of benchmarking. In this step, building energy performance indicator of the assessed building(s) is evaluated against certain criteria, such as available reference. The analysis helps to identify the relative energy performance of the assessed building(s), thus enabling ranking the candidate buildings for future energy plan. The analysis' results might also give guide on potential energy management, which would help to improve energy efficiency of the buildings.

2.4.3. Requirement for Setting up a Benchmark System

There are many goals of benchmarking of commercial buildings. Therefore, many approaches are utilized to benchmark buildings according to proposed aim and availability of data. In the same time, establishing benchmark imposes certain requirements to develop robust benchmark. Database is an essential part of setting a benchmark, sufficient dataset with acceptable quality are required. Analysis approach is another part to interpret dataset into guideline for compression process. Different factors determine the adequate approach to analysis dataset such as aim, scope, accuracy, complexity and the character of dataset itself. Statistical, engineering and simulation approaches are used in different studies to analyze energy performance for various buildings categories. Main approaches are listed in the table (3-1); These methods are classified according to different aspects related to usability, accuracy, structure and required inputs.

Table 3-1: Approaches for Developing Benchmark

Methods	Complexity	Usability	Accuracy	Inputs
Simulation (Engineering)	Fairly high	No	Fairly high	Detailed
Statistical	Fair	Yes	Fair	Historical data
Artificial Neural Networks	High	No	High	Historical data
Support vector machines	Fairly high	No	Fairly high	Historical data

3. Analysis of Energy Performance in Accommodation Building

This chapter consists of the description of database of accommodation buildings. Database includes energy consumption data and building's characters. The database was quantified to have more clear understanding of the impact of different factors.

3.1. Database for Energy Consumption of Commercial Buildings (DECC)

The availability of data of energy consumption is the main obstacle to assess the energy consumption of commercial buildings. There are many reasons make the accessibility into data related to privacy issue or lack of documentation. The quality of data, collecting interval and size of data play an essential role to assess the energy performance of buildings.

The data used in the present analysis was taken from two different sources. First, Database for Energy Consumption of Commercial Buildings (DECC) from Japan Sustainable Building Consortium (JSBC). Second, Occupancy data from Ministry of Land, Infrastructure, Transport and Tourism (MLIT) under project name (overnight trips statistical survey).

The "Data-base for Energy Consumption of Commercial building" (DECC) disclosed the energy consumption data of commercial buildings. The DECC project established with the support of the Ministry of Land, Infrastructure, Transport and Tourism, and the energy industry. In addition, DECC research committee collected the data examined thereafter and updated the consumption data as the 2013 version, and will be disclosed later.

The DECC currently allows users to access data for 38,273 samples. Approximately 9,000 samples were added in 2006, 16,000 samples in 2008. The data collected focused mainly on areas that were under an advisory to reduce power consumption. Furthermore, the DECC contains a statistically significant number of data sets for most building types.

There are few studies that used the DECC for analyzing the energy performance of commercial buildings in Japan from different prospective such as the impact of temperature on energy consumption[63] or comparing the energy consumption based on floor area of retail buildings[64]. Except the combination between department store and shopping center, these retail categories showed a significant difference in the total floor area and/or annual energy consumption per total floor area. Another study depended on DECC to develop a nationwide database on CO_2 emission and water usage of commercial buildings[65]. The estimation of energy saving of office buildings in 2009 using DECC was analyzed[66]. Not only for energy analyzing but also for other aim such as analyzing water consumption of buildings[67].

The overnight trips survey established to investigate the actual number of guest of accommodation facilities on national scale. The survey classified the monthly data according to the purpose of visit (tourism or non-tourism), the number of employee, international or domestic guest and the other criteria for 2007 until 2015. The survey includes the number of surveyed, number of guest and occupancy rate for each prefecture in Japan. In addition, a franchised hotel

Kanto area will be examined in the current study to examine the used data that are used from previous sources. The franchised hotels contains six block in different location with different size.

As described earlier, the data of energy consumption and occupancy rate contain manifold data in many categories. Therefore, more filtration and classification of obtained data have to take place to minimized the size of unused data and ensure the quality of selected database. For example, DECC has eight main regions as shown in figure (3-1). Each region classified commercial buildings into 12 categories. While each building ID has a reference letter to indicate its main region.

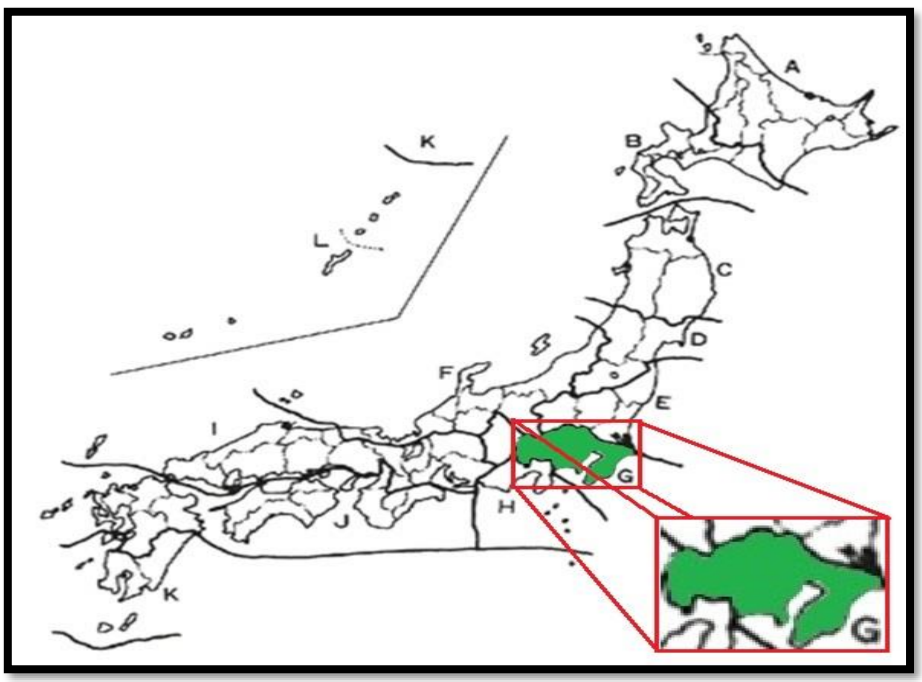

Figure 3-1: The Regions Classification by DECC

The current study depends on the DECC segments to ensure accurate usage of data. According to coding system of DECC, it is possible to recognize the sample location as regional scale. Unfortunately, it is not possible to have more detailed location. Current study cover Kanto region that have similar climate zone that will eliminate the effect of location for selected samples.

Kanto region was selected as case study; it includes Kanagawa prefecture, Tokyo City, Chiba city, Saitama city and main part of Gunma city. Kanto region are coding with “G” as ID for all commercial buildings. Some part of selected cities are not included in this survey but such point will not affect the quality of database. In addition, DECC research committee classified the commercial buildings into 24 categories as shown in table (3-2). DECC has variety of commercial buildings with different functions. The main factor of this classification is building function that characterizes the energy consumption trend for each category. In the same time, each category has various type, size and class of building such as accommodation, retail, food services and other.

Table 3-2: Component of Building ID, DECC project, Japan Sustainable Building

Survey Region ID							
A	Hokkaido	B	Tohoku	C	Hokushinetsu	D	Kanto
E	Chubu	F	Kansai	G	Chugoku ,Shikoku	F	Kyushu
Building Activity ID							
01	Office	02	Information Center	03	Public Assembly	04	Department Store
05	Mercantile(Retail)	06	Convenience Store	07	Food Service	08	Accommodation
09	Health Care	10	Welfare Facility	11	Kindergarten/ Preschool	12	Education(K1-K9)
13	Education(K10-K12)	14	Education(Higher education)	15	Laboratory	16	Theater
17	Exhibition Facility	18	Sport Facility	19	–	20	Complex Facility
21	Appliance Stores	22	Large Suburban Store	23	Retail Store	24	Barber Shop
99	Other						

More details about each region or category can be obtained from the official guide of DECC online where it can provide more details about the number of surveyed samples, total floor area and other statistical information[68]. In addition, some of previous studies conducted statistical studies regarding either overall commercial buildings or certain types of buildings of DECC[64][65][66][40].

For example: D08000001 refers to building in Kanto, accommodation function. Also overnight trips survey includes too much information regarding tourism situation in accommodation sectors. Include the original destination of occupant either domestic (with same prefecture or out of it) or international occupant with his/her nationality.

The selection of Kanto region as a case study is related to different reasons. First, the region contains the biggest number of collected samples of DECC survey. In addition, the selected region has the high annual energy consumption comparing to other region. Figure 3-2 shows the number of samples and the annual primary energy intensity of all eight regions of DECC survey.

The total floor area of surveyed accommodation facilities of Kanto region is about 5 million square meter, which is the biggest floor area of surveyed accommodation facilities of other regions. Another reason of selecting Kanto region is the population of it, since 1/3 of total population of Japan are lived in Kanto region. Kanto region has a homogenous geographic character; this property eliminates the effect of climate zone during analyzing the energy consumption of region's samples. The temperature and other weather indicators are nearly similar within Kanto region.

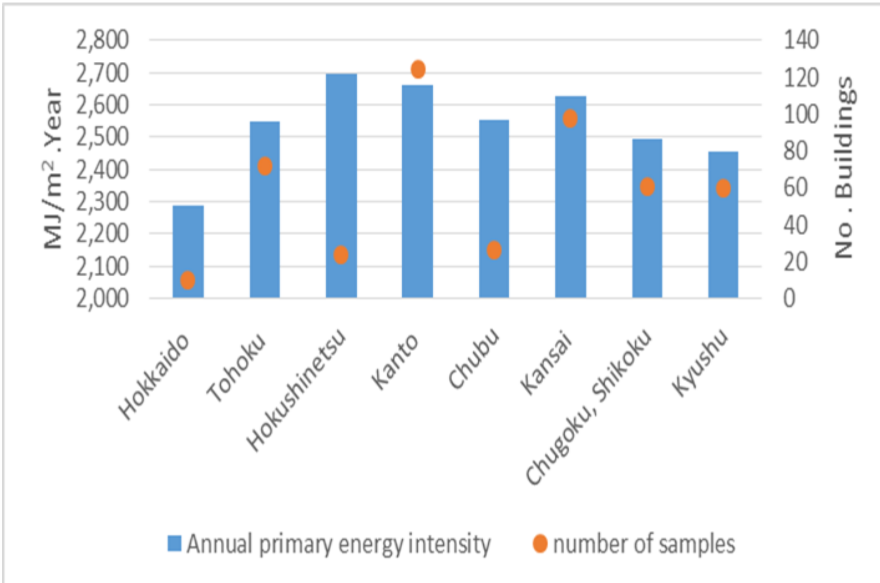

Figure 3-2: Annual Primary Energy Intensity and Number of Buildings in Japan (Main Regions)

There are many factors and variables related to building design or operational parameters. They can affect the energy consumption of accommodation building. Some of variables have no high impact on energy use, some of them have no clear impact on energy consumption or it can not be measured easily such as gust behavior. Recent study focuses on variables that have clear correlation with energy consumption of accommodation buildings to obtain accurate estimation.

The database consists of many factors and variables of accommodation buildings related to building character such as building age, number of stories and area category. Some of operation parameters are introduced such as operation hours, cooling hours, heating hours and the cooling/heating periods.

The classification of effective factors was done using ANOVA test as common statistical method. Table (3-3) shows the summary of R and R square for four variables; cooling hour, number of stories, heating hours and operation hours. These values evaluate the impact of each variable on energy use of accommodation buildings in Kanto.

Table 3-3: Model summary of number of stories, heating, cooling and operation hours

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.266[a]	.071	.069	955.44101
2	.296[b]	.088	.084	947.55002
3	.314[c]	.099	.093	942.98382
4	.330[d]	.109	.101	938.78386

a. Predictors: (Constant), cooling

b. Predictors: (Constant), cooling, stories

c. Predictors: (Constant), cooling, stories, heating

d. Predictors: (Constant), cooling, stories, heating, operation

Table (3-4) show the ANOVA results to test cooling hour, number of stories, heating hours and operation hours. Where F value and ρ value are calculated for previous variables.

Table 3-4: the ANOVA results of DECC variables

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	31330244.793	1	31330244.793	34.321	.000[b]
	Residual	412616116.687	452	912867.515		
	Total	443946361.480	453			
2	Regression	39015545.636	2	19507772.818	21.727	.000[c]

	Residual	404930815.844	451	897851.033		
	Total	443946361.480	453			
3	Regression	43798041.819	3	14599347.273	16.418	.000[d]
	Residual	400148319.661	450	889218.488		
	Total	443946361.480	453			
4	Regression	48235863.898	4	12058965.975	13.683	.000[e]
	Residual	395710497.582	449	881315.139		
	Total	443946361.480	453			

a. Dependent Variable: Primary

b. Predictors: (Constant), cooling

c. Predictors: (Constant), cooling, stories

d. Predictors: (Constant), cooling, stories, heating

e. Predictors: (Constant), cooling, stories, heating, operation

3.2. Quantitating Energy Performance

The investigation will examine certain variables according to DECC database. The relation between this variables and energy consumption are evaluated statistically to determine if there is any relation or impact. For each variable, the descriptive findings have been shown separately into following graphs:

Building Size

The total floor are is one of most important factor that reveal the energy intensity in certain facility. In addition, it can be used to normalize the energy consumption while comparing groups of buildings with different area. In this study, all accommodation buildings are classified into 5 categories of size. As shown in table (3-5)

Table 3-5: classification of the building floor category (exclude indoor parking area)

Area Category	Minimum floor area m^2	Maximum floor area m^2
1	-	300
2	300	2000
3	2000	10,000
4	10,000	30,000
5	30,000	-

The figure (3-3) shows buildings belong to category 3 has highest number of buildings with various level of energy intensity. In most case, this category includes the business hotels class which are the preferable category for wide occupant.

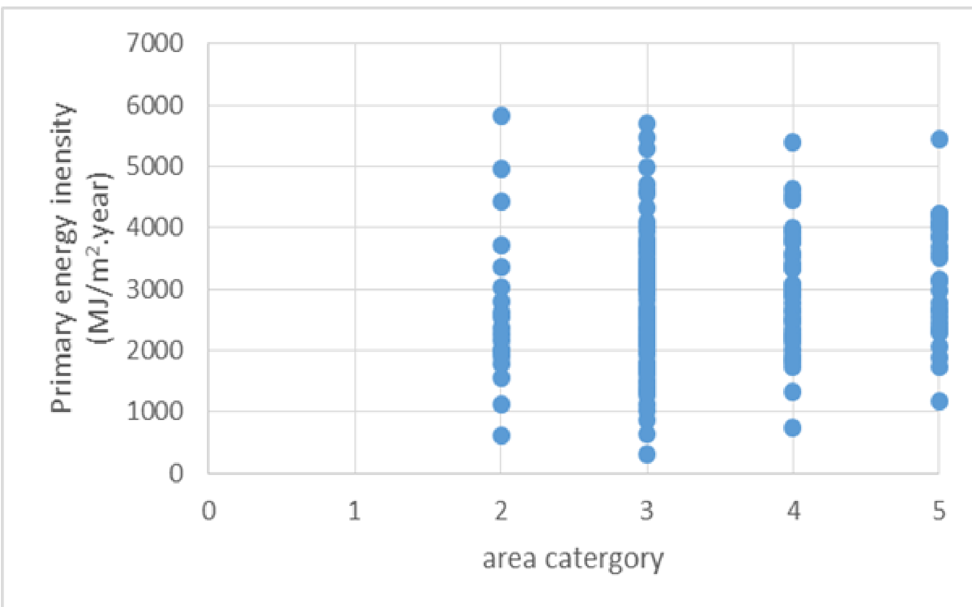

Figure 3-3: Annual Primary Energy Intensity and Area Categories. 2007

It can be seen that category 5 which has the highest floor area has not the highest average of primary energy. It means there is no clear relation between floor area size and the energy consumption. The figure (3-3) shows close energy consumption trend between categories 4and 5 that proves the previous argue.

The category 3 has the highest average of energy consumption; this result requires more concentration of buildings in this category.

Building Construction Date

The construction date of buildings indicates the age of building structure, it is an important factor that reflect building ability to conserve energy through building structure itself. Other factors are related to building age can be considered in term of energy conservation such as maintenance and renovation of building. These two factors inform auditors how much efforts have been done to maintain buildings condition in term of energy conservation. In DECC, most of accommodation buildings are constructed in period between 1970~1990. As it shown in figure (3-4) the buildings which are constructed in 1990 has the high primary energy intensity.

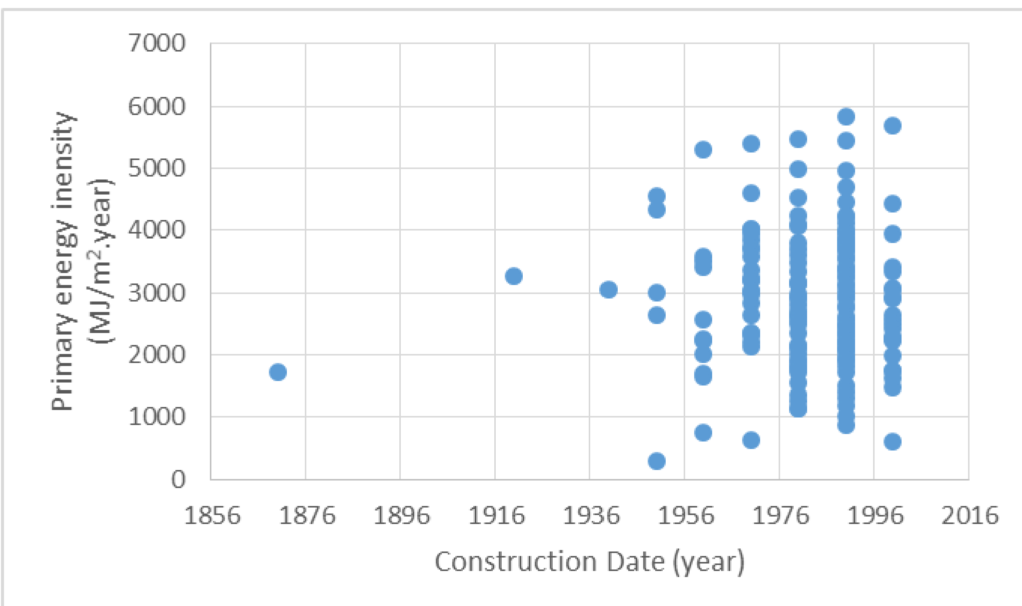

Figure 3-4: Annual Primary Energy Intensity and Construction Date. 2007

However, the construction date or building age is not enough to determine the real relation between building age and energy consumption. The renovation history or maintenance schedule are important factors to estimate the correlation between energy performance and buildings age. Therefore, future studies have to consider these factors in case of considering building age as an important variable.

Number of Building Floors

Zmeureanu *et al.* (1994) made a breakdown of the floor areas in 16 Ottawa hotels. He found that guest rooms cover, on average, 85 per cent of the total floor area, which is followed by convention centers, with 5 per cent of the entire floor space. For the rest area, restaurants cover 3 per cent, and retail stores and swimming pools, each has 1 per cent share of the total floor area. The energy efficiency study in Australia's hotel industry used allocation of floor area as one of the criteria to define hotel categories. Those in the "business hotel" category must have significant areas for functions, dining and entertainment; whereas restaurants, bars and function rooms only occupy a relatively small proportion of the total floor area in "accommodation hotels" (Australian Government, 2002). The difference of energy use intensity between those two hotel categories demonstrated that, among other factors, allocation of floor area in a hotel might have significant effect on its energy use.

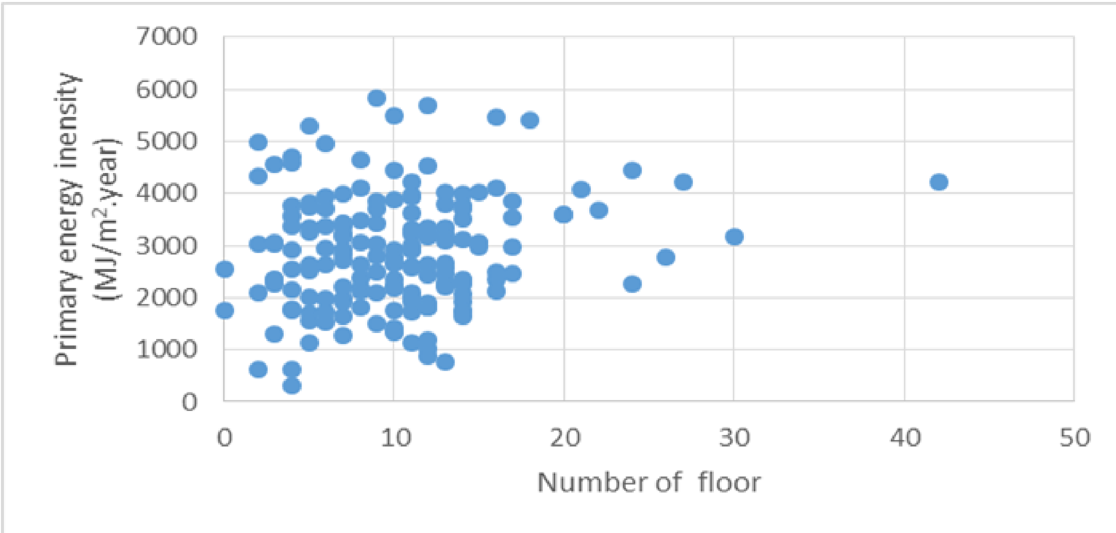

Figure 3-5: Annual Primary Energy Intensity and Number of Floors. 2007

The number of floors accounted as building's size, it can be seen that most of buildings of DECC samples in 207 are between 5 floors and less than 15 floors. The average of primary energy intensity is 3000 MJ/m^2.year figure (3-5). As we noticed before, most of building are within category 3 that represents the business hotel. This category of buildings are not considered as high-rise buildings as general case.

Daily Operation Hours

In Japan, accommodation buildings have various working hours. Most of them are working 24 hours such as city/ business hotels that provide services over the year. Family and seasonal facilities have limited time of working hours 12 either per day or during certain seasons. DECC includes some of family or seasonal facilities, the majority are 24hours facilities. As expected, high-energy use is consumed in building which work 24 hours comparing to other category. Some of buildings work less than 24 hours and have low energy use intensity than accommodation facilities of 24 hours of operation. Most of these low energy use building belong to traditional hotel or family-run guesthouses figure (3-6).

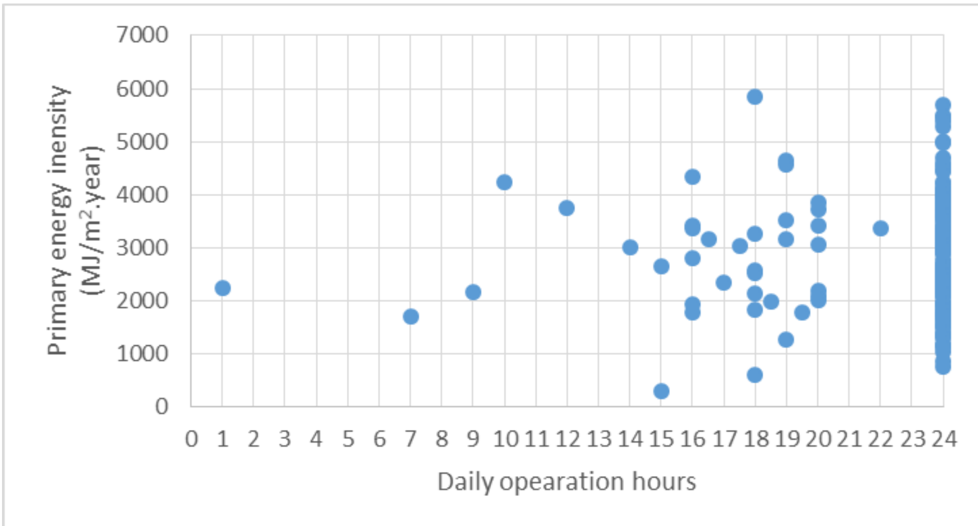

Figure 3-6: Annual Primary Energy Intensity and Operation Hours. 2007

Most of facilities that work less than 24 hours are seasonal accommodation and they have various facilities such as big restaurant and halls.

Daily Condition Hours

Same argument can be applied in case of condition system use in accommodation facilities. Whenever facility runs for 24 hours, the condition system will work synchronously. Buildings with 24 hours' operation, the accommodation facilities that use condition system for entire year has the highest number of buildings with high-energy intensity. Followed by 10 month of condition. In addition, the average of annual primary energy intensity of buildings with 12 months of condition is 3000 MJ/m^2.year. As in figure (3-7).

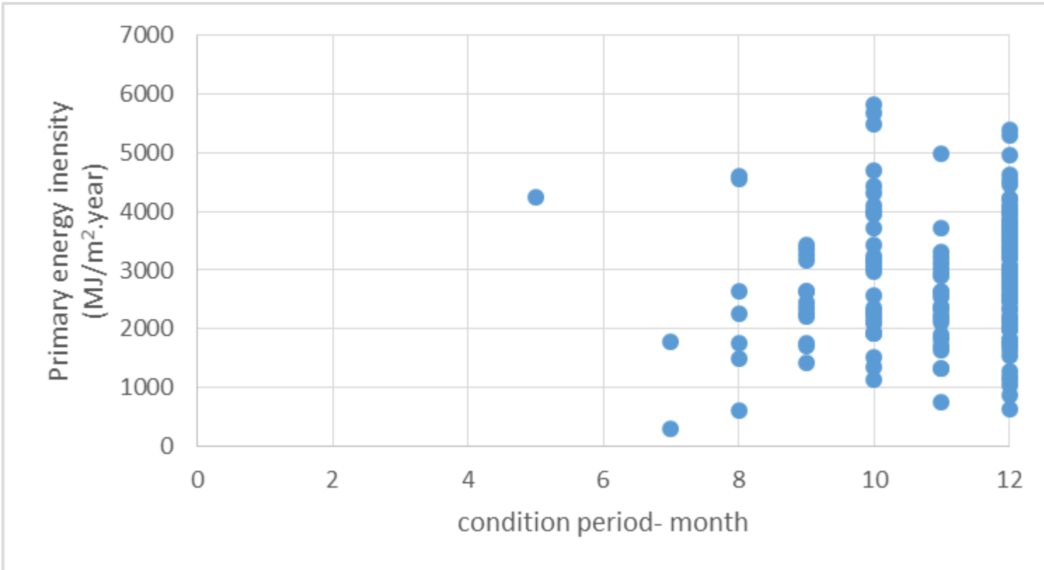

Fig 3-7: Annual Primary Energy Intensity and Using Condition Period. 2007

To have more accurate analysis of the contribution of air-condition system on energy consumption, other parameters are required. Insulation, window/wall ratio and the type of condition system are important parameters that affect the performance of condition system in accommodation buildings. In addition, control system and smart management for using condition system in rooms and other spaces will improve energy usage in such buildings.

<u>Temperature Correlation</u>

The weather condition plays an essential rule to drive the energy consumption of accommodation buildings. These rules differs from one energy form to another form. Because of the mix use of energy in accommodation buildings, the intensity of using fuel can be changed according to season and temperature situation.

For instance, the electricity use is mainly consumed through cooling system during summer, lighting through whole year and ventilation through whole year. Therefore, there is recognized increase in electricity consumption during summer but it becomes steady for other seasonal periods. Figure (3-8) shows clearly this results for DECC samples in 2012.

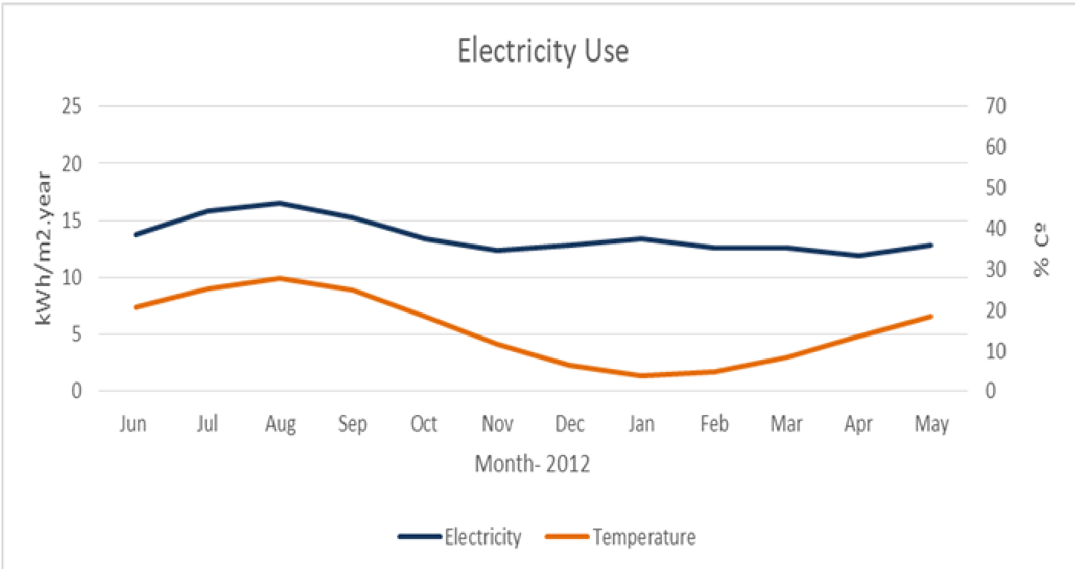

Figure 3-8: Correlation between Electricity and Temperature

In case of City gas usage, gas consumption has different trend because mainly it is used for cooking and hot water supply. Recently, some buildings shift to using gas more than electricity in energy supply to reduce the emission and have more dependency from grid system. Generally, city gas consumption is effected by use intensity and temperature either in summer or winter. Because of daily usage of the hot water, it becomes higher during winter time more than summer. In figure 30-9, it can be seen obviously the increase of gas consumption effected by high occupancy during summer especially in August; also high consumption during cold weather in winter especially during end of January and during February.

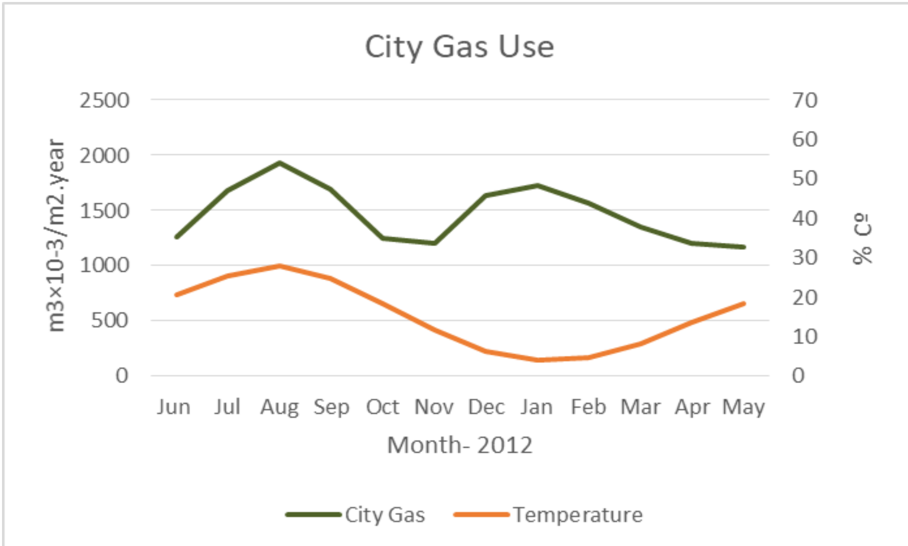

Figure 3-9: Correlation between City Gas and Temperature

The consumption of propane gas (LPG) and other liquid oil, it is affected by low temperature because LPG are used in some family hotel for cook use and heating and hot water supply during winter. It is clear form figure (3-10), the steady use of LPG during warm weather then increase during cold weather.

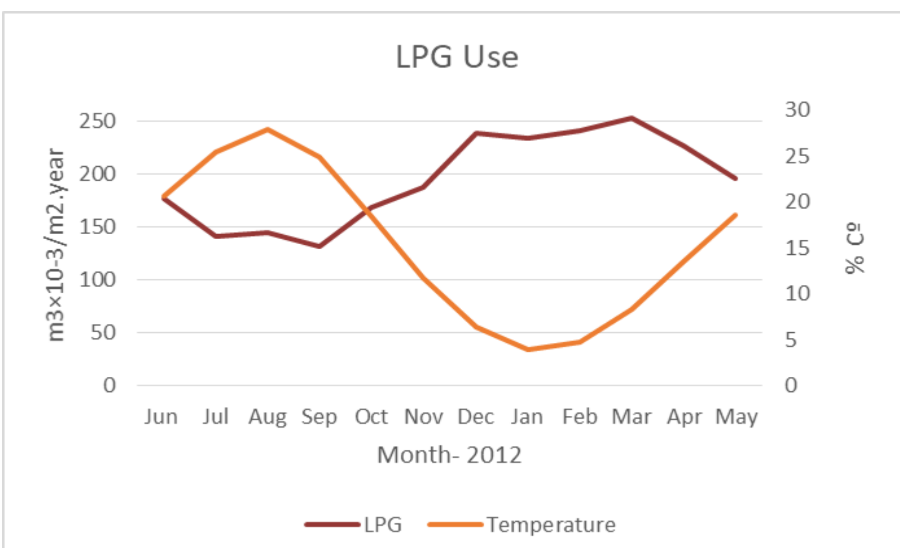

Figure 3-10: Correlation between LPG and Temperature

Similar trend can be noted for liquid oil which is used mainly for hot water supply and heating in some accommodation building especially the small size buildings. In figure (3-11), the usage of oil fuel are steady during summer season then increase during winter especially during end December and January.

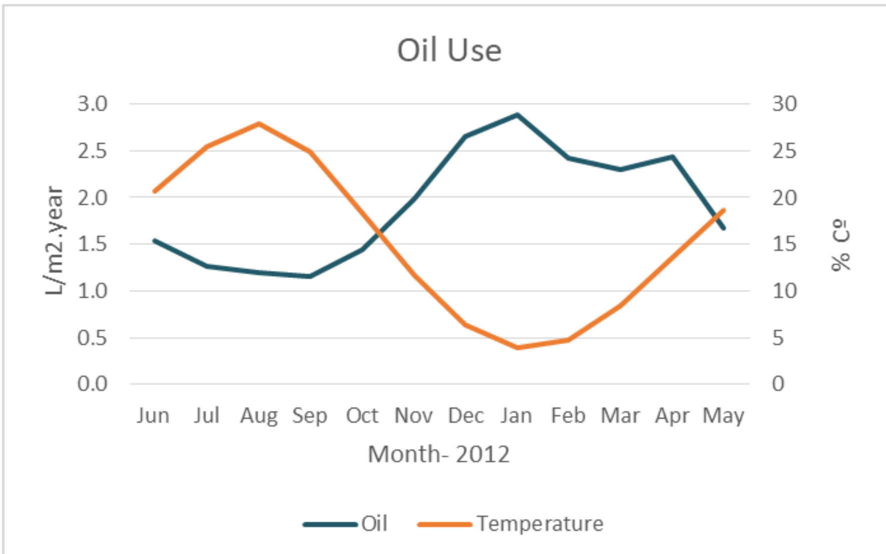

Figure 3-11: Correlation between Oil Fuels and Temperature

To sum up, ambient temperature has clear effect on energy consumption of all energy forms in accommodation building. The heating degree-day (HDD) and cooling degree-day (CDD) are often used to consider the effect of temperature on energy consumption of buildings.

3.3. Clustering the DECC Samples

Usually to investigate a group of buildings with various characters, it is more accurate to classify similar buildings in separated groups. Class, size and other characters can be main factors to cluster samples. Clustering the DECC sample is an important step to group similar building in homogenous groups.

Mainly the size of area is the most important factor of clustering process because it reflects the intensity of energy consumption of building. DECC has determine 5 groups of buildings based on its size. Using K-means method, the selected samples are grouped into four different clusters up to its size. Table (3-6) shows the average primary energy consumption of each group as center of cluster and primary energy is the dependent variable to measure the distance between samples as clusters.

Table 3-6: the center of DECC clusters

Cluster Centers

	Cluster			
	1	2	3	4
Primary Energy	2273	2700	3023	3337

The clustering enhances more homogenies samples in term of building size, other aspect can be applying if it is applicable such as building class or location. K-means method was used to cluster the DECC samples into 4 clusters. Each cluster is defined in the following table (3-7):

Table 3-7: Clusters of DECC database

Cluster No.	Area Category (DECC)	Size category (m^2)	Sample No.
Cluster 1	Area 2	300~2,000	29
Cluster 2	Area 3	2,000~10,000	157
Cluster 3	Area 4	10,000~30,000	101
Cluster 4	Area 5	≥30,000	52

The four clusters in Table (3-7) will represent the total sample of current study either in analyzing or benchmarking processes.

3.4. Correlation between Energy Use and Occupancy

The correlation between different energy forms and occupancy rate cannot be concluded easily. Therefore, as previous studies which is done in different climate zones and accommodation buildings types R^2 has different values related to energy form, period of time, the accommodation type and climate zone. Hence, in this study breaking-down the energy sources and entire year is used to illustrate the correlation easier and more understandable.

The regression model is applied to find out relation between energy consumption and different parameters of building such as age, number of stories, operation hours, cooling period and heating period.

On the other hand, a correlation equation (1) is used to find out the correlation between energy consumption and Occupancy rate. In addition, a breakdown approach was applied on energy sources and on entire year of working period of accommodation buildings. This approach enhances better understanding of energy trend for each type of energy form.

$$R^2 = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \qquad (1)$$

Where: R^2 correlation coefficient

x Energy use $\bar{x}$ the average of energy use

y Occupancy rate $\bar{y}$ the average of occupancy rate

The accommodation buildings are multi-function buildings with variety facilities, therefore different forms of energy are used to perform these functions.

Beside to guest facilities, the location and size of accommodation building require variety forms of energy sources.

Electricity is the primary energy source to run air condition, lighting and other tasks. Natural gas (called city gas in Japan); it is used widely as better energy type to power heating equipment in accommodation facilities.

Propane gas (LPG) is consumed also in Japanese accommodation buildings especially in family accommodation's facilities; it is used mainly for heating, hot water supply and cooking. Last source of energy is oil fuel (diesel and kerosene) which is mainly used either for heating or to produce steam.

The study will breakdown the different types of energy to correlate the relation between energy use and occupancy rate separately. This procedure will enhance more deep understand of the expected relation between energy consumption and occupancy rate. Also will enhance more useful implementation of expected results in benchmarking energy performance of accommodation buildings.

3.4.1. Electricity Use

The electricity use is considered as the main form of energy use in accommodation for air-conditioning, lighting, ventilation and other utilities. From figure (3-12), it can be seen that the maximum electricity consumption corresponds to August where the highest temperature is recorded with longest vacation period in Japan's calendar. Therefore, the usage of air-condition system consumes the highest level. It is clear that same trend of electricity consumption is illustrated for 2007, 2010 and 2012 data.

The electricity consumption during the hot season is clearly correlated to temperature increase. However, when temperature decreases in cold periods the electricity consumption is increased but still lower than in hot season. This is because the other energy sources are being used for heating. The electricity use intensity has clear correlation with mean air temperature R^2= 0.7.

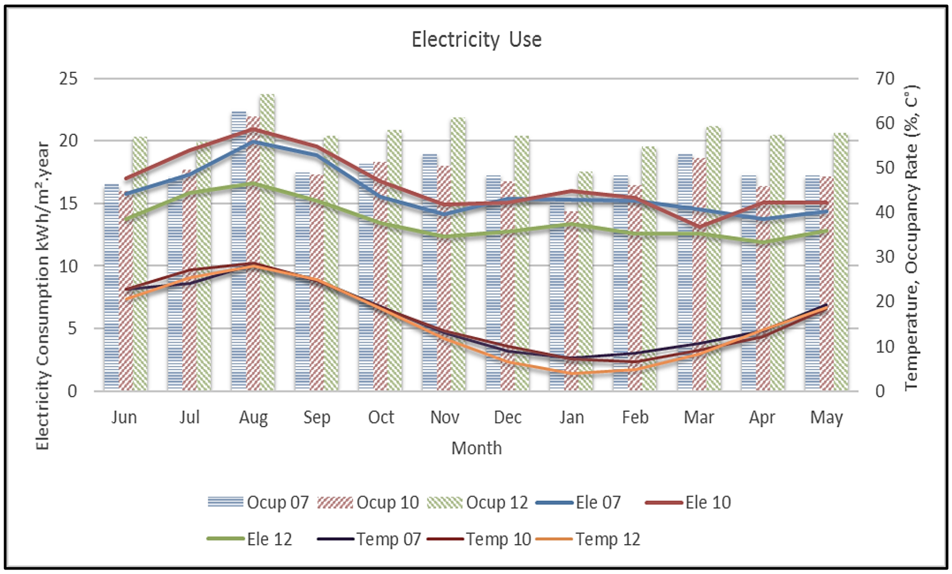

Figure 3-12: Electricity Use Intensity with Occupancy Rate and Mean Air Temperature

On the other hand, the electricity consumption has two different correlations with occupancy rate during the whole year. The breaking down of entire year will enhance better understanding for consumption trend. It can be seen clearly in figure (6) that from June to October the electricity consumption is correlated with occupancy. It has considered value of R^2 0.70, 0.68, 0.52 for 2007, 2010 and 2012 respectively. In other hand, the period from November until May has negative correlation with occupancy rate. This negative value of R^2 refers to low correlation with occupancy rate, it is more affect by reduction of mean air temperature.

3.4.2. City Gas Use

Typically, city gas used in accommodation facilities to supply hot water, heating and cooking. Figure (3-13) shows the trend of city gas usage.

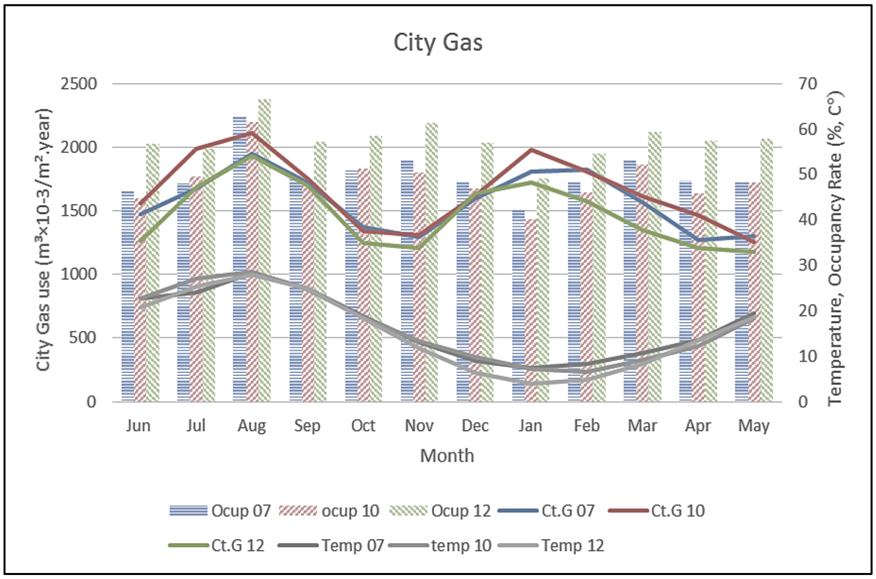

Figure 3-13: City Gas Use Intensity with Occupancy Rate and Mean Air Temperature

City gas is used broadly in cold season and during high occupancy rate, but it shows different correlation with occupancy rate. For instance, from June to October R^2 = 0.71, 0.57, 0.57 for 2007, 2010 and 2012 respectively. The acceptable values reflect considered correlation because of the high rate of occupant during hot season and summer vacation.

However, in second period, the correlation records negative value because during this cold period the intensity of city gas usage depends on mean air temperature more than on occupancy rate. It is important to take in account that the majority of air-condition system usage are not in guest room only, but also it will be used heavily in other facilities such as restaurant, halls reception and other which are not related to occupants' number.

3.4.3. LPG Use

LPG usage has low percentage comparing to city gas, only within small accommodation such as family hotels or Ryokan it can be used. The propane gas is used mainly for hot water supply, cooking and heating. The main difference between city gas and LPG is the Conversion factor of Primary Energy 45 MJ/m3, 103.9 MJ/m3 respectively.

The LPG trend are too different from city gas as shown in figure (3-14). It can be seen good value R^2= 0.89, 0.70 for 2007 and 2010 respectively within the period from June to October, but it has negative low value R^2= -0.12 for 2012 in the same period.

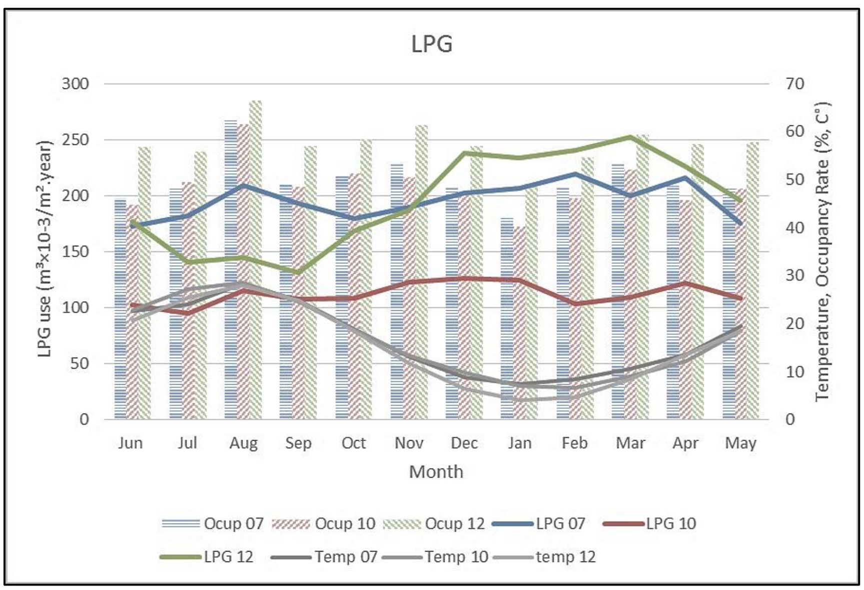

Figure 3-14: LPG Use Intensity with Occupancy Rate and Mean Air Temperature.

The same negative low values are observed for the second period from November to May R^2= -0.25, -0.35, -0.36 for 2007, 2010 and 2012 respectively. These different values indicate low correlation or not clear correlation between

LPG consumption and occupancy rate. It is more correlated with mean air temperature.

3.4.4. Oil Fuel Use

The oil consumption in surveyed buildings includes diesel and kerosene. It can be noticed as shown in figure (3-15) that oil consumption increases significantly during cold weather due to use it to produce steam and other heat application.

Oil usage trend has high R^2 = 0.90 and 0.89 for 2007 and 2010 respectively from June to October, but low negative correlation R^2= -0.32 in 2012 in the same period. The high value presents the impact of high number of occupants who used to enjoy hot spring (Onsen) during summer vacation.

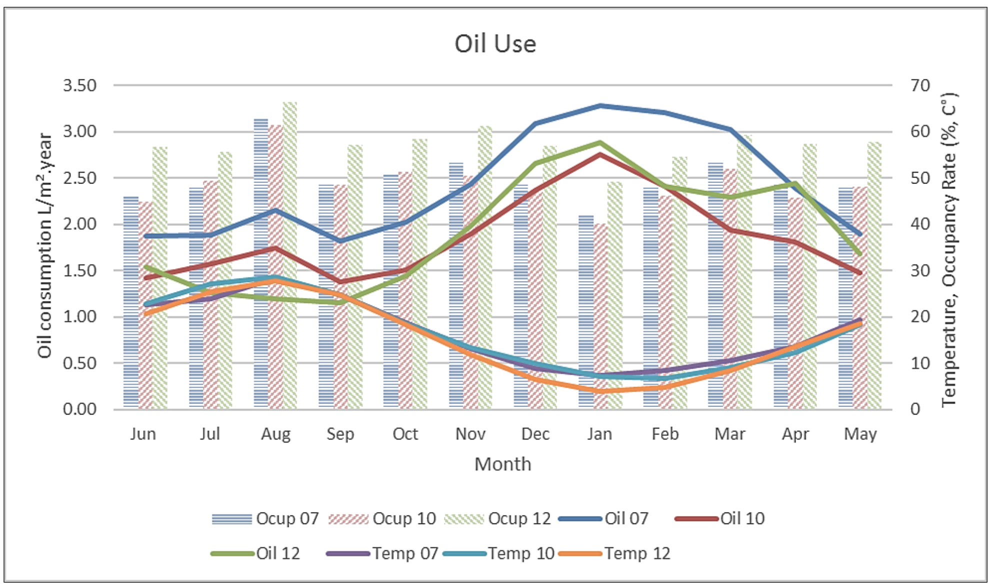

Figure 3-15: Oil Use Intensity with Occupancy Rate and Mean Air Temperature.

In addition, it is clear the considered negative value R^2= -0.30, -0.66 and – 0.69 in 2007, 2010 and 2012 respectively between November and May because of the cold climate and the high demand of steam and hot water which are produced mainly by using diesel fuel.

Correlation Coefficient

Previous graphs illustrate the correlation between different forms of energy and occupancy rate. It was clear the complex relation with entire year, so the period break-down takes places to enhance better understanding for correlation. Table (3-8) illustrates the values of R^2 between different energy forms and occupancy rate for selected period and the total R^2 value for entire period. It is obviously clear that big different between periods' value and annual R^2 values.

Table 3-8: Correlation coefficient between energy use and occupancy and temperature

	Correlation coefficient R^2								
	Occupancy rate % (2007)			Occupancy rate % (2010)			Occupancy rate % (2012)		
	Jun-Oct	Nov-May	Annual	Jun-Oct	Nov-May	Annual	Jun-Oct	Nov-May	Annual
Electricity	0.70	-	0.5	0.68	-	0.4	0.52	-	0.31
City Gas	0.71	-	0.2	0.57	-	0.2	0.57	-	-
LPG	0.89	-	0.2	0.70	-	-	-	-	-
Oil	0.90	-	-	0.89	-	-	-	-	-

The main factor of select this two period is the climate condition since the summer season in Japan starts from end of June until mid of September, therefore, major usage of energy sources will be affected mean air temperature directly or indirectly.

To sum up, a descriptive statistical analysis through DECC and occupancy data in Kanto region for 2007, 2010 and 2012 points out the correlation between energy consumption of different energy forms with occupancy rate. It is clear that there is no clear relation between energy usage and occupancy rate of accommodation buildings during the whole year, since the usage of energy sources has fluctuated behavior against the change of occupancy rate for the entire year.

The correlation coefficient R^2 shows acceptable value during period from June to October especially in case of 2007 data. Nevertheless, the R^2 has various values within period from November until May. These values has either unclear correlation values like case of electricity and Gas or low correlation value like case of LPG and Oil. Therefore, this paper empathizes the result of previous studies about the difficulty to proven the correlation between energy use and occupancy rate, but it is important to consider the occupancy rate with the consumption of electricity and gas whenever it is possible to account it especially in benchmarking system.

The research's results are useful to evaluate the energy consumption of the accommodation buildings in Kanto area. For instance, the weight of the occupancy rate within assessment process or benchmark equation will not be high or equal to other effective factors. Other building's parameters, which have a clear impact on energy consumption such as building size, operation hours, construction date has bigger weight within evaluation process.

4. Benchmark Energy Performance of Accommodation Buildings

Energy benchmarking is often referred as entire building benchmarking. It uses a simple method to inform decision makers with a relative energy performance level by comparing the building energy performance index of the assessed building with designed benchmarks. Customized and model-based benchmarks can be very powerful tools. However, significant time and resources are often needed to set such benchmarks, which can become big obstacles in real applications. Regression-based benchmarking needs less detailed data, but can effectively tackle a few problems inherent in some of other benchmarking approaches. Hence, it has been adopted in many benchmarking systems.

Benchmarking energy performance helps energy managers to identify best practices that can be replicated, either within a building or across a portfolio of buildings. Benchmarks can be reference points for measuring and rewarding good performance. They allow an organization to identify top-performing facilities for recognition and to prioritize poorly performing facilities for immediate improvement. Energy benchmarking offers an initial building energy performance assessment without rigorous evaluation. It is the process of comparing the energy performance of a particular commercial building to a range of energy-performance values of similar buildings, so as to rank the building in terms of energy efficiency among its peers, and then assess opportunities for energy efficiency. Just as Energy Guide labels on appliances indicate where the labeled appliance fits into the range of similar appliances from most to least efficient; benchmarking allows a ranking system for buildings to be defined.

There are many goals of benchmarking of commercial buildings. Therefore, many methods are used to benchmark buildings according to proposed aim and availability of data. These methods can be categorized according to different aspects related to usability, accuracy, structure and required inputs.

This study points out the necessity to benchmark the energy performance of accommodation buildings and other categories in Japan. In addition, it is important to consider other variables that affect energy use of buildings. Base on DECC, a benchmark system is developed by applying regression and Artificial Neural Network (ANN) methods to assess the energy performance of accommodation building in Kanto Region-Japan. The study investigates the primary energy model of selected samples according to consumption' trends of electricity, gas and clean water. The developed benchmarks by ANN and regression models were compared to ensure a robust benchmark system as a powerful tool for energy performance' assessment.

4.1. Developing Benchmark Using Linear Regression Model

The most commonly used statistical method to develop benchmark tools is the linear regression technique. It is a statistical method used to model a linear relationship between a scalar dependent variable 'y' and one or more explanatory variables indicated by 'X'. The case of one explanatory variable is called simple linear regression. Linear regression is unlikely to yield optimal results, since non-linear relations cannot be introduced and the technique is limited to continuous variables.

First time the regression method was introduced in the 1980s. Monts and Blissett concluded this statistical approach is more reliable and provides more information, compared to a simple EUI comparison, as the latter remains unadjusted for significant sources of variation [69]. In the 1990s, Sharp further demonstrated linear regression models can be used to compare building energy performance by using the data of office buildings and schools in 1992 CBECS database, and identified influential determinants of building EUIs [70]. For the 1358 office buildings, it was found that the most dominant variables among all the CBECS variables were the number of workers, the number of personal computers, owner-occupancy, operating hours and the presence of an economizer or chiller. For the 449 schools, the primary determinants of electricity use were gross floor area, year of construction, use of walk-in coolers, electric cooling, non-electric energy use, roof construction, and HVAC operational responsibility [70].

The ENERGY STAR Portfolio Manager was developed a benchmarking as tool and became widely adopted in the United State. The data used to build the regression models in the Portfolio Manager is from the CBECS 1999 and 2003. The regression models for major commercial building types including Office, Hotel, Hospital, Refrigerated/Non-refrigerated Warehouse, etc. Note that among more than 80 property types built into the new Portfolio Manager, only 20 of them are eligible to receive an ENERGY STAR score, and the convenience store type is not included.

Chung et al. obtained a regression model with an R^2 value of 0.7082 for 30 supermarkets. In this model, the response variable is EUI and the predictors are building age, gross floor area, operation schedule, number of customers, and occupants' behavior [29]. Overall, developing benchmarking system using regression models is inexpensive, efficient and easily understood by decision makers, and therefore, highly applicable to facilitate building energy savings in practice.

Linear regression model is a simplest statistical approach, also known as ordinary least square (OLS) method. Regression model is a fast method for estimating energy use intensity (EUI) for energy benchmarking. it allows one to model, examine, and explore spatial relationships, and can help explain the factors behind observed spatial patterns. The factors contributing to the EUI are supposed to be linearly correlated, and regression model defines the best fit of the EUI over "n" number of observations.

EUI is widely used as an energy benchmark in building energy analysis. It is expressed in kWh/sqft/yr or BTU/sqft./yr. EUI is an attempt to normalize the energy use corresponding to a strong determinant so that the energy use of many buildings is comparable. EUI is a standard unit of measurement for building energy analysis and have been investigated for use as whole buildings energy goals.

Regression techniques are used to identify the determinants of energy use intensities in buildings. It enables the resulting benchmark to account for the inflexible determinants and hence make comparisons fairer. Naturally, the first step is to collect a list of variables as potential energy use factors, which has been done in the data collection. The statistical model can be established directly if the independent variables to be included in it are already known.

The regression model is applied to find out the benchmark equation (2) of energy database. The benchmark equation calculates EUI based on major parameters of consumption such as electricity, city gas and water consumption.

$$EUI = \propto + b_1 \times X_1 + \cdots \ldots . + b_k \times X_k + \varepsilon \quad (2)$$

α is the intercept; $b_1, \ldots, b_k$ are the regression coefficients; $X_1, \ldots, X_k$ are the significant standardized factors; and ε is the random error.

Using the statistical analyzing, the calculated EUI of buildings of each cluster was determined and illustrated. The regression analyzing for cluster "1" is shown in figure (4-1) where the cluster has low number of samples (29).

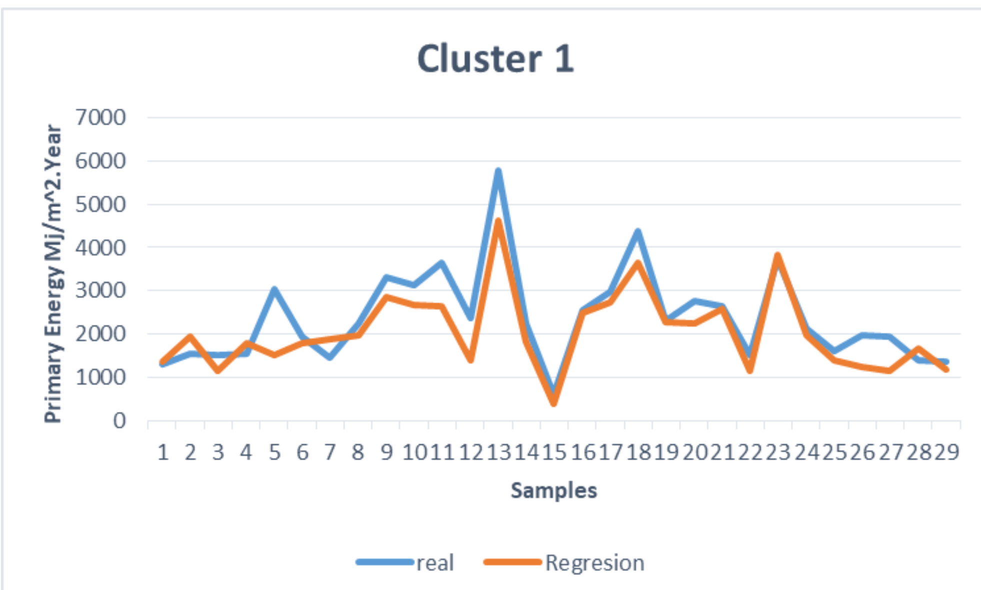

Figure 4-1: Outputs of Regression Model for Cluster1 of DECC

Therefore, the predicted values of primary energy are not corresponded with real value of DECC. Beside of samples size, there is possibility to have such out points because of the quality of data certain buildings or the difference in buildings function from other peer buildings of same cluster. The predicted value of primary energy has less values than real values that means the performance of these samples are not efficient. In this case, more efforts have to be done to improve or modify the energy plan. The coefficient of variation (CV) value was as average 0.1 for this cluster.

In case of cluster "2", which has 157 samples of DECC database. The outputs of regression analysis show better corresponding with the real values of primary energy. Notably, figure (4-2) illustrates the great correspondence between real value and predicted value of primary energy.

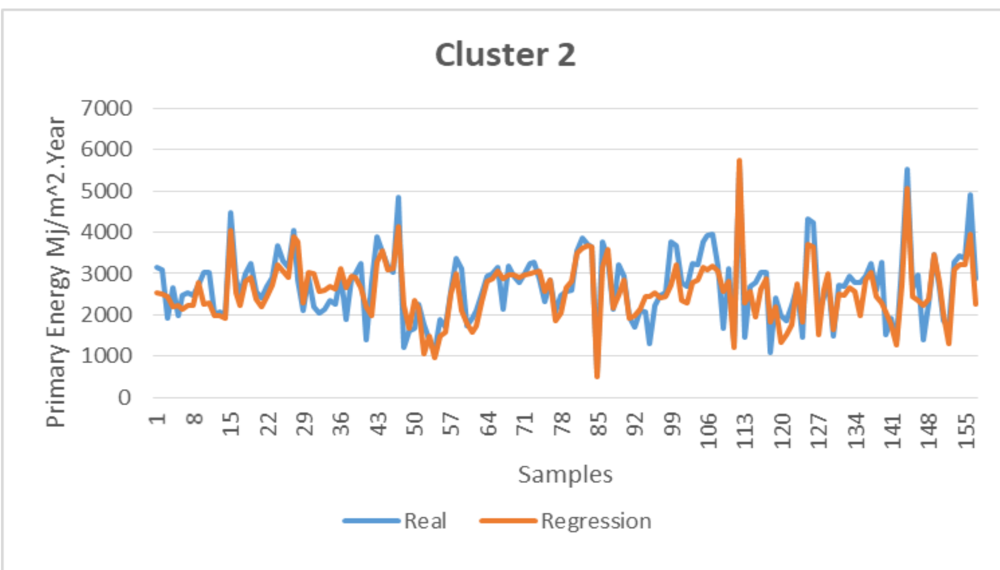

Figure 4-2: Outputs of Regression Model for Cluster2 of DECC

The graphs shows close values between predicted and real one, the coefficient of variation CV=0.08 as average. The predicted value are less than real one that means still the energy performance of these samples are not sufficient but it is better than previous case.

Cluster “3” has sufficient size of samples (97) and shows acceptable correspondence between real value of primary energy and predicted value of regression analysis CV=0.11. As shown in figure (4-3), there is a clear fluctuation in consumption value. This fluctuation can be result of different size or class of buildings that have variety trend of facilities.

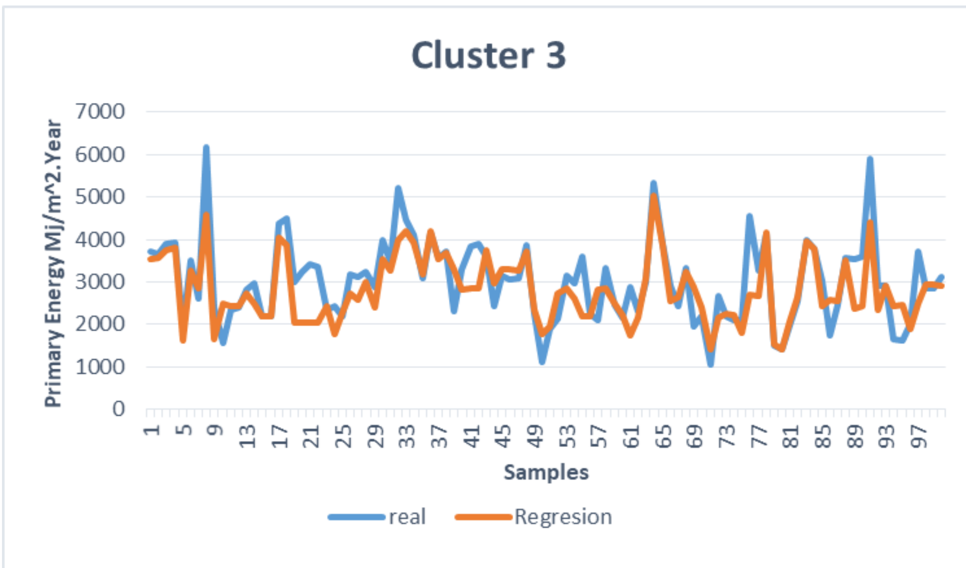

Figure 4-3: Outputs of Regression Model for Cluster3 of DECC

Last cluster has (51) samples shows acceptable results comparing to cluster1, but it has less correspondence comparing to cluster “2” and cluster “3” .as illustrated in figure (4-4). Cluster “4” have good value of CV=0.1 but there are considered fluctuation that means big difference between cluster’s samples. Again, the predicted values are less than real one that means less efficiency performance.

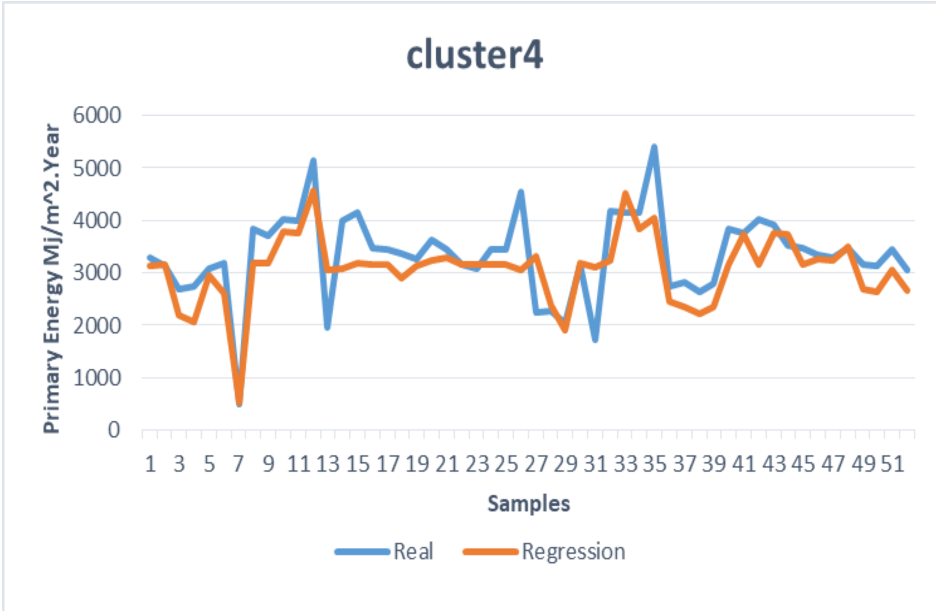

Figure 4-4: Outputs of Regression Model for Cluster4 of DECC

The benchmark processing using regression model aims to find out the regression coefficient of each variable that weights the impact of each variable on energy consumption. Then, these values will be used in the general equation of benchmarking (2); this equation is a reference to evaluate the energy performance of target buildings within same cluster.

Using SPSS software, this coefficient was calculated for each cluster. The weight of electricity, city gas and clean water was estimated. Depend on equation (2), the benchmark for each cluster will be as following:

Cluster 1: EUI= 369.52+1.01X + 0.83 Y + (-0.18) Z + 421.47 (3)

Cluster 2: EUI= 358.21+1.08 X+0.45Y+ 0.035 Z +111.14 (4)

Cluster 3: EUI= 56.52+0.99 X + 0.9 Y+0.07 Z +153.38 (5)

Cluster 4: EUI= 620.67+1.3 X+ 0.13 Y + (-0.01) Z+271.95 (6)

Where “X” electricity consumption. “Y” city gas consumption. “Z” clean water consumption.

The equations (3, 4, 5, 6) are the reference for all samples of each cluster to evaluate the energy performance either comparing to its history or to peer buildings. These equations introduce a basic benchmark to assess the energy performance among different accommodation building that have similar characters in each cluster. Using electricity, city gas and water consumption can reflect the total energy usage in selected buildings.

4.2. Adopting the Artificial Neural Networks Model

The complexity of building energy occupant’s behavior and the uncertainty of the important variables, such as more fluctuations in demand, make energy analyzing a different problem. These fluctuations are given by weather conditions, the building construction and thermal properties of the physical materials used, energy forms, the occupants and their behavior, sub-level systems components lighting or HVAC. Many approaches have been proposed aiming at accurate and robust forecasting of the energy consumption. The most approaches depend on the type of building and the number of parameter used.

Artificial neural network is a common category for several simple mathematical models that try to simulate the way a biological neural network works. The main feature of such models, which is important for this study, is the capability of learning. This learning process is called network training.

Recently, many researchers have used ANNs to model different types of building energy consumption for various categories of buildings in different climate zones [29] [30] [31] [32]. The input data require specific processing to remove noise and insignificant variables and achieve the best training results. Some research has focused on the preprocessing stage of input data [33]. The output of ANNs may not be close to expectations and can be inaccurate. Therefore, some correction or calibration is required to achieve high-accuracy outputs [34]. Some comparisons have been made between ANNs and other prediction models, such as regression models [35] [36] [37] and engineering models [38].

Artificial Neural Networks (ANNs) are the most widely used artificial intelligence models in the application of building energy prediction. This model is good for non-linear problems and is an effective approach to this complex application. ANNs have been used broadly to analyze various types of building energy consumption in a variety of conditions, such as heating/cooling load, electricity consumption, sub-level components operation and optimization, estimation of usage parameters.

Artificial Neural Networks (ANNs) it imitates the working principles of human brain and performs learning and prediction. It has a structure like nervous system and bases on biological learning. In this study, ANN was trained and tested using the software MATLAB. In figure (4-5), the topology of MLP network is shown to point out the input and output of ANNs model. In this study, an ANN was trained and tested using the software MATLAB.

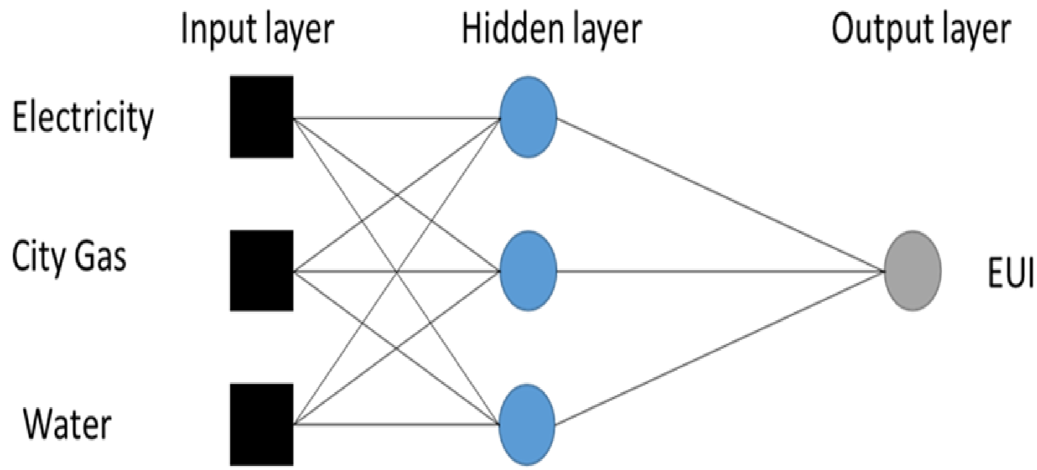

Figure 4-5: Topology of Fully Connected Three-layered MLP Network

4.2.1. ANNs Design

MATLAB provides built-in transfer functions that have been used for the hidden layers and outputs a pure linear function for the output neurons. The output of an artificial neuron can be mathematically expressed by:

$$y = \mathrm{f}.\{\textstyle\sum_{i=1}^{h}(W_i X_i + b)\} \qquad (7)$$

where y is the output of one neuron, h is the number of hidden layers, W is the connection weight, X is the input data, b is the bias value and f is the transfer function.

The Neural Network toolbox of MATLAB software was used for adopting ANN model. The first step is to design the learning prediction system by choosing the best learning algorithm and the number of hidden layers. In this research, four types of learning algorithms and three different numbers of hidden layers were tested.

Bayesian algorithm is an interpretation of the concept of probability, in which, instead of frequency or propensity of some phenomenon, probability is interpreted as reasonable expectation[81] representing a state of knowledge [82] or as quantification of a personal belief.

The Bayesian interpretation of probability can be seen as an extension of propositional logic that enables reasoning with hypotheses, i.e., the propositions whose truth or falsity is uncertain. In the Bayesian view, a probability is assigned to a hypothesis, whereas under frequentist inference, a hypothesis is typically tested without being assigned a probability. learning paradigm is founded upon the premise that all forms of uncertainty should be expressed and measured by probabilities[83]. it is characterized by The use of random variables, or more generally unknown quantities,[84] to model all sources of uncertainty in statistical models including uncertainty resulting from lack of information. It is important in specific settings, especially when we care about uncertainty very much.

Levenberg-Marquardt Algorithm (LMA or just LM), also known as the damped least-squares (DLS) method, is used to solve non-linear least squares problems. These minimization problems arise especially in least squares curve fitting.

The LMA is used in many software applications for solving generic curve-fitting problems. However, as with many fitting algorithms, the LMA finds only a local minimum, which is not necessarily the global minimum. The LMA interpolates between the Gauss–Newton algorithm (GNA) and the method of gradient descent. The LMA is more robust than the GNA, which means that in many cases it finds a solution even if it starts very far off the final minimum. For well-behaved functions and reasonable starting parameters, the LMA tends to be a bit slower than the GNA. LMA can also be viewed as Gauss–Newton using a trust region approach. The algorithm was first published in 1944 by Kenneth Levenberg,[85] while working at the Frankford Army Arsenal. It was rediscovered in 1963 by Donald Marquardt,[86].

Scaled conjugate gradient is an algorithm for the numerical solution of particular systems of linear equations, namely those whose matrix is symmetric and positive-definite. The conjugate gradient method is often implemented as an iterative algorithm, applicable to sparse systems that are too large to be handled by a direct implementation. Large sparse systems often arise when numerically solving partial differential equations or optimization problems[87].

The conjugate gradient method can also be used to solve unconstrained optimization problems such as energy minimization. The method provides a generalization to non-symmetric matrices. Various nonlinear conjugate gradient methods seek minima of nonlinear equations.

Resilient Back-propagation (Rprop) Algorithm is the result of back propagation. Change weights on back propagation are affected of the learning rate and depending on the slope of the error curve. The smaller the learning rate, learning the longer. While the greater the learning rate, the weighting values will be far from the minimum weights. To overcome this, developed a new algorithm is Rprop. This algorithm uses the sign of the gradient to show the direction of the adjustment weight. While size of the change the weights is determined by the value adjustment[88]. The algorithm is Resilient to change weights and bias network with direct adaptation process of weighting based on local gradient information from iteration of learning, so that the number of iterations needed to reach the target[89].

In addition, the number of hidden layers was examined for 15, 20, 25, and 30 layers for the same algorithms. A hidden layer in an artificial neural network is a layer in between input layers and output layers, where artificial neurons take in a set of weighted inputs and produce an output through an activation function. It is a typical part of most neural network in which engineers simulate the types of activity that go on in the human brain. There are many indicators and measurements can estimate the accuracy of each model of ANNs based on certain set of learning algorithm or hidden layers.

Mean Squared Error (MSE): For an unbiased estimator, the MSE is the variance of the estimator. If $\hat{y}_t$ represents the predictions of the regression's dependent variable, and y_t represents the true values of this variable, then MSE of the predictor is

$$MSE = \frac{\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}{n} \qquad (8)$$

Mean Absolute Percentage Error (MAPE): The mean absolute percentage error (MAPE), also known as mean absolute percentage deviation (MAPD), is a measure of prediction accuracy of a forecasting method in statistics. It usually expresses accuracy as a percentage, and is defined by the formula:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \qquad (9)$$

Where A_t is the actual value and F_t is the forecast value.

The difference between A_t and F_t is divided by the actual value A_t again. The absolute value in this calculation is summed for every forecasted point in time and divided by the number of fitted points n. Multiplying by 100% makes it a percent. Although the concept of MAPE sounds very simple and convincing, it has major drawbacks in practical application[90]. The output of the ANN model using different algorithms are examined using three main measures. These measures are (MSE), (MAPE), and (R), as shown in Table (4-1).

Table 4-1: the performance of the ANN models for different training algorithms

Method	cluster	Train				Test			
		MSE	MAPE	R	Best net	MSE	MAPE	R	Best net
Bayesian	C1	88430.5	0.105	0.96	23	1319749.4	0.28	0.64	28
	C2	196227.7	0.142	0.85	11	233921.15	0.161	0.83	8
	C3	184357.54	0.124	0.898	6	555881.86	0.221	0.671	14
	C4	984475.58	0.241	0.592	20	1416811.9	0.322	0.168	1
Levenberg	C1	703564.2	0.241	0.85	10	4350022.4	0.59	0.40	10
	C2	170293.8	0.13	0.88	28	596872.9	0.21	0.65	19
	C3	292271.3	0.15	0.86	11	1986277	0.28	0.51	30
	C4	1172343	0.22	0.72	1	1986277	0.28	0.51	13
Scaled conjugate gradient	C1	1199184.6	0.34	0.69	26	2470866.3	0.60	0.36	19
	C2	313568.3	0.18	0.78	29	501071	0.20	0.65	22
	C3	537631.3	0.20	0.73	13	794414.1	0.24	0.62	12
	C4	691076.5	0.20	0.64	7	1569684	0.24	0.19	10
Resilient	C1	1747183.6	0.396	0.79	20	3801363.3	0.58	0.46	23
	C2	291211.5	0.17	0.80	14	549758.4	0.23	0.66	5
	C3	448423.2	0.19	0.77	23	811113.4	0.24	0.58	2
	C4	691076.5	0.20	0.64	26	1569684	0.24	0.19	7

From table (4-1), the best learning algorithm is Bayesian, especially in cases of clusters “2” and “3”. The overall measures show good values, and they are not too different from the trained outputs and the tested output. Other algorithms show good values in some clusters, but there were large differences between the trained and tested outputs.

For hidden layers, different number of layers are tested to increasing the accuracy of ANNs performance. The measures are used to validate ANN performance as in Table (4-2).

Table 4-2: The performance of the ANN models for different hidden layers

Hidden layer	Cluster	Train				Test			
		MSE	MAPE	R	Best Net	MSE	MAPE	R	Best Net
15	C1	3258528.84	0.483	0.45	6	47971.70	0.104	0.95	16
	C2	190424.7	0.14	0.85	28	252405.6	0.17	0.81	14
	C3	258905.9	0.16	0.85	23	314016.4	0.17	0.82	12
	C4	71599.54	0.05	0.94	27	1708986	0.38	0.12	21
20	C1	96033.47	0.114	0.95	16	915133.4	0.351	0.67	13
	C2	193978.1	0.14	0.85	8	238427.3	0.16	0.82	21
	C3	193647.1	0.13	0.89	1	567313	0.23	0.64	4
	C4	115072.4	0.07	0.90	23	1550812	0.40	0.13	24
25	C1	114693.3	0.13	0.95	22	889943.7	0.25	0.72	11
	C2	89104.76	0.09	0.93	6	653461.6	0.22	0.63	16
	C3	171377.7	0.12	0.90	12	918517.3	0.23	0.60	14
	C4	208009.5	0.12	0.82	2	1546237	0.28	0.22	26
30	C1	133314.8	0.14	0.94	25	423986.7	0.21	0.78	28
	C2	69234.11	0.08	0.95	5	880523	0.24	0.61	4
	C3	161023.6	0.11	0.91	22	918051.5	0.24	0.56	17
	C4	224478	0.12	0.80	24	2067659	0.40	0.26	9

From Table (4-2), the best results have been obtained with 20 hidden layers for clusters “1, 2, and 3”. Therefore, the ANNs in this research are designed using the Bayesian algorithm with 20 hidden layers. The adopted ANNs model will be used for the next step to predict the primary energy values based on DECC samples of each cluster.

4.2.2. Modeling Energy Consumption Using ANNs

ANNs model used the electricity, city gas and clean water as input variable to forecast the primary energy of DECC samples for each cluster.

The previous results pointed out the importance of assessing the energy use of accommodation building through a designed benchmark system. For each cluster, the outputs are illustrated as graph and the process of predication was illustrated as the following:

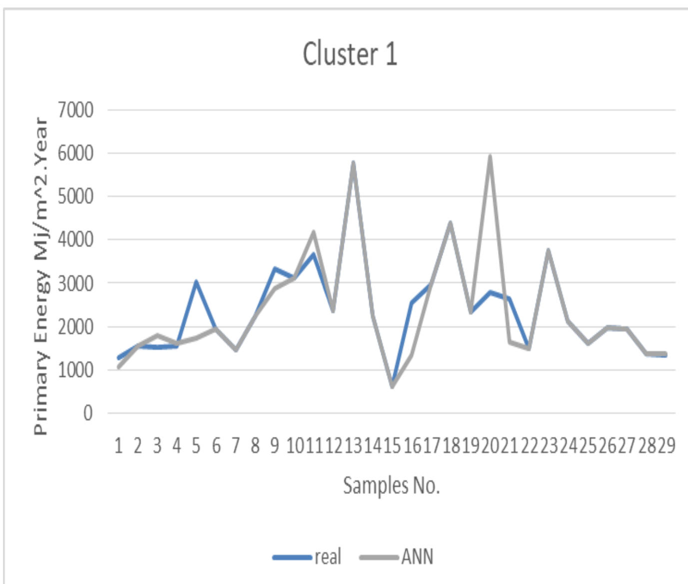

Figure 4-6: Outputs of ANNs with Real DECC Samples- Cluster1

In figure 4-6, it can be seen low correspondence between predicted values and real values CV=0.07. This low value indicates less variation between real and predicted values of energy use, but it is clear from graph there is no constant trend.

In figure (4-7), the process of prediction of cluster “1” was illustrated as following:

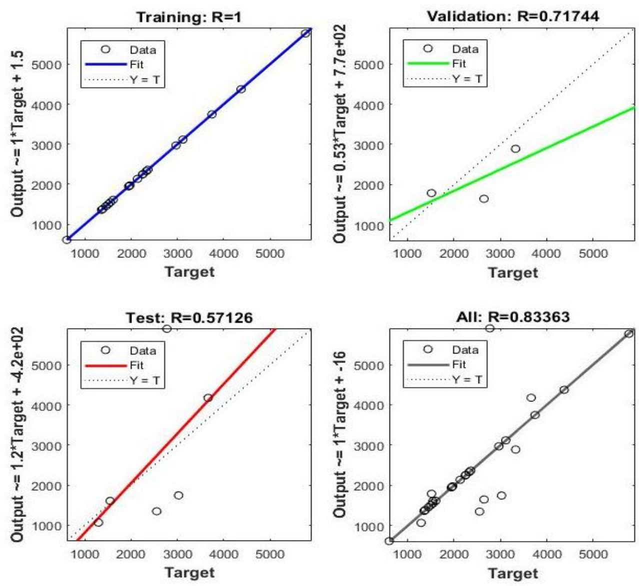

Figure 4-7: Regression Plot of Cluster 1

The validation value R shows good performance of prediction process since R=0.7.

Same procedure have been followed for cluster “2”, where the outputs of ANNs model was figured in figure (4-8). I t shows high correspondence with real values of primary energy CV=0.08.

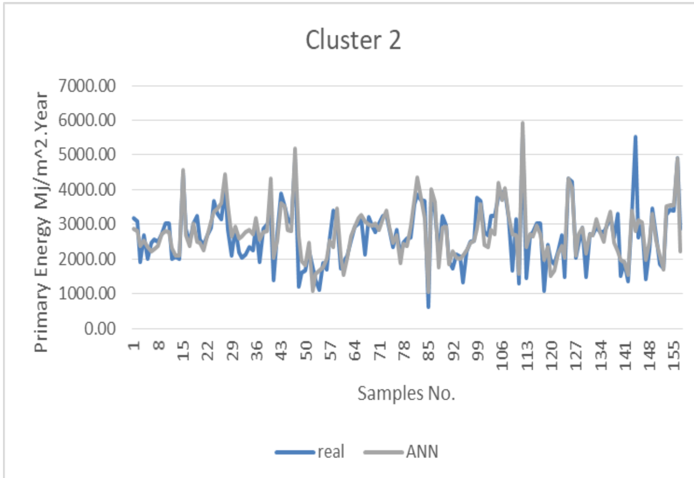

Figure 4-8: Outputs of ANNs with Real DECC Samples- Cluster2

The prediction process was illustrated in figure (4-9) to point out the validation value of ANNs modeling.

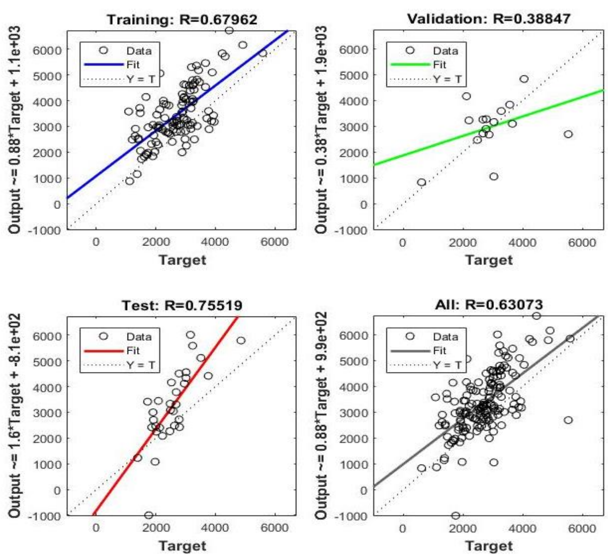

Figure 4-9: Regression Plot of Cluster 2

The cluster "3" was used in ANNs model to predict the primary energy values as in figure (4-10). The coefficient of variation in this case is bigger than in regression analysis CV=0.15.

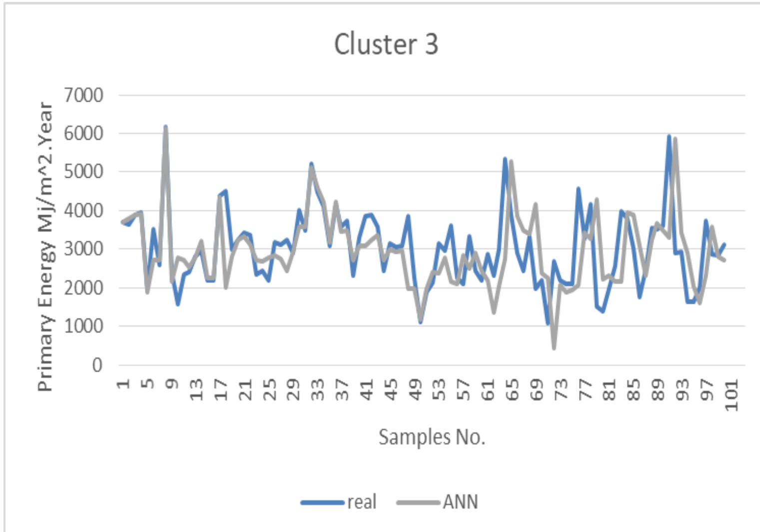

Figure 4-10: Outputs of ANNs with Real DECC Samples- Cluster3

The predicted values have not constant trend, since it is lower than real value and some cases is higher than real value. It means the buildings within this cluster have different performance.

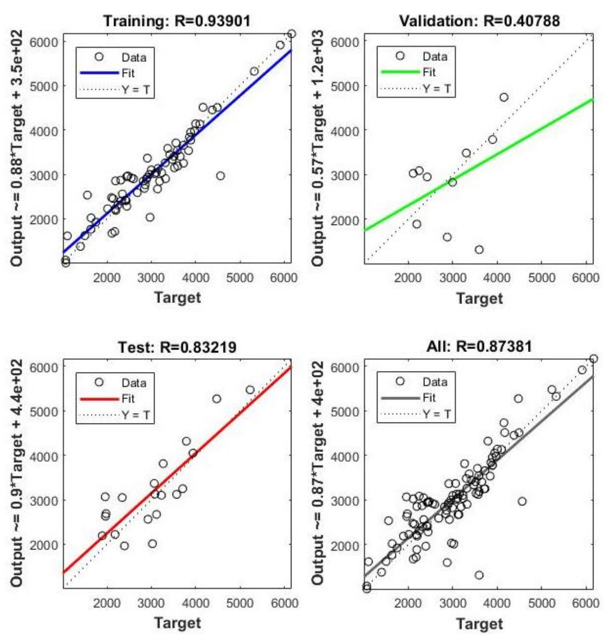

Figure 4-11: Regression Plot of Cluster 3

The outputs shown good correspondence with real data of DECC. The prediction process was figured in figure (4-11).

Final cluster has been analyzed and the predicted values of primary energy was illustrated in figure (4-12). In Cluster “4” the coefficient value CV=0.03; while the coefficient value is low, the overall trend does not have constant trend between real and predicted values. Few samples have good energy performance since they have lower value of primary energy consumption.

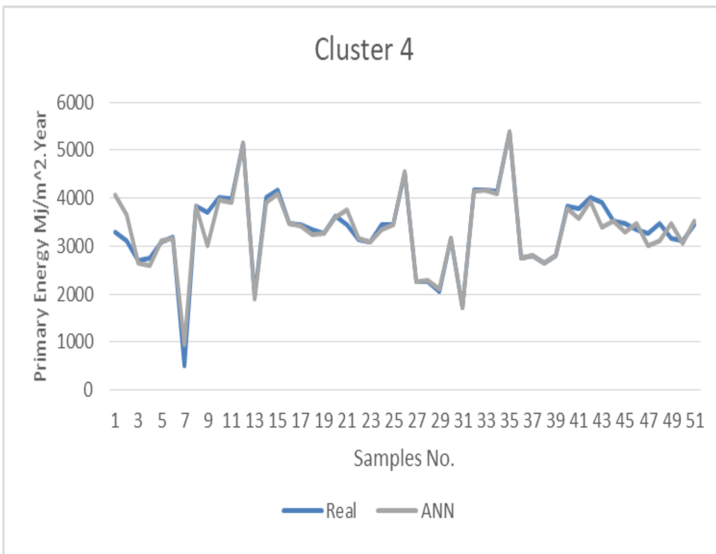

Figure 4-12: Outputs of ANNs with Real DECC Samples- Cluster4

The regression plot of cluster “4” was shown in figure (4-13) to figure out the prediction process using designed ANNs model.

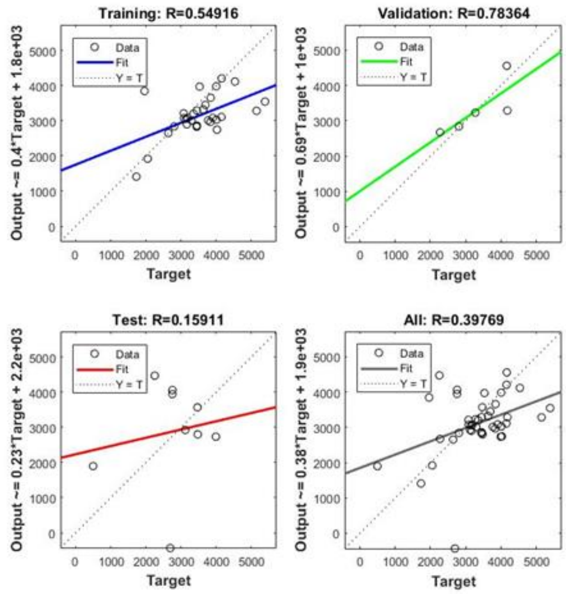

Figure 4-13: Regression Plot of Cluster 4

4.2.3. Validation of Regression Model

Regression model was used to find out the benchmark equation. While all previous studies depend on regression model as easy, inexpensive and powerful method to benchmark the energy consumption of different categories of buildings. This method has fair accuracy comparing to other methods such as engineering or artificial intelligent methods. Therefore, this study will used adopted ANNs model to validate the outputs of the regression model.

A descriptive comparison between regression outputs and ANNS outputs for each cluster of DECC samples. In figure (4-14) the outputs of both models are illustrated with real values of primary energy of accommodation buildings.

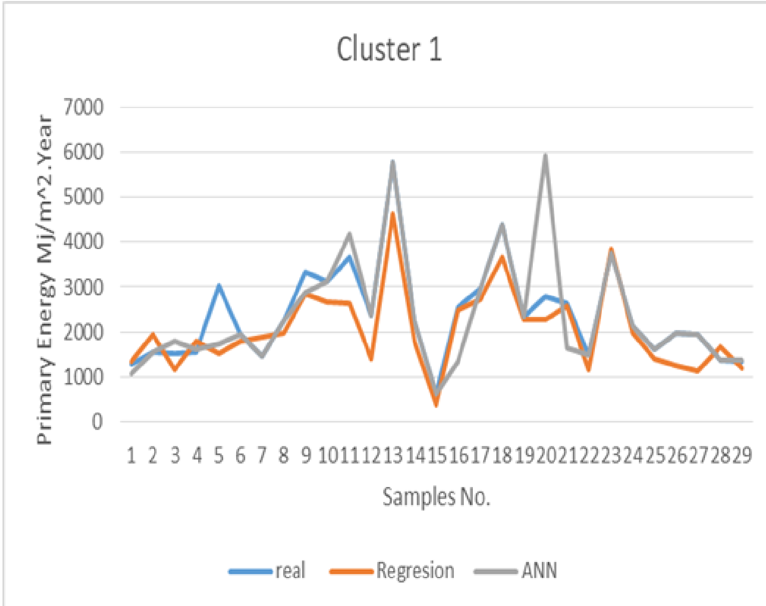

Figure 4-14: Comparison Outputs of Regression and ANNs- Cluster1

Form figure (4-14), it can be seen better consistency between ANNs predicted value and real value. Anyway, still there are many far points of ANNs outputs of primary energy because of the low number of samples which can affect the accuracy of ANNs model.

Figure (4-15) shows the comparison between ANNs model and regression model for cluster “2” of DECC samples of accommodation buildings in Kanto region.

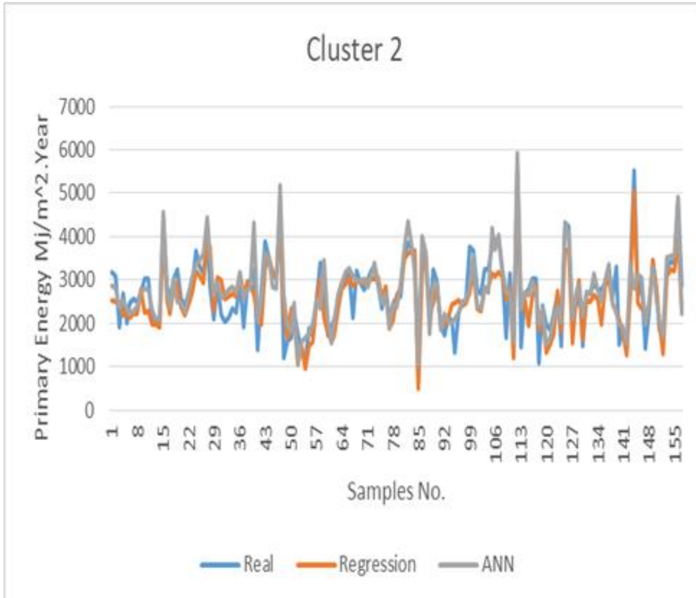

Figure 4-15: Comparison Outputs of Regression and ANNs- Cluster2

The sufficient number of samples in this cluster, better consistency between predicted values and real data of both methods. Similar results were obtained for cluster3 as shown in figure (4-16).

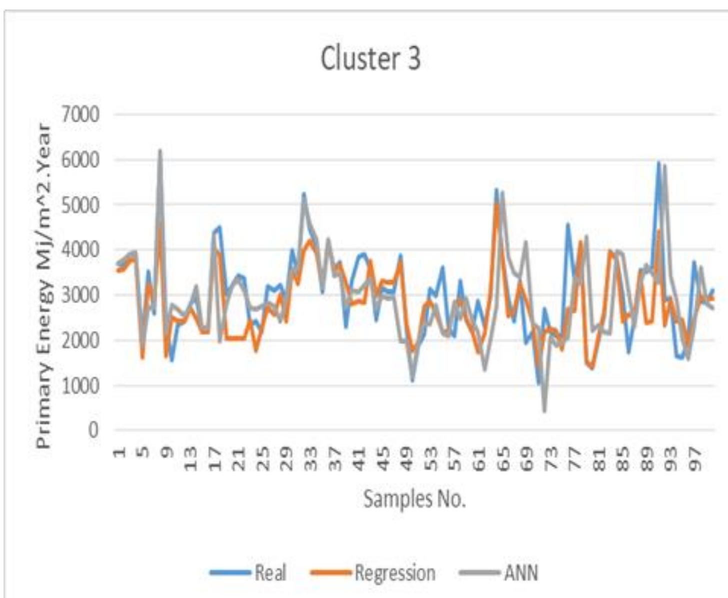

Figure 4-16: Comparison Outputs of Regression and ANNs- Cluster3

Finally, cluster “4” shows better performance of regression model comparing to ANNs model in term of consistency with real values of primary energy as illustrated in figure (4-17).

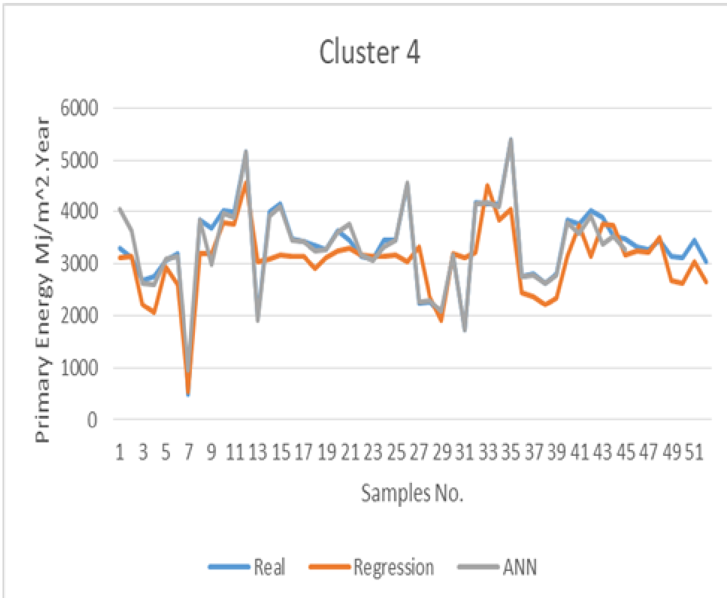

Figure 4-17: Comparison Outputs of Regression and ANNs- Cluster4

The mean absolute percentage error (MAPE) was calculated to evaluate the outputs of both methods for each cluster of DECC

Table 4-3: The MAPE value for regression and ANN methods

	MAPE	
	Regression	ANN
C1	18.97	11.4
C2	14.64	14.3
C3	14.90	13.2
C4	13.85	7.92

MAPE values shows close value of both methods in case of cluster “2” and cluster “3”. In the other hand, in case of cluster “1”, regression model shows best performance comparing to ANNs model. Cluster “4”, shows big difference of performance between ANs and regression model.

The mean reason of MAPE for cluster “1” and “4” is the size of sample in these clusters. Since regression model has less sensitivity toward data size, the outputs will not be affected as much as in case of ANNs model.

4.3.Franchised Hotel

A franchised hotel in Kanto was used as case study to test research’s approach and finding out the benchmark of energy consumption. There are six blocks of buildings in different locations and different floor area. Dataset of energy consumption includes energy use from 2011 until 2015, it includes electricity consumption, city gas consumption, clean water usage and occupancy rate.

In this study, each block will be named by symbol F_n, it is not possible to give the exact name and location for selected buildings because of privacy issue.

Figure 4-18 illustrates the location of two hotel blocks “F_1,F_2” which is located in Tokyo city. Block “F1” is pointed by orang triangle; the approximate floor area for Bloch “F_1” is 2500 meter square. The average primary energy is 500 MJ/month; it has not high number of floors. The occupancy rate is about 67% in normal season, 85% in hot season; considered reduction in energy consumption can be seen after 2011.

Figure 4-18: Location of Two Blocks of Franchised Hotel (F_1-F_2)

Block "F_2" is pointed by yellow triangle; the approximate floor area is 7500 meter square, with more than 30 floors. The average of primary energy is 4500 MJ/month; the occupancy is ranging from 703% to 85%.

Figure 4-19 illustrates the Blocks (F_3, F_4), both blocks located in center Tokyo. Block "F3" which is pointed by red triangle; it has approximate 1600 meter square. The primary energy consumption is around 1200 MJ/month as average from January until June. In summer, it rises up to 1600 MJ/month for July and August. In September, it reduces to 1300 MJ/month to be 750 MJ/month as average from October until December. The occupancy rate does not change as much as energy use does. It is from 70% to 80% as average and get 90% in August. This proves study's finding that there is no clear relation between occupancy and energy use. The high intensity of energy can be related to variety of services which are included in this block such as conference halls, restaurant and public activities halls.

Figure 4-19: Location of Two Blocks of Franchised Hotel (F_3-F_4)

Block “F_4” Located close to Block “F3” and pointed by red triangle, it has 8500 meter square of floor area and around 10 floors. The average of primary energy is 1300 MJ/month, only in January and August it records approximately 1500 MJ/month. It can noticed that there is no big fluctuation in energy use during the year. In the same time, the occupancy rate records from 77% for May, June and January. Although high consumption have been recorded in January there was not high occupancy comparing to August where high occupancy rate have been achieved as average.

Figure 4-20 figures hotel block “F_5” which pointed by light beach color; it has 9500 meter square of floor area. It has high tower with more than 34 floors and huge area of different facilities serve hotel’s users.

Figure 4-20: Location of Block (F_5) of Franchised Hotel

Block “F_5” has not high energy intensity comparing to its size, it ranges from 2200 MJ/ Month for normal season to 2850 in August. Overall, it can seen good reduction in energy consumption from 2011 until 2015. Comparing to Block “F_2” which is close in size but bigger than in number of guest and energy consumption with more than 34 floors tower, Block “F_5” has around 72% of occupancy rate and the number of guest does not reflect the percentage of energy use. The wide variety and big floor area of service facilities can be the reason of less energy consumption comparing to total floor area.

Last block is “F_6” which is located in Tokyo; it is shown in figure 4-21 with green triangle with 1500 meter square of floor area. The average energy consumption ranges from 640 MJ/Month to 870 MJ/ Month; sometimes it reached 900 MJ/Month in August. The occupancy rate is about 75% to 85% in certain month such as April.

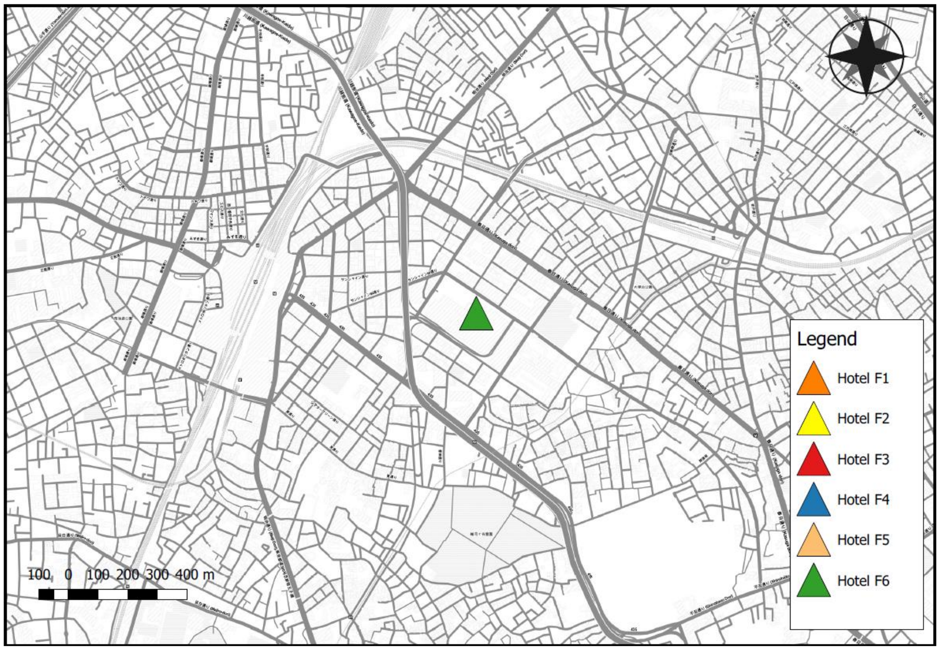

Figure 4-21: Location of Blocks (F_6) of Franchised Hotel

Based on K-means, the six blocks are classified into two cluster with three blocks in each cluster. The regression analyzing carried out to find out the benchmark equation for each cluster.

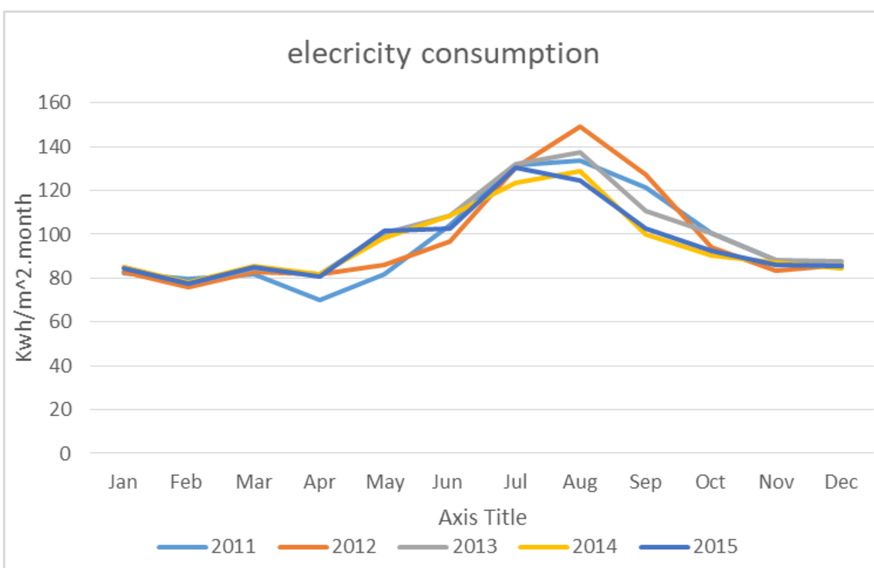

Figure 4-22: Electricity Use Trend of Franchised Hotel

Figure 4-22 reveals considered reduction in electricity after 2012 during summer that means improving the energy consumption of condition system for six blocks.

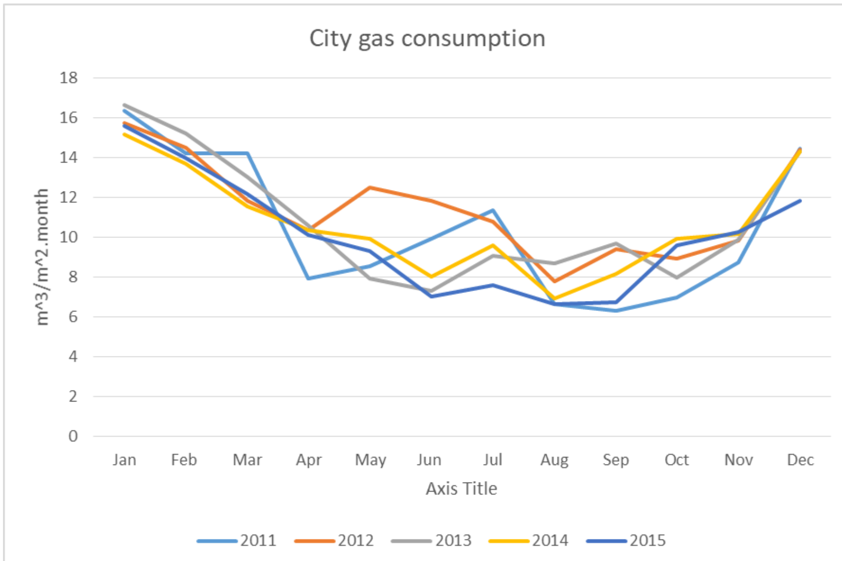

Figure 4-23: City-gas Use Trend of Franchised Hotel

City gas usage has different trend than electricity, as shown in figure 4-23; it has fluctuated trend between April and November from 2011 to 2015. More details are required to understand this trend for selected blocks.

In figure 4-24, primary energy intensity of blocks in two groups have been illustrated. They have similar trend in both groups in term of change energy consumption from season to other season during five years. General speak, significant reduction of energy consumption of energy can be seen for both groups during five years.

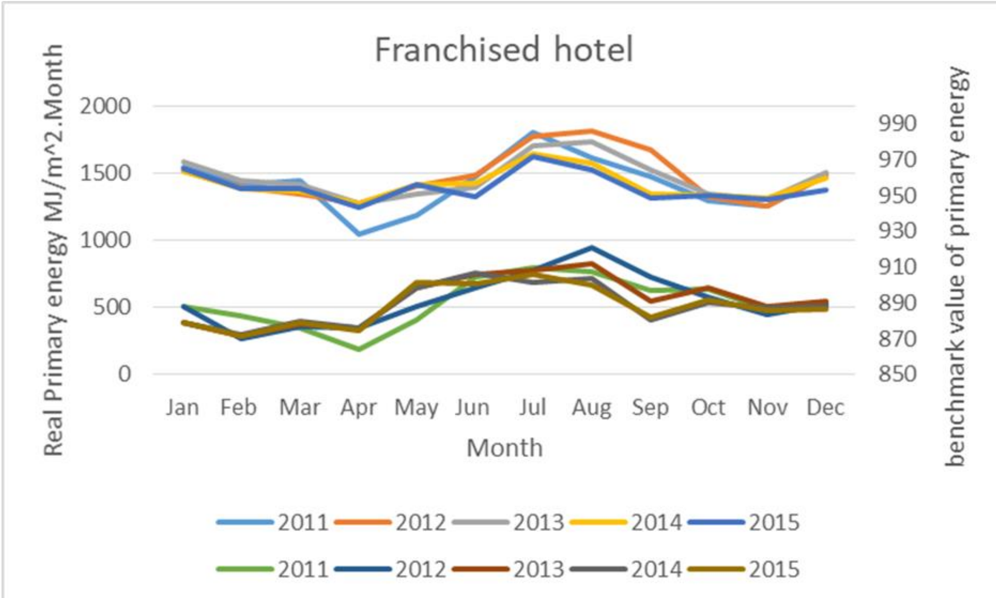

Figure 4-24: Electricity Trend of Franchised Hotel Based on DECC Benchmark Equations

Applying DECC benchmark equations that represent the same primary energy intensity shows low accurate estimation value. In figure 4-25 illustrates the graphs of real and predicted value of group A samples.

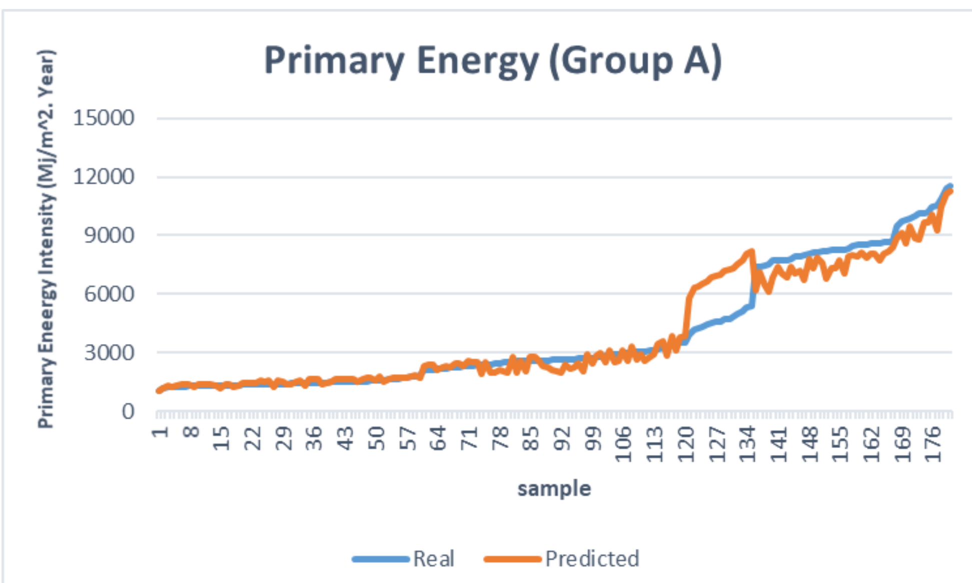

Figure 4-25: Predicted Values of Group (A) using DECC Eq.

There are significant difference between two values in case of group (A), it means used equation could not represent perfectly the energy use of hotel blocks. In figure 4-26, energy use of group (B) have been figured to show the predicted values of hotel blocks comparing to its real values.

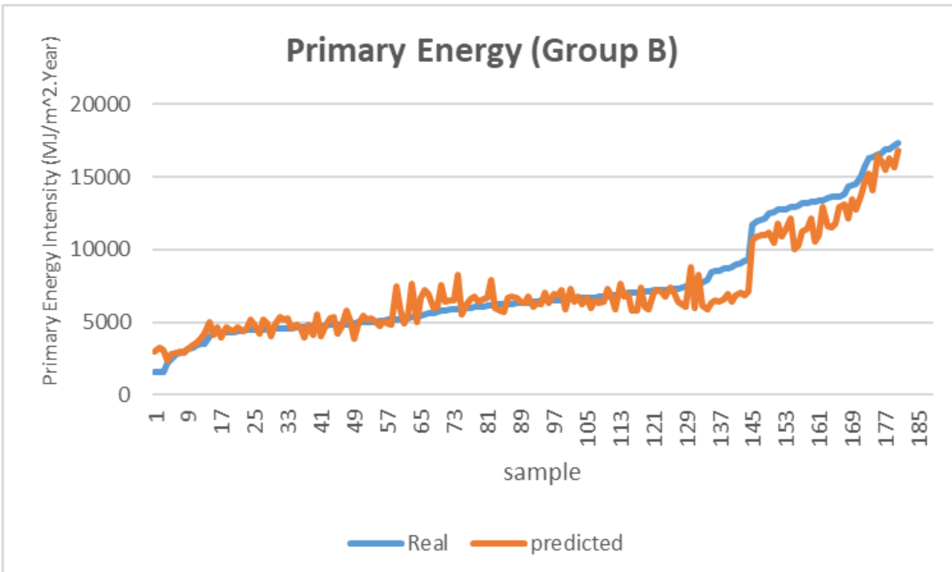

Figure 4-26: Predicted Values of Group (B) using DECC Eq.

Overall trend of predicted values show fluctuated estimation using DECC equation for this group. Some samples show good efficiency based to difference between predicted and real values.

To sum up the implementation of DECC benchmark's equation on the samples of franchised blocks, the equations could not reveal the energy use in selected samples. These findings can be results of multifunction of most selected blocks or the change of energy consumption in these buildings after 2011. To ensure better benchmark for franchised hotel, it is recommended to develop special one for these franchised blocks to fulfil its own character and dataset.

5. Discussion

The chapter reveals the findings from the previous four chapters and discuss the approach of benchmark the energy performance of accommodation building in Kanto region and its implications for assessment energy performance of selected sector.

5.1.Energy consumption of accommodation buildings

Recently, literatures focus on sustainability- especially, how climate change will affect tourism and how destinations can be adapted. Considerable attention is paid to tourism’s role as a contributor to greenhouse gas emission and how these can be mitigated. Accommodation facilities are main component in hospitality and tourism sectors. Its multifunctional character causes significant energy use and other natural resources, considered environmental impacts come up because from accommodation buildings. Therefore, the study introduced a benchmark for energy consumption to improve energy saving and reduce environmental impacts. As mention in chapter 2, different forms of energy are used to operate the facilities in accommodation buildings.

In general, electricity are used for condition, lighting, ventilation and other devices; city gas are used for heating, cooking, hot water and recently for power generation. In Japan, low percentage of buildings are using LP gas or liquid fuel for main operation process.

5.2.Benchmarking Energy Performance of Accommodation Buildings

Benchmarking is to measure the quality/ performance of process/service by comparing it to similar process/ services within certain criteria. Base on this definition, benchmarking energy performance of accommodation buildings is to compare the energy performance of certain buildings with their peer buildings based on quantified reference. In the current study the benchmark have been developed based on DECC dataset. Benchmark energy performance developed using statistical and artificial intelligent approaches, the linear regression model have been used as easy and common method to analysis energy use in various residential and non-residential buildings. Benchmark equations was produced using three variables; electricity, city gas and clean water consumption for four clusters of DECC samples. These equations prove the benefit of using city gas as main energy to reduce the total energy intensity and CO_2 emission in accommodation buildings. Artificial Neural Networks (ANNs) model have been utilized to verify regression's results. ANNs model has been adopted to fulfil the study's data set, learning algorithm and hidden layers were investigated. Bayesian algorithm and 20 hidden layers were selected to conduct predication of energy use intensity of DECC's samples.

In this study, regression model shows better performance comparing to ANNs especially in case of small size of samples. However, there is now big different between two models in term of measurement indicators.

5.3.Robustness of Benchmark

Robustness of energy use benchmark can be defined by an accurate estimation of energy consumption. Therefore, it is highly recommended to include as much as possible of effective variables that influence energy use of accommodation buildings. In current study and based on DECC few variables could be involved in designed benchmark. Electricity, city gas and clean water consumption were main variables in the study, it have clear impact on final energy use intensity. Other operation and design variables of DECC buildings have not clear impact on energy consumption such as floor number, operation hours and construction age. Based on literature review, another variables has significant impact on energy consumption but it did not include in DECC such as renovation schedule, facility structure, facility class and other operation data.

Up to previous condition, the develop benchmark in current study; have limitation in representing sufficient accuracy of estimation energy use. However, the study presents a basic benchmark to assess energy consumption of accommodation building in Kanto since there is no such benchmark yet to be used from owners and facility managers. Recently, efforts take place to set such a benchmark category of accommodation buildings in Japan. Unfortunately, same limitation came up in front of performing such benchmark.

5.4.The Contributions of Study

Many of studies used DECC to analysis the energy use of different categories of commercial buildings. There is no study improved a systemic approach to develop a benchmark of energy consumption either for accommodation building or other categories.

Current study introduced two method to benchmark energy use using DECC. This benchmark enables owners and facility manager in Kanto region to understand/ assess their facility then to achieve energy saving without affecting the quality of service. The internal use of benchmark enhances reduction of energy cost and maintaining customer’s satisfaction, which are main priorities for all owners and managers. In addition, public use will promotes good repetition for facility as sustainable building and to support users awareness about energy saving and environmental issues.

This study aims to consider enhance future benchmark platform that can be used easily from different stockholders in the future. This platform requires more related studies about different samples of accommodation buildings and examine new variables to be added to the projected platform. After obtaining sufficient understanding of energy consumption and the weight of various parameters, the establishing of beneficial platform will be feasible.

6. Conclusion and Future work

6.1. Conclusion

The objective of this study was to develop a benchmark for energy consumption of accommodation building in Kanto region. The study was based on utility national scale database of energy consumption of commercial building (DECC). The results of this study form a roadmap into hospitality sector and provide benchmarks for different accommodation buildings. From the results presented, it can be seen that energy performance is very complex issue. It is not easy to assess accommodation buildings because of its multifunction character and the variety of buildings categories.

A review of the literature revealed the lack of systemic approach for energy assessment in accommodation buildings in Japan. This may reflect the complex and multifunctional character of this sector. Benchmarking a building for its energy use gives the building owner and the facility manager a fair understanding about the energy use efficiency of the building compared to its peer group and its potential for energy savings, thereby decreasing their continuing costs and CO_2 emission of operation in terms of economic and environmental aspects.

As the main objective of current study is to develop benchmark of energy consumption for accommodation building in Kanto region, based on regression model the benchmark equation have been developed to assess the energy performance of one building with its history or peer buildings. The reliability study was carried out using ANNs to validate the regression model. The study design the ANNs model by selecting learning algorithm and hidden layers to ensure high accuracy of results.

Finally, the current study is considered as yardstick to other future studies for different commercial studies either in regional or national scale. In the same time, it points out the necessity to improve the quality and quantity of building database either as energy consumption or operational database. In addition, the study will enhance better understanding of energy performance that means improve the economic and environmental performance of accommodation buildings.

6.2.Limitation

Some limitations restrict better results of current study. Some of these limitations related to Japanese case and others are related to energy assessment of accommodation building worldwide. It can be listed as the following:

1) *Lack of Previous Research Reference*

There are very limited, if not none, previous researches on accommodation buildings' energy performance using benchmark approach that creates extreme difficulties in comparing and verifying the results of the current investigation. On the other Hand, due to the building character and operating mode, the possibilities to refer to other building types and other industries are not possible either locally or globally.

2) *Limitation of data set*

Most of studies face the same problem in academic field. However, to assess the energy performance of accommodation building through benchmark it requires certain data related to operation and building design to develop sufficient benchmark. More information regarding building class, renovation time, maintenance schedule, occupancy and building design will enhance better results.

3) *Other factors not able to be considered*

There are factors not able to be considered, such as change of equipment, change of management staff, change of guest behavior, change of guest mix, customer satisfaction, service qualities, scale factors, etc.

6.3.Future works

The benchmark method is a powerful tool to assess the energy performance of accommodation buildings and other commercial buildings. This study is a yardstick for other future studies that can investigate in detail one type of different types of accommodation buildings in Japan. The linear regression and ANN models used in current benchmarking tool. However, other model can be applied to compare the outputs of different methods. Few recommendations for future studies can be introduce from the literature review and this study:

More studies by linear regression or ANN in this area are encouraged, further research with sufficient data set and different variables are beneficial to verify and validate the finding of this study.

Using new method to establish energy use benchmark such as decision tree, data envelope analysis or hybrid method. New model will improve the accuracy of benchmark by avoiding the lack of other models; the combination between different methods can also give very conclusive results.

Review of effective variables have to be included in future studies to measure their impact on energy consumption and to increase the efficiency of benchmark tool. It is recommended to cooperate with certain type of accommodation buildings owners or chain hotel to develop public or private benchmark. It can enhance more concentrated finding and accurate.

Using new technology to obtain different data set are recommended to overcome the limitation of data and the quality of collected data. Real-time data becomes more affordable with low cost and easy use sensors.

7. Reference

[1] L. Pérez-Lombard, J. Ortiz, and C. Pout, “A review on buildings energy consumption information,” *Energy Build.*, vol. 40, no. 3, pp. 394–398, 2008.

[2] S. Gössling, “Global environmental consequences of tourism,” *Glob. Environ. Chang.*, vol. 12, no. 4, pp. 283–302, 2002.

[3] D. N. Trung and S. Kumar, “Resource use and waste management in Vietnam hotel industry,” *J. Clean. Prod.*, vol. 13, no. 2, pp. 109–116, 2005.

[4] I. Rahman, D. Reynolds, and S. Svaren, “How ‘ green’ are North American hotels? An exploration of low-cost adoption practices,” *Int. J. Hosp. Manag.*, vol. 31, no. 3, pp. 720–727, 2012.

[5] H. Han, L. T. J. Hsu, J. S. Lee, and C. Sheu, “Are lodging customers ready to go green? An examination of attitudes, demographics, and eco-friendly intentions,” *Int. J. Hosp. Manag.*, vol. 30, no. 2, pp. 345–355, 2011.

[6] P. Bohdanowicz and I. Martinac, “Determinants and benchmarking of resource consumption in hotels-Case study of Hilton International and Scandic in Europe,” *Energy Build.*, vol. 39, no. 1, pp. 82–95, 2007.

[7] H. Wallbaum, Y. Ostermeyer, C. Salzer, and E. Zea Escamilla, “Indicator based sustainability assessment tool for affordable housing construction technologies,” *Ecol. Indic.*, vol. 18, pp. 353–364, 2012.

[8] L. H. Chung and L. D. Parker, “Managing social and environmental action and accountability in the hospitality industry: A Singapore perspective,”

Account. Forum, vol. 34, no. 1, pp. 46–53, 2010.

[9] E. Robinot and J.-L. Giannelloni, “Do hotels’ ‘green’ attributes contribute to customer satisfaction?,” *J. Serv. Mark.*, vol. 24, no. 2, pp. 157–169, 2010.

[10] P. Bohdanowicz, “European Hoteliers’ Environmental Attitudes: Greening the Business,” *Cornell Hotel Restaur. Adm. Q.*, vol. 46, no. 2, pp. 188–204, 2005.

[11] L. Miao and W. Wei, “Consumers’ pro-environmental behavior and the underlying motivations: A comparison between household and hotel settings,” *Int. J. Hosp. Manag.*, vol. 32, no. 1, pp. 102–112, 2013.

[12] N. Erdogan and E. Baris, “Environmental protection programs and conservation practices of hotels in Ankara, Turkey,” *Tour. Manag.*, vol. 28, no. 2, pp. 604–614, 2007.

[13] “STATISTICAL HANDBOOK OF JAPAN,” 2014. .

[14] N. A. Vorobeva and M. V. Kolesnikov, “National policy of japan for stimulating innovation process in the energy industry,” *Int. J. Econ. Financ. Issues*, vol. 6, no. 1, pp. 237–244, 2016.

[15] I. Ayres and J. Braithwaite, *Responsive regulation: Transcending the deregulation debate*. Oxford University Press, USA, 1995.

[16] T. E. C. center; Japan, “Japan Energy Conservation Handbook 2013,” 2013.

[17] H. Yoshino, T. Hong, and N. Nord, “IEA EBC annex 53: Total energy use

in buildings—Analysis and evaluation methods," *Energy Build.*, vol. 152, pp. 124–136, Oct. 2017.

[18] "WTTC 2017." [Online]. Available: https://www.wttc.org/search-results/?query=Japan. [Accessed: 14-Jun-2017].

[19] S. Murakami, M. D. Levine, H. Yoshino, T. Inoue, T. Ikaga, Y. Shimoda, S. Miura, T. Sera, M. Nishio, Y. Sakamoto, and W. Fujisaki, "Energy consumption and mitigation technologies of the building sector in Japan," *6th Int. Conf. Indoor Air Qual. Vent. Energy Conserv. Build. IAQVEC 2007*, no. December 2006, 2007.

[20] X. Tong, "Energy-Efficiency Improvement in the Japanese Hotel Sector," *Ritsumeikan J. Asia Pacific Stud.*, vol. 30, pp. 56–76, 2011.

[21] C. P. Barros and M. J. Mascarenhas, "Technical and allocative efficiency in a chain of small hotels," *Int. J. Hosp. Manag.*, vol. 24, no. 3, pp. 415–436, 2005.

[22] H. X. Zhao and F. Magoulès, "A review on the prediction of building energy consumption," *Renew. Sustain. Energy Rev.*, vol. 16, no. 6, pp. 3586–3592, 2012.

[23] P. Bohdanowicz, "Environmental awareness and initiatives in the Swedish and Polish hotel industries-survey results," *Int. J. Hosp. Manag.*, vol. 25, no. 4, pp. 662–682, 2006.

[24] D. De Grosbois, "Corporate social responsibility reporting by the global hotel industry: Commitment, initiatives and performance," *Int. J. Hosp. Manag.*, vol. 31, no. 3, pp. 896–905, 2012.

[25] E. S. W. Chan and R. Hawkins, “Application of EMSs in a hotel context: A case study,” *Int. J. Hosp. Manag.*, vol. 31, no. 2, pp. 405–418, 2012.

[26] T. Sharp, “Energy Benchmarking In Commercial Office Buildings,” *ACEEE Summer Study Energy Effic. Build.*, vol. 4, pp. 321–329, 1995.

[27] R. Priyadarsini, W. Xuchao, and L. S. Eang, “A study on energy performance of hotel buildings in Singapore,” *Energy Build.*, vol. 41, no. 12, pp. 1319–1324, 2009.

[28] V. Shabunko, C. M. Lim, and S. Mathew, “EnergyPlus Models for The Benchmarking of Residential Buildings in Brunei Darussalam,” *Energy Build.*, 2016.

[29] W. Chung, Y. V. Hui, and Y. M. Lam, “Benchmarking the energy efficiency of commercial buildings,” *Appl. Energy*, vol. 83, no. 1, pp. 1–14, 2006.

[30] S. Petcharat, S. Chungpaibulpatana, and P. Rakkwamsuk, “Assessment of potential energy saving using cluster analysis: A case study of lighting systems in buildings,” *Energy Build.*, vol. 52, pp. 145–152, 2012.

[31] H. Alkhalaf, M. N. Ibrahim, and W. Yan, “Numerical Study about Improvlng the ProflCiency of an Earth Air Heat Exchanger System (EAHE) Employing Ground Cover Material,” *J. Clean Energy Technol.*, vol. 6, no. 2, pp. 106–111, 2018.

[32] M. A. Kamal, “An Overview of Passive Cooling Techniques in Buildings : Design Concepts and Architectural Interventions,” vol. 55, no. 1, 2012.

[33] M. Kepes, S. Brum, J. Vaz, M. Computacional, U. Federal, G. Furg, R. Grande, and R. Grande, “Numerical investigation about the improvement of the thermal potential of an Earth-Air Heat Exchanger (EAHE) employing the Constructal Design method,” vol. 80, pp. 538–551, 2015.

[34] C. C. Taljaard, “I S PA S S I V E C O O L I N G B Y M E A N S O F E A RT H - A I R E X C H A N G E R S E F F E C T I V E I N P R E TO R I A ?,” no. April, 2012.

[35] R. S. Brum and L. A. O. Rocha, “Development of Simplified Numerical Model for Evaluation of the Influence of Soil - Air Heat Exchanger Installation Depth over Its Thermal Potential,” vol. 1, pp. 506–514, 2012.

[36] K. Fabbri and V. Tarabusi, “Top-down and Bottom-up Methodologies for Energy Building Performance Evaluation at Meso-scale Level — A Literature Review,” *J. Civ. Eng. Archit. Res.*, vol. 1, no. 5, pp. 283–299, 2014.

[37] H. Li, Y. Yu, F. Niu, M. Sha, and B. Chen, “Performance of a coupled cooling system with earth-to-air heat exchanger and solar chimney,” vol. 62, pp. 468–477, 2014.

[38] M. De Paepe and A. Janssens, “Thermo-hydraulic design of earth-air heat exchangers,” vol. 35, pp. 389–397, 2003.

[39] O. Ozgener, L. Ozgener, and J. W. Tester, “Three Heating Seasons Monitoring of Usage of Low Enthalpy Geothermal Resources : Exergetic Performance Analysis of an Eahe,” 2013.

[40] H. Alkhalaf and W. Yan, “A study on the Correlation between the Energy

Use and Occupancy Rate of Accommodation Buildings," *Internatioanal J. Acad. Sci. Res.*, vol. 5, no. 2, pp. 96–109, 2017.

[41] H. Zhao and F. Magoulès, "A review on the prediction of building energy consumption," *Renew. Sustain. Energy Rev.*, vol. 16, no. 6, pp. 3586–3592, Aug. 2012.

[42] N. Fumo, P. Mago, and R. Luck, "Methodology to estimate building energy consumption using EnergyPlus Benchmark Models," *Energy Build.*, vol. 42, no. 12, pp. 2331–2337, 2010.

[43] S. Attia, A. Evrard, and E. Gratia, "Development of benchmark models for the Egyptian residential buildings sector," *Appl. Energy*, vol. 94, no. 2012, pp. 270–284, 2012.

[44] V. Bianco, O. Manca, and S. Nardini, "Electricity consumption forecasting in Italy using linear regression models," *Energy*, vol. 34, no. 9, pp. 1413–1421, Sep. 2009.

[45] A. I. K. Szűts, "Estimating Hungarian Household Energy Consumption Using Artificial Neural Networks The Structure of Household Energy Consumption," vol. 11, no. 4, pp. 155–168, 2014.

[46] N. Fumo, "A review on the basics of building energy estimation," *Renew. Sustain. Energy Rev.*, vol. 31, pp. 53–60, 2014.

[47] S. Alexander, C. Kennedy, P. Bohdanowicz, A. Churie-Kallhauge, I. Martinac, D. Rezachek, H. and the A. Cityswitch Department of Environment, Water, C. M. Fiol, D. Kirk, and A. Kasim, "Green hotels: Opportunities and resources for success," *J. Manage.*, vol. 8, no. April,

pp. 691–699, 2002.

[48] S. Becken, C. Frampton, and D. Simmons, “Energy consumption patterns in the accommodation sector—the New Zealand case,” *Ecol. Econ.*, vol. 39, no. 3, pp. 371–386, 2001.

[49] P. Mitchell and H. Ingram, “Space revenue and valuation models in retailing and hotels,” *Int. J. Contemp. Hosp. Manag.*, vol. 14, no. 1, pp. 28–33, 2002.

[50] M. Santamouris, C. A. Balaras, E. Dascalaki, A. Argiriou, and A. Gaglia, “Energy conservation and retrofitting potential in Hellenic hotels,” *Energy Build.*, vol. 24, no. 1, pp. 65–75, 1996.

[51] J. G. S. R.G. Zmeureanu, Z.A. Hanna, P. Fazio, “Energy performance of hotels in Ottawa,” 1994.

[52] S. Deng, “Energy and water uses and their performance explanatory indicators in hotels in Hong Kong,” *Energy Build.*, vol. 35, no. 8, pp. 775–784, 2003.

[53] S. Önüt and S. Soner, “Energy efficiency assessment for the Antalya Region hotels in Turkey,” *Energy Build.*, vol. 38, no. 8, pp. 964–971, 2006.

[54] S. M. Deng and J. Burnett, “Water use in hotels in Hong Kong,” *Int. J. Hosp. Manag.*, vol. 21, no. 1, pp. 57–66, 2002.

[55] M. Papamarcou and S. Kalogirou, “Financial appraisal of a combined heat and power system for a hotel in Cyprus,” *Energy Convers. Manag.*, vol. 42, no. 6, pp. 689–708, 2001.

[56] C. Norén and J. Pyrko, “Typical load shapes for Swedish schools and hotels,” *Energy Build.*, vol. 28, no. 2, pp. 145–157, 1998.

[57] M. Auffhammer and E. T. Mansur, “Measuring climatic impacts on energy consumption: A review of the empirical literature,” *Energy Econ.*, pp. 0–28, 2014.

[58] C. Dictionary, “Cambridge dictionaries online.” Cambridge University Press, Cambridge, UK, 2015.

[59] L. Brady and M. Abdellatif, “Assessment of energy consumption in existing buildings,” *Energy Build.*, vol. 149, pp. 142–150, Aug. 2017.

[60] B. Poel, G. van Cruchten, and C. A. Balaras, “Energy performance assessment of existing dwellings,” *Energy Build.*, vol. 39, no. 4, pp. 393–403, 2007.

[61] S. Wang, C. Yan, and F. Xiao, “Quantitative energy performance assessment methods for existing buildings,” *Energy Build.*, vol. 55, pp. 873–888, 2012.

[62] A. Goodrich, T. James, and M. Woodhouse, “Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities,” no. February, 2012.

[63] Y. Hirano, K. Gomi, S. Nakamura, Y. Yoshida, D. Narumi, and T. Fujita, “Analysis of the impact of regional temperature pattern on the energy consumption in the commercial sector in Japan,” *Energy Build.*, vol. 149, pp. 160–170, 2017.

[64] H. Y. Yamaguchi Yohei , Yusuke Suzuki , Masato Yamazaki , Yoshiyuki Shimoda , Syuzo Murakami , Bogaki Kazuaki , Matsunawa Katashi , Shigeki Kametani , Hiroto TAKAGUCHI , Hisashi Hanzawa , Hiroshi Yoshino , Yoshiharu Asano , Masaya Okumiya , Saburo Murakawa, "Comparision of energy consumption per unit floor area among retail catergories on the database of energy consumption for commercial buildings (DECC)," *J. Environ. Eng. (Transactions AIJ)*, vol. 77, no. 681, pp. 889–897, 2012.

[65] H. Takaguchi, S. Izutsu, S. Washiya, S. Kametani, H. Hanzawa, H. Yoshino, Y. Asano, M. Okumiya, Y. Shimoda, and S. Murakawa, "Development and analysis of DECC (Data-base for energy consumption of commercial building). Part 1 development on basic database of DECC," *J. Environ. Eng. Archit. Inst. Japan*, vol. 77, no. 678, pp. 699–705, 2012.

[66] I. Yorimasa, H. Y. S. MURAKAMI, Satoshi SUDO, K. BOUGAKI, K. MATSUNAWA, S. K. H. T. H. HANZAWA, M. O. Y. A. Y. SHIMODA, and H. Y. Saburo MURAKAWA, "An Analysis of the Energy- Saving Measures in Office Buildings (Analysis on 2009 Fiscal Year of DECC Survey Data)," *J. Environ. Eng. Archit. Inst. Japan*, vol. 2013.9, pp. 161–164, 2013.

[67] S. Satoshi, I. Yorimasa, Y. Hiroshi, W. Hironori, and Xu Lei, "An Analysis of Water Consumption of Buildings in Tohoku Area (Analysis on 2007-2009 Fiscal Year of DECC Survey Data)," *J. Environ. Eng. Archit. Inst. Japan*, vol. 2013.9, pp. 185–188, 2013.

[68] "http://www.jsbc.or.jp/decc_download/."

[69] J. K. Monts and M. Blissett, “Assessing energy efficiency and energy conservation potential among commercial buildings: A statistical approach,” *Energy*, vol. 7, no. 10, pp. 861–869, Oct. 1982.

[70] T. R. Sharp, “Benchmarking Energy Use in Schools,” *Proc. 1998 ACEEE Summer Study.Washington, DC*, p. 3.305-3.316, 1998.

[71] J. Yang, H. Rivard, and R. Zmeureanu, “Building Energy Prediction with Adaptive Artificial Neural Networks,” *Ninth Int. IBPSA Conf.*, pp. 1401–1408, 2005.

[72] G. Oğcu, O. F. Demirel, and S. Zaim, “Forecasting Electricity Consumption with Neural Networks and Support Vector Regression,” *Procedia - Soc. Behav. Sci.*, vol. 58, pp. 1576–1585, 2012.

[73] S. . Kalogirou, “Applications of artificial neural networks in energy systems,” *Energy Convers. Manag.*, vol. 40, no. 10, pp. 1073–1087, 1999.

[74] C. Buratti, M. Barbanera, and D. Palladino, “An original tool for checking energy performance and certification of buildings by means of Artificial Neural Networks,” *Appl. Energy*, vol. 120, pp. 125–132, 2014.

[75] P. A. González and J. M. Zamarreño, “Prediction of hourly energy consumption in buildings based on a feedback artificial neural network,” *Energy Build.*, vol. 37, no. 6, pp. 595–601, Jun. 2005.

[76] K. W. Chau, “Particle swarm optimization training algorithm for ANNs in stage prediction of Shing Mun River,” *J. Hydrol.*, vol. 329, no. 3–4, pp. 363–367, Oct. 2006.

[77] G. K. F. Tso and K. K. W. Yau, "Predicting electricity energy consumption: A comparison of regression analysis, decision tree and neural networks," *Energy*, vol. 32, no. 9, pp. 1761–1768, 2007.

[78] O. S. Maliki, A. O. Agbo, A. O. Maliki, L. M. Ibeh, and C. O. Agwu, "Comparison of Regression Model and Artificial Neural Network Model for the prediction of Electrical Power generated in Nigeria," vol. 2, no. 5, pp. 329–339, 2011.

[79] E. Tosun, K. Aydin, and M. Bilgili, "Comparison of linear regression and artificial neural network model of a diesel engine fueled with biodiesel-alcohol mixtures," *Alexandria Eng. J.*, vol. 55, no. 4, pp. 3081–3089, Dec. 2016.

[80] M. Aydinalp-Koksal and V. I. Ugursal, "Comparison of neural network, conditional demand analysis, and engineering approaches for modeling end-use energy consumption in the residential sector," *Appl. Energy*, vol. 85, no. 4, pp. 271–296, 2008.

[81] R. T. Cox, "Probability, frequency and reasonable expectation," *Am. J. Phys.*, vol. 14, no. 1, pp. 1–13, 1946.

[82] J. H. Justice, "Maximum entropy and Bayesian methods in applied statistics," in *Proceedings of the 4th Maximum Entropy Workshop, University of Calgary, 1984, Cambridge: University Press, 1986, edited by Justice, James H.*, 1986.

[83] J. M. Bernardo and A. F. M. Smith, "Bayesian theory wiley," *New York*, p. 49, 1994.

[84] M. J. Dupré and F. J. Tipler, "New axioms for rigorous Bayesian probability," *Bayesian Anal.*, vol. 4, no. 3, pp. 599–606, 2009.

[85] K. Levenberg, "A method for the solution of certain non-linear problems in least squares," *Q. Appl. Math.*, vol. 2, no. 2, pp. 164–168, 1944.

[86] D. W. Marquardt, "An algorithm for least-squares estimation of nonlinear parameters," *J. Soc. Ind. Appl. Math.*, vol. 11, no. 2, pp. 431–441, 1963.

[87] T. A. Straeter, "On the extension of the davidon-broyden class of rank one, quasi-newton minimization methods to an infinite dimensional hilbert space with applications to optimal control problems," 1971.

[88] M. Riedmiller and H. Braun, "RPROP-A fast adaptive learning algorithm," in *Proc. of ISCIS VII), Universitat*, 1992.

[89] W. Sulistijanti, "Peramalan Curah Hujan Wilayah Semarang Barat dengan Algoritma Resilient Backpropagation," *Median*, 2013.

[90] C. Tofallis, "A better measure of relative prediction accuracy for model selection and model estimation," *J. Oper. Res. Soc.*, vol. 66, no. 8, pp. 1352–1362, 2015.