THE IMPACT OF USER BEHAVIOR ON ENERGY CONSUMPTION: A CASE STUDY ON KILYOS CAMPUS DORMITORIES

by

Gökhan Kazar

B.S., Civil Engineering, Yıldız Technical University, 2012

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Civil Engineering
Boğaziçi University
2015

ACKNOWLEDGEMENTS

I would like to special thanks to my dear older and biggest supporter, Muhammed Ali Ildız, my family and friends who have never deprived me from their support and encouragement during my academic life.

I also would like to express my deepest gratitude to Assist. Prof. Semra Çomu for her supervision, guidance and advice throughout all phases of my graduate study.

ABSTRACT

THE IMPACT OF USER BEHAVIOR ON ENERGY CONSUMPTION: A CASE STUDY ON KILYOS CAMPUS DORMITORIES

Since the buildings consume approximately 40% of the total energy in the world, the energy efficient buildings have been gained an importance for recent years. Various approaches such as energy efficient measures and renewable energy techniques have been developed to achieve high energy performance buildings. To assess the energy performance of the buildings, different energy simulation tools have been developed. However, there is a gap between the actual and the estimated energy consumption, because of not accurately considering the user energy behavior in the energy simulation tools. In this study, to demonstrate the gap between real and predicted energy consumption, the energy consumers were classified based on their energy consumption preferences in the buildings. The survey was conducted with 529 students on Bogazici University Kilyos Campus dormitories. The students were defined in three different behavior groups by using cluster analysis. Three groups were identified as Cluster A, B and C based on their electricity consumption attitude and time spent in the rooms. Using the cluster analysis results, 6 different energy analyses were performed for each dormitory building. In the first three energy analysis, all the students in each of the dormitory were considered as belonging to just one cluster. In addition, all cluster groups were assigned to each dormitory building based on the actual distribution ratio. Besides, the default settings provided by DesignBuilder and Green Building Studio were also used to estimate energy consumption. The results show that the electricity consumption and carbon emission can be different in crucial levels by accounting of user energy consumption in the energy performance analysis.

Dünyada harcanan toplam enerjinin yaklasik40%'i binalar tarafindan tüketildiginden dolayi, binalardaki enerji verimliligi son yillarda önem kazanmaktadir. Binalarda yüksek enerji verimliligine ulasmak adina enerji verimliligi uygulamalari ya da yenilenebilir enerji teknikleri gibi yöntemlere basvurulmustur. Enerji tüketiminin tahmin edilebilmesi ve degerlendirilmesi için enerji tüketimini tahmin eden birçok program gelistirilmistir. Gelistirilen bu programlarin en büyük eksikligi; tahmin edilen ile gerçekte tüketilen enerji arasinda ciddi farkliliklarin bulunmasidir. Bunun en önemli sebebi olarak da insan enerji tüketim davranislarinin bu yazilimlarda detayli bir sekilde dikkate alinmamasidir. Bu probleme isik tutmak ve ayni zamanda programlar tarafindan tahmin edilen enerji tüketiminin daha kesin hesaplanabilmesi amaçlanmistir. Dogrultusunda binalarda yasayanlarin enerji tüketim davranislarini siniflandirarak belli kategorilerde tanimlanmasi ve bu dogrultuda yeniden enerji tüketimin tahmin edilmesi öngörülmüstür. Bogaziçi Üniversitesi Kilyos Kampüs yurtlarinda 529 ögrenci ile anket çalismasi yürütülmüstür. Anketin analiz kisminda kümeleme yöntemi kullanilmis ve sonuç olarak ögrenciler verdikleri cevaplara göre 3 farkli gruba ayrilmistir. Küme A, B ve C olarak tanimlanmistir. Analizlerin ilki, yurtlarda kalan bütün ögrenciler Küme A'ya ait kabulü yapilarak gerçeklestirildi. Ikinci ve üçüncü analizlerde ayni yaklasimla Küme B ve C için yapildi. Analiz ise, bütün kümelenmis ögrencilerin yurtlarda gerçek dagilimi göz önüne alinarak yapildi. Son 2 analiz ise enerji tüketimini tahmin eden programlarin, DesignBuilder ve Green Building Studio, sabit verileri kullanilarak yapildi. Analizlere göre, kümeler arasinda ciddi elektrik tüketimi farkliliklari ortaya çikmistir. Bu da bizlere enerji tüketim aliskanliklarinin enerji tüketimi üzerinde ne kadar önemli bir etkisi oldugunu göstermektedir.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

$CO2$	Carbon Dioxide
MWh	Megawatt-hours

LIST OF ACRONYMS/ABBREVIATIONS

BEP	Building Energy Performance
BLAST	Building Loads Analysis and System Thermodynamics
BREEAM	Building Research Establishment Environmental Assessment Methodology
DB	Design Builder
DHW	Domestic Hot Water
DOE-2	Development of Energy - Version 2
EEM	Energy Efficient Measure
EPC	Energy Performance Certificate
EU	European Union
GBS	Green Building Studio
GHG	Green House Gas
HVAC	Heating - Ventilation and Air Condition
LEED	Leadership in Energy & Environmental Design
MANOVA	Multivariate Analysis of Variance
NPB	Net-Positive Building
RET	Renewable Energy Technology
SPSS	Statistical Package for the Social Sciences
UK	Unite Kingdom
UNDP	United Nations Development Program
USA	United States of America
ZEB	Zero Energy Building

1. INTRODUCTION

1.1. General

Along with the industrial revolution and high population increase at the beginning of the 20th century, energy consumption and energy demand have been increased substantially. Especially, the energy consumption has been dominated by the developed countries such as the USA and European Union countries due to the meeting of the industrial energy demand. Furthermore, the climbing number of the inhabitant is also another impact on the increasing energy demand and consumption as well as the industrial energy requirement. According to the World Energy Council report published in 2013, the energy requirement, approximately 82% of the total energy supplying, has been relied on fossil fuels such as oil, coal and natural gas [1]. It is known that the consumption of the fossil fuel has brought various environmental problems together. In recent years, the environmental issues particularly climate change or global warming have been detected because of an increase in the overall atmosphere temperature towards the risky levels. According to many studies, greenhouse effect or carbon emission, under the global warming issue, has been emerged significantly around the world on account of increase in human activities by 70% [2, 3]. As a consequence, 181 countries except the USA and Canada signed the agreement which is Kyoto Protocol negotiated in December 1997 at the city of Kyoto, Japan and came into force in February 16th, 2005 to take this problem under control [4]. The goal of this agreement is to struggle with the global warming issue through various measures such as energy efficient solutions. It was noticed that between 1974 and 2004, global carbon emission has been increased by 70% and one third of this ratio was caused by the residential and commercial buildings because of daily human life activities [5]. The statistical report of BP oil and gas company indicated that the oil consumption and production ratio have been increased significantly from 1983 to 2013 [3]. Because of changing oil and natural gas consumption and production rate, the energy prices have been dramatically fluctuated. For instance, whereas the price of oil barrel was approximately 140 dollar two years ago, the current oil price is around 55 dollar over the last few months. Thus, the world financial structure has been influenced by the fluctuation of fossil fuel demand and production rate [6]. Especially, the energy dependent countries such as Turkey have been more impacted financially than others because of importing the energy requirement from abroad.

Many research indicated that the building energy consumption rate, approximately 41%, is higher than other sectors such as transportation and industry [7-9]. For example,40% of the energy is consumed in the commercial and residential buildings in the EU countries; this ratio is greater than industry (28%) and transportation (32%) [7, 8]. In Turkey, the energy consumption rate based on the sectors is also similar; 36% of the total energy is consumed by the buildings, the industry energy demand is around 32% of the total energy consumption and the energy consumption for transportation is 20% of the total energy usage as illustrated in Figure 1.1 [10, 11]. The reason of high proportion of the energy consumption in the buildings is due to using a wide range of energy services such as lighting, heating, ventilation and air condition (HVAC) systems and domestic hot water (DHW). Also, when taken the estimation of the future energy consumption into consideration, the buildings especially commercial and residential ones will increase the final energy consumption by 34% for the next 20 years [7].

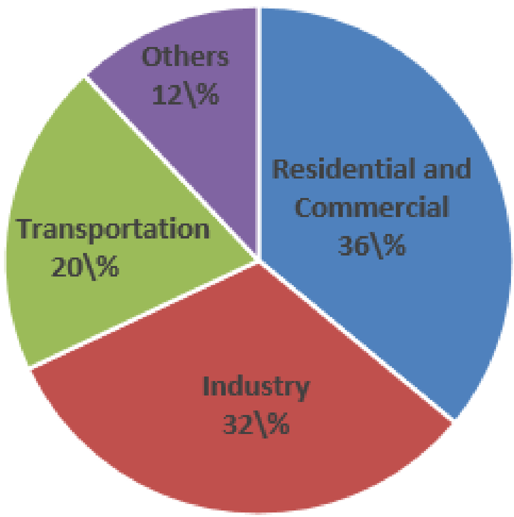


Figure 1.1. Energy Consumption Based on The Sectors [10].

Many research implies that there is a significant relationship between the energy usage of the buildings and climate change [2, 5, 7, 12]. The report of the United Nation Environment Program addressed that the building sector has a major potential for greenhouse gas emission reduction by means of cost effective solutions. In other words, the report says that the countries cannot accomplish the emission reduction targets without supporting energy efficient practices in the building sector [13]. The International Energy Agency proposed 25 energy efficiency measures including home appliances, lighting and power utilities for buildings that have potential savings of one fifth of world energy and carbon emission reduction together by 2030 [12]. Upon stressing the potential energy savings of the buildings, especially many emerging countries such as Turkey determined national objectives for efficient energy consumption in the buildings.

In Turkey, there are roughly 8.5 million existing buildings92% of them cannot meet the energy efficiency standards [5]. Hence, Turkey has a major potential in energy conservations in the buildings by applying the energy efficient measures. Usually, the emerging countries have high population growth rate and housing demand. Turkey well known as an emerging country in the Middle East and east Europe region is an energy dependent country. Along with existing buildings as stated above, 0.5 million unit resident are being built every year in Turkey. In addition, the half of the existing buildings will be reconstructed in the next 30 years [5]. Due to the fact that the rate of 75% of the energy consumption in the buildings have been imported from foreign countries, the Turkish Ministry of Energy and Natural Resources announced the national target for 2023 as 20% energy efficiency increase in buildings based on year 2011 [14]. So, the aim of the energy efficiency for 2023 is expected to be accomplished by the energy efficient buildings. The number of existing to be retrofitted and planned new building constructions show the high potential of energy conservations in the residential and commercial buildings in Turkey.

In order to reduce the energy consumption in the buildings, two domain strategies have been implemented in the industry and emphasized in the literature. The first application includes behavior change strategies and the second one is related to the conventional techniques. Firstly, the information technology strategies providing real time feedback concerning with energy consumption in units to the occupants have begun to gain importance for recent years. Many eco-feedback systems have been developed with its various components such as social pressure [15], real-time feedback [16] and information strategies [17] to reduce energy consumption. As the second strategy, conventional implementations can be considered in order to achieve energy efficiency targets in the buildings. Most of the execution methods with traditional techniques have been focused on improving the building infrastructure systems such as upgrading HVAC systems involving boilers and air conditions, using energy efficient appliances for lighting or other services and insulation [17].

In this sense, the designers have crucial role in achieving energy efficient buildings. Since designers take part during design process of new building and retrofitting the existing buildings, their architectural and mechanical decisions about building systems can directly affect the energy efficiency. Especially material and device preferences in the HVAC or architectural implementations play a significant role to decrease energy consumption in the buildings. The decision makers as stated above architects and engineers generally have focused on existing and new buildings to reduce energy usage. However, the existing buildings have the potential to save energy through retrofitting the buildings such as upgrading the material efficiency. In the new buildings, it is a fact that the decision makers should also consider the design strategies prior to construction process to achieve an energy efficient building. During the design stage of new buildings and retrofit planning of the existing buildings, the decision makers utilize energy performance simulation tools to obtain design alternatives in optimum approach and to make comparison among them. Particularly for the engineers, while achieving the energy efficiency targets in the buildings, the cost of the design should be also considered. The energy performance simulation tools have been utilized more frequently among the decision makers in recent years to achieve sustainable buildings with cost effective and energy efficient solutions.

Energy simulation tools use various inputs to assess the energy performance of the buildings such as; building geometry, internal and external loads, HVAC system components, operating strategies and schedules etc. Another important input parameter that is occupant schedules can be changed according to the building types. However, there are many inputs stated before that has been depended on the assumptions in the simulation tools. The assumption of the inputs causes a gap between predicted and actual energy performance in the buildings. As a consequence of the assumptions defined into the energy performance software, the range of the energy performance calculations can be wide between the actual and estimated energy consumption. Many research demonstrated that the occupant behavior assigned with default templates into the simulation tools is one of the most prominent factors causing the discrepancies between real and predicted energy performance [18-21]. In addition, the occupancy schedule and indoor activities especially usage of lighting, heating systems and electricity devices could be difficult to estimate for new buildings during the early design phase compared to existing ones.

The main objective of this study is to state the impact of the user behavior on the energy consumption. In addition, the estimation of the accurate energy performance of the buildings is aimed by accounting the energy consumption behavior of the occupants in the energy simulation. In order to mitigate the differences between the predicted and actual energy consumption, a survey approach was adapted. By conducting a survey, the energy user behaviors can be defined in accurate groups. Therefore, the energy user behavior can be easily integrated into the energy performance analysis through the simulation tools. This kind of approach enables the designers such as architects and engineers to develop different design alternatives by obtaining a precise estimation of energy consumption. Especially, before the implementations of the retrofitting projects, the precise estimation of the energy consumption can lead to determining the right energy efficient measures. For instance, the survey can be conducted to define the energy user profiles in the buildings. Accordingly, the energy efficient applications can be determined considering the energy consumption behavior of the residents for the existing buildings.

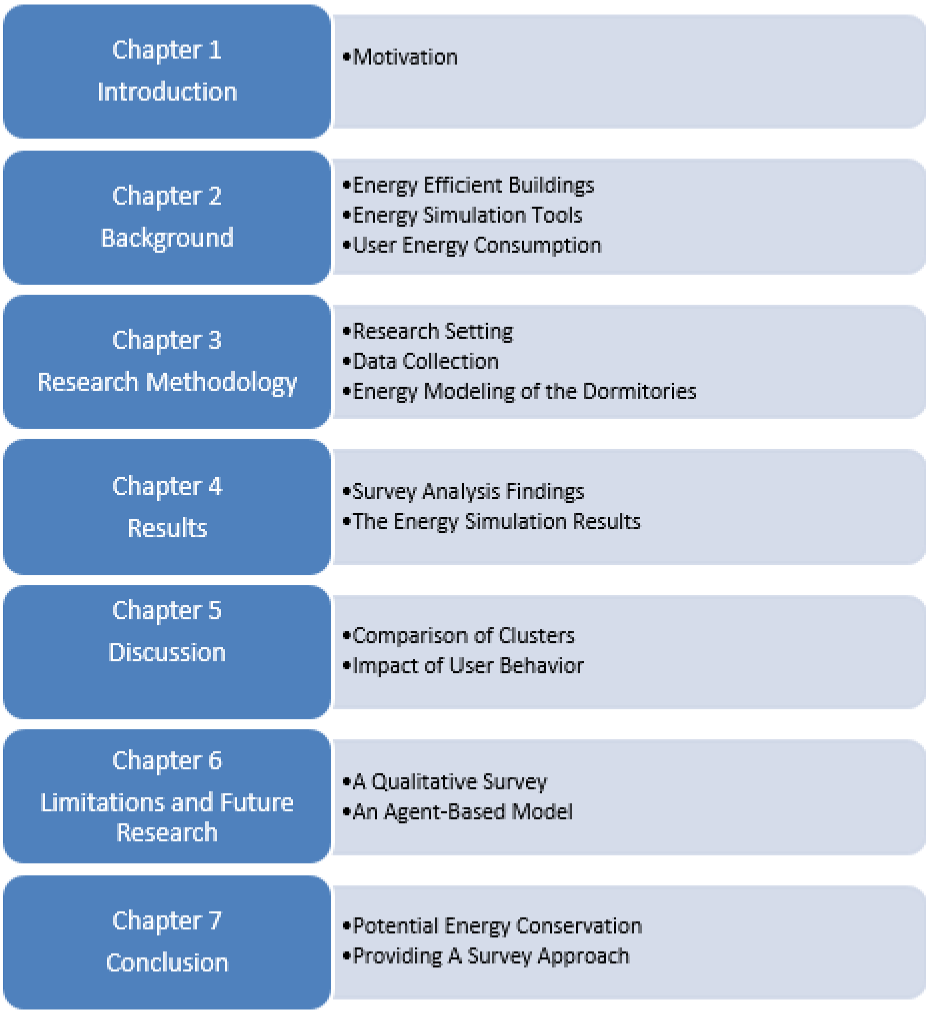


Figure 1.2. The Structure of the Thesis.

This thesis is structured following the general academic research format as presented in Figure 1.2. In Chapter 2, the importance of the energy efficient buildings with different application strategies is introduced. Also, the perspective of Turkey in energy efficient buildings is discussed to understand the potential energy efficient applications. The general information with drawbacks and advantages of the energy simulation tools is also provided in Chapter 2. The last topic of this chapter is about the user energy consumption in the buildings to state the major reason for the difference between the actual and predicted energy in the buildings. In Chapter 3, the followed research methodology is explained. First of all, the detailed information about the dormitories where the survey was conducted is given. Then, the energy modeling and data collection steps are introduced with all the analysis methods and soft-ware applications. At the end of this section, the survey data analysis process is provided. The results of the survey and energy performance analysis are illustrated in Chapter 4. The students classified into three groups based on the energy consumption behavior are identified according to the daily occupancy and equipment usage schedules. The difference in the electricity consumption and carbon emission of the dormitory buildings according to the analysis methods are also explained in this chapter. Then the findings are discussed in Chapter 5 to show the impact of the user behavior on the energy consumption. Then, the limitation of this research and the future research topics are discussed in Chapter 6. At the end of the thesis, the conclusion of this study is explained in Chapter 7. Finally, a reference section is provided with a bibliographic list of the publications cited in this work.

2. BACKGROUND

All over the world, there is a growing interest regarding energy efficiency due to its significant impact on environmental and financial problems. The necessity of the energy efficiency applications gained importance in 1970s because of the extinction of the natural resources and global warming issue. In this sense, various energy efficiency strategies have been developed and implemented in different sectors such as transportation, industry and built environment. However, the required level of energy efficiency has not been achieved yet. Consequently, this issue has taken place with its importance in the governmental agendas. As an illustration, many government institutions such as US Energy Department and Renewable Energy Administration in Turkey have developed and executed new regulations to encourage the local authorities and decision makers in energy efficiency implementations [22, 23].

The energy efficiency term has two prominent meanings; using less energy to achieve the same result and using the same amount of energy to produce a better result [24]. In energy efficient applications, it is difficult to get positive efficiency feedback in a short time, so the regulations and the sustainable investments should be considered for a long time period. It is well known that the energy efficiency practices in the buildings are appropriate examples for sustainable investments to achieve the long targets planned [24-26].

In this part of the thesis, the energy efficient buildings included both new and existing building stocks in Turkey will be introduced. Then, the energy simulation tools developed to date will be presented with their technical information and they will be compared based on their advantages and drawbacks. In the last section, the impact of energy user behaviors within occupancy and indoor activities on the building energy consumption will be discussed.

2.1. Energy Efficient Buildings

While it is challenging to identify every single characteristic of the energy efficient buildings, these characteristics can be categorized in three main groups; energy efficient equipment applications, design approach and cost effective implementations [27]. The initial criteria of the buildings is related with the energy efficient structural materials depending on building's location and region [27]. Second one is that the building must be designed according to intended use to provide thermal comfort for the occupants. Actually, the energy efficient building designs should meet the energy efficiency standards considering building intended use [27]. The last feature of the sustainable building is related with low energy consumption by bringing cost effective solutions compared to reference building in the same location [27]. For example, the energy efficient kitchen devices which consume low electricity and reduce electricity payments can be considered as cost effective implementations. The energy efficient buildings are not only environment friendly but also should be economically efficient. In addition, the properties of the low energy and cost effective buildings must be sustainable and designed for a long operation time to obtain positive results after implementation [24].

Since the global demand for all energy sources is forecasted to grow by 57% over the next 25 years and the electricity demand in the developed countries will grow by at least 40% by 2032, the management of the natural sources will be crucial [28]. Hence, considering the potential energy conservation capacity of the existing and new buildings, the energy efficiency in the buildings becomes a significant topic. The energy efficient buildings avoid the wasteful usage of natural sources such fossil fuel, natural gas and water. In short, energy efficient buildings consider environmental impacts and waste minimization in order to create healthy and comfortable environment by promoting resource conservation and energy efficiency. To increase the energy efficiency especially in the buildings, the governments started to release regulations and future strategy reports. Accordingly, with energy efficiency implementations, the environmental problems are expected to decrease. For example, the buildings account 27% of the total greenhouse gas emission in the UK, the government announced the energy efficient building targets in 2008 [29]. The greenhouse gas emission is planning to be reduced by 60% based on 2000 level by 2050 [30]. Apart from this, because of the fact that the buildings account of 41% of total energy consumption in the United State, in other words they are the major contributor of the carbon emissions, the US government launched the aim that all commercial buildings will be converted to the zero energy building by 2030 [16]. Similarly, the European Commission report stated that the construction sector has an important role in environmental issues and energy policies as the buildings use 40% of total EU energy consumption and generate36% of greenhouse gases in Europe [31]. Thus, the replacement of the existing resident stocks to the energy efficient buildings is a crucial path to achieve the 2020 targets for European Union. By retrofitting the existing buildings with technological implementations in the European countries, the energy usage is expected to be reduced up to 20% and declined the carbon emission by 20% compared to 2010 [31]. Also, the application of smart building technologies have been considered to meet the future targets in energy efficiency by the authorities. The smart buildings provide various opportunities for using the devices energy efficiently such as an electrical device can be remotely controlled via wireless network system when the occupant is not at home. As an illustration, the smart sensor systems in the buildings enable the residents to use efficient lighting and heating system depending on absence or presence of the house members which reduce the energy consumption crucially through smart technology. Moreover, energy efficient investments are usually cost effective and high potential energy saving solutions, so the distribution of the energy consumption based on the energy services such as electricity, heating ventilating and air condition (HVAC) and domestic hot water (DHW) were began to be inspected in detail. In the US, the final energy usage has been distributed in different proportion. While the HVAC systems consume about 53% of the total building energy in the residents, the lighting and devices accepted under the electricity usage are consuming roughly 30% of the total building energy [7]. The rest of the total energy is being consumed by domestic hot water system (17%) [7]. In general, the energy consumption distribution in the buildings can be summarized as follows; the half of the total energy is consumed by the HVAC systems and one third of the total building energy is consumed by the lighting system and electricity home devices[7].

2.1.1. The applications of the energy efficient buildings

From the beginning of 1970s, there is a growing interest in energy efficiency for buildings to reduce energy consumption, manage the natural resources efficiently and mitigate the greenhouse gas emission throughout the world. To encourage the investors and decision makers for the energy efficient buildings, various types of incentives and regulations have been put into action so far. The energy efficient standards, the most prominent and common ones among the governmental implications, have been released in recent years [22, 23]. Apart from the mandatory sanctions, there are various voluntary certification systems such as LEED, BREEAM, HQE, DGBN and Energy Star in Europe and the USA that have been developed and implemented all around the world [19, 21]. Along with these voluntary obligations, not only the building energy efficiency has been aimed, but also the appliances used in the buildings have been graded depending on their energy usage and efficiency. Therefore, the consumers are motivated to prefer energy efficient devices in their home.

In order to meet the entire energy efficient building standards, all the parties such as investors, decision makers including architects, engineers, and facility managers should take place during the entire project life cycle. The design process is accepted as the most crucial step of constructing new buildings for energy efficient applications. To achieve sustainable building standards, there are two common design approaches that have been executed in the projects [32]. The first one is the Energy Efficient Measures (EEMs) to increase energy efficiency for existing and new buildings and the second one is the renewable energy technologies (RETs) to meet the energy demand usually applied to new buildings [32].

The EEMs that have significant impact on the buildings to decrease the energy consumption can be divided into three groups based on their implementation types.

(i) Building envelopes; thermal insulation, thermal mass, windows/glazing (including daylighting) and green roofs
(ii) Internal conditions; indoor design conditions and internal heat loads due to elec-

tricity equipment

(iii) Building services systems; HVAC (heating, ventilating and air conditioning), electricity (lighting, home appliances) and vertical transportation systems such as lifts and escalators. There are numerous example of energy efficient measure applications from the UK to Australia presented in the below table [5, 32].

Table 2.1. Energy Efficient Measures Applied Before (Li *et al.*, 2013) [32].

Country/city/climate	Building	Energy-efficient measures/energy performence imlications
Australia, 8 climate	Residential	Thermal insulation, low-emissivity glass and double glazing, high energy efficiency appliances (especially for cooling-dominated climates)
	Office	Thermal insulation (less effective in cooling-dominated climates), lower WWR (window-to-wall ratio), reflective glass, lower LLD (lighting load density, partucularly effective in cooling-dominated climates).
China, 5 major architecutural climate zones	Office	Thermal insulation (effective in severe cold climates), double and triple glazing, lower WWR, raise summer SST (set point temperature), lower LLD, imprave chiller COP (coefficient of performance).
Hong Kong SAR	Residential	Thermal insulation, thermal mass, reflective coating windows, lever WWR, solar shading, 9-19% redction in cooling load and 11-29% reduction in peaking cooling demand.
United Arab Emirates United States, 8 climate zones	Residential Non-residential (office, hodel, school, etc.)	Thermal insulation, thermal mass, double glazing, lower WWR, daylighting, 28% reduction thermal insulation, low-emissivity windows, solar shading, dayyighting in CO2 emissions.
United Kingdom	Residential	Thermal insulation, cavity wall, double glazing (best option because of highest saving in heating energy demand and lowest induced increase in cooling load).
	Office	Thermalinsulation, low-emissivity glass, triple glazing, LED lighting, thermal mass with high ventilation and solar shading help reduce summer overheating.
Berlin (cold), Barcelona (temperature), Palermo (warm)	General, no specific building type	Traditional air-cavity wall, plus-insulated (air-cavity with additional cork covering) wall, ventilated wall, good energy and environmental saving in extreme weather conditions in Berlin and Palemo.
Switzerland	Office	Solar shading, night ventilation, special design strategies to minimize summer overheating and reduce the need for cooling energy use.
Burkina Faso (Sub-Saharan Africa)	Office	solar shading, up to 40% reduction in cooling load.

Even though the energy efficient measures have been adopted to increase the efficiency, the energy demand of the buildings still has to be supplied by the natural sources. In order to achieve self-sufficient buildings in terms of energy, Zero Energy Buildings (ZEB) and Net-Positive Buildings (NPB) has been constructed in recent years. The future energy efficiency objectives are being planned on the implementation of the ZEB and NPBs. The ZEBs were defined as “having a total annual sum of zero energy transfer across the building-district boundary in a district energy system, during all electric and any other transfer that is taking place in a certain period of time" [33]. These buildings are energy-efficient so that they can rely mainly on renewable energy sources to supply the energy demand. As a consequence, the second approach of the energy efficient building abovementioned is coming from the net zero and net positive building executions. The widespread common examples of the renewable applications to obtain sustainability in the buildings are as listed below;

(i) The photovoltaic executions on the roofs and facades to produce electrical energy from the sunlight
(ii) Wind turbine implementations to produce electricity that have great impact on reducing greenhouse gas emission
(iii) Solar thermal by using heat to obtain domestic hot water that have significant potential cost and energy savings
(iv) The heat pumps recovering heat from different energy sources for utilization in the buildings.
(v) District heating and cooling system that provides efficient central systems for heating and cooling demand [30, 32-35]

2.1.2. The energy efficient buildings in Turkey

The total population of Turkey increased from 56.5 million in 1990 to 77.6 million by the end of 2014 [36]. The urbanization rate increased as well as population by the end of 1990 [36]. Consequence of this increase in population and urbanization, the building stock in Turkey was around 8.8 million at the end of 2012. 86% of this building stocks were residential buildings, and the number of dwellings was approximately 19.2 million at the end of 2012 [5, 13]. The growing rate of the building stock was roughly around 8.1% between 2000 and 2010 and the annual rising of the building stock is expected to be higher than before due to the high speed urbanization [25]. Between 1990 and 2010, the primary energy consumption continuously increased about 4.6% annually and this increase will be around 5% until 2023 [25]. In addition, the built environment is consuming 34.7% of the total energy consumption in Turkey [13]. In this sense, the existing and new buildings have been accepted as an important element for the energy efficiency strategies by the authorities in order to address the environmental problems. According to Kanan [26], the building sector can contribute to decrease the carbon emission by 10% and the financial gain could be 1 billion US dollar if the insulation is just implemented for heating and cooling systems based on TS 825 standard. The potential conservation of the total energy consumption is predicted around between 30% - 50% for commercial and residential buildings [37]. Furthermore, the total cost saving when the energy efficiency regulation executed in the buildings is up to 7 billion US dollars in Turkey [26].

Along with the potential gain of the energy efficiency buildings, there are different energy efficient projects that have been accomplished to date in Turkey. According to the UNDP report, The Ministry of Energy and Natural Sources was supported by UNDP financially to promote the energy efficiency in buildings in Turkey. "Promoting Energy Efficiency in Buildings Project is being executed by General Directorate of Renewable Energy (YEGM) of Ministry of Energy and Natural Resources. UNDP is the implementing agency of the project which is financially supported by Global Environment Facility (GEF)" [13]. The government institutions have taken placed in the UNDP project mentioned before; The Ministry of Environment and Urbanization and Ministry of National Education are other partners of the project. The total budget of the project is USD 17,580,000. The project begun in 2011 and it was planned to be in operation at the end of 2015.

The aim of the "Promoting Energy Efficiency in Buildings" project supported by UNDP is to decrease the energy consumption and GHG emissions together in the buildings in Turkey. In addition, improving the building energy performance standards, bringing new perspective to the building energy management and introducing the use of an integrated building design approach were planned with UNDP project. These objectives of the UNDP project are expected to be achieved by the three following outcomes;

(i) Improved energy efficiency in new and existing buildings by revising, enhancing and improving the building energy performance standards;

(ii) With Integrated Building Design Approach (IBDA), cost-effective energy efficiency solutions will be brought to the buildings in Turkey

(iii) The energy management term could be common among the authorities and decision makers [13].

Another important energy efficiency related project in Turkey is the renovation of the public office buildings to increase their energy efficiency performance. Up until now, 166 office buildings have been detected for retrofitting [38].

Apart from the energy efficient project for the public buildings, there are many executed examples to increase the energy efficiency in the buildings in Turkey. There has been a significant attention since the first LEED Gold Certificate building by Siemens Factory in Gebze, Kocaeli in 2008. There were 80 other projects that have been updated for green building classification until May 2012 [39].

The various type of private sector projects were granted energy efficiency certificates in Turkey such as shopping centers (Redevco's Erzurum and Ankara Malls, Corio's Tarsus Mall, Torunlar REIC's Torium Mall and Deepo Istanbul AVM in Istanbul, etc.), industrial facilities (Wilo Pump Factory Tuzla-Istanbul, BASF Chemicals Dilovasi-Kocaeli, Inci Battery Factory Manisa, Turkish Airlines Engine Center, Schneider Electric Transformer in Istanbul), hotels and restaurants (Hilton Inn Golden Horn, KFC Bostanci, Baylo Suites- all in Istanbul), office buildings (Soyak Holding Headquarters, Philips Head Office in Turkey, Unilever Head Office in Turkey, Kavacik Trade Center, TekfenOz Levent Office - all in Istanbul). Furthermore, there are also non-commercial green buildings including educational facilities (Sabanci University Nanotechnology Center, Piri Reis Maritime University, H. Özyegin University Campus), public buildings (Kucukcekmece District Municipality in Istanbul) and residences (Varyap Meridian in Istanbul) [39].

In Turkey, to encourage and empower the investors and decision makers, the Energy Efficiency Law put into act in 2007. In addition to this, the regulation of

Building Energy Performance (BEP) was declared in the Official Newspaper and BEP regulation was revised based on the European Energy Standards in 2009. The standards of BEP including both requirements and recommendations have been executed in new and existing buildings since 2011 in Turkey. After passing the BEP Code, the "Energy Performance Certificate" (EPC) has been required for new buildings to rate the energy efficiency of new buildings. Besides, all the existing buildings have to obtain the same certificate before 2017 [22]. The Energy Performance Certificate experts and authority companies certificated by the Ministry of Environment and Urban Planning can use BEPTR online certification software developed based on the regulation. Moreover, Thermal Insulation Requirements for Buildings, Turkish Standard 825, addressed by the BEP is also an important regulation for the energy efficient buildings in terms of thermal insulation.

During the design of the energy efficient new buildings and retrofit planning of the existing buildings, the Integrated Design Approach (IBDA) is adopted by the decision makers, architects and engineers, to provide solidarity among the project members. Actually, the IBDA means that all the stakeholders such as municipality, employer, customer, financial supporters, architects, engineers, contractors and end users should take an active part during all the phases of the project to achieve energy efficient building design completely [40]. The general design steps of the energy efficient new buildings followed by decision makers can be explained as follows;

(i) Determining the construction site
(ii) Achieving the optimum layout and building orientation
(iii) The design of building geometry (the height, depth, volume, facades and roof types of a building)
(iv) The detail design of all indoor spaces should be divided regions depending on thermal properties such as being exposed to sunlight, rain and wind and the insulation of the building within facades and roofs.
(v) The renewable energy source opportunities may be also considered. For instance, the domestic hot water produced by sunlight or photovoltaic system could be taken into account.

(vi) The building energy performance can be calculated by using the energy simulation tools. With this way, the energy consumption of the building can be estimated by calculating both renewable energy systems and building total energy consumption together to obtain net energy demand.

(vii) The last stage is to compare and quantify various energy efficient implication scenarios and decide the optimum solution considering both cost effective and ecological ones among each design alternative by means of using building energy performance simulation tools [41, 42].

2.2. Energy Simulation Tools

2.2.1. General information

The designers usually rely on various simulation tools providing a wide range of calculation methods to analyze and quantify the building energy performance at the design stage. Most of the energy simulation tools have been developed to reduce the complexity of the calculation methods based on mathematical formulas. Using simulation tools reduce the complex calculation burden of the users that makes easier assessment of the energy results. The initial intention of developing energy simulation tools was to easily assess the energy performance of the buildings. In this sense, first generation soft-wares were easy to apply but difficult in terms of interpreting the results due to various limitations. As a consequence of the limitations and new requirements, the energy simulation soft-wares have been improved in the following years. Hence, the building energy performance simulation results achieved have been more realistic and comprehensive for users than before. Among the energy performance simulation programs such as DOE-2 (LBL, 1981), BLAST (BLAST, 1991) and ESP-r can be accounted as early generated and prominent ones [43, 44].

Each energy simulation tool has a basic modeling approach about how the different simulation engines are incorporated in the building energy analysis software. In wide perspective, there are three main modeling strategies for building and its energy performance calculation as listed below [45];

(i) Load model: This modeling strategy demonstrates the thermal behavior of the building structure. Total building structure, internal loads and infiltration are regarded in the load calculations for amount of the heat added or excluded.

(ii) System Model: It shows the thermodynamic behavior of the air-side or plant system. Air handling equipment, fans and terminal units are analyzed to decide the energy demand of the building.

(iii) Plant Model: This strategy displays the relationship between the load and the energy requirements of the primary energy equipment such as chiller or boiler plants to meet the building energy loads.

Each modeling strategy is carried out for room spaces defined in the BIM tool. The energy modeling processes can be counted under three main parts; inputs, simulation and outputs.

2.2.1.1. Inputs. Before energy performance analysis, the simulation tools need inputs such as weather and building data (both geometric and non-geometric data), HVAC and lighting system definitions, occupancy schedules. The users should have prior knowledge about the building details and intended use. Especially for existing buildings, the HVAC and lighting systems have to be inspected by doing real observation survey to obtain accurate and real results in the energy efficiency simulation. The identification of MEP elements such as miscellaneous and electricity devices for buildings can provide more realistic inputs after observation. Furthermore, the internal or space loads such as equipment properties, density usage of equipment and occupancy schedules should be defined in detail. Therefore, the decision of energy efficient applications could be more rational. For new energy efficient and existing buildings, the inputs can be differentiated by design alternatives to obtain various scenario results.

2.2.1.2. Simulation. During the simulation process, the energy simulation engines calculate the energy consumption of the building using complex thermal equations and algorithms. The simulation tools offer various analysis choices such as winter or summer analysis or harsh weather conditions. Also, providing the consumed energy quantity and energy prices monthly or annually, the cost analysis can be done by simulation tools. The users can make sensitivity analysis based on cost and investment for retrofitting.

2.2.1.3. Outputs. At the end of the simulation process, the tools give the energy consumption results in the form of graphs and HTML reports as an output. The output options can be selected before simulation process. The users can eliminate the undesirable or redundant results to accelerate the simulation process. The building total room electricity usage due to equipment, lighting or heating and cooling is presented in daily, monthly or annual graphs. Besides, the carbon emission and total fuel usage of the building can be displayed by the energy simulation tools as an output. Since the users can compare different simulation results, the decisions could be more realistic for new building designs and retrofitting solutions for existing building in terms of energy efficiency standards.

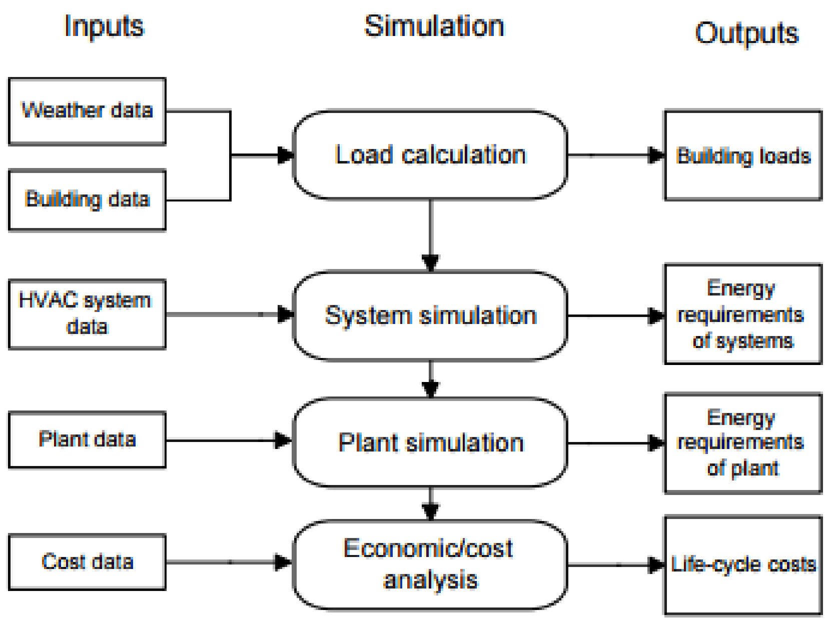


Figure 2.1. Basic Concept of Sequential Simulation (Hui, 1996) [45].

2.2.2. The comparison of existing Energy simulation tools

The energy simulation tools can be divided into two fundamental groups based on their main components; the engine and the Graphical User Interface (GUI). Generally, the simulation engines have been developed through academic studies (e.g. DOE2.1E 1994 and BLAST 2003) but the graphical user interfaces have been developed on the simulation engines as a commercial product by the private sector companies. While the simulation engines were improved on the mathematical and thermodynamic algorithms that calculates the energy performance of the buildings, the graphical user interfaces provide easier generation of the input files and analyzing the output files in graphical illustrations that enables users to comprehend the calculation results accurately [44, 46]. To date, several building energy simulation programs have been developed and used. The most notable ones compared in this section are based on the following criteria; general energy modeling features, simulation process, internal load specification, reports and the capability of graphical user interface integration with other programs [44, 47].

<u>2.2.2.1. DOE-2 (version 2.1).</u> DOE-2.1 E the most popular thermal simulation engine was developed by the Lawrence Berkeley National Laboratory. The engine estimates the hourly energy performance and energy cost based on the utility information of the buildings by using several inputs such as hourly weather data from building region using real weather information such as winter and summer daily temperature values, building geometry including all the materials used and thermal zones, HVAC systems, equipment loads, electricity system description and utility ratios. However, the engine needs a simplified geometry of the building as an input. During the simulation phase, the indoor materials and walls are used as the determination factors for heat transfer between spaces. The DOE-2 does not have any capability of importing and exporting such as using CAD geometry as an input for the simulation engine. Therefore, the interoperability and data exchange facilities are restricted. However, there are lots of energy simulation software that have been developed on the DOE-2 simulation engine by integration of the graphical user interface such as RIUSKA and eQUEST. The

simulation engine can be used in energy modelling of the buildings and analyzing the retrofit scenarios predominantly.

2.2.2.2. Building loads analysis and system thermodynamics. BLAST as a simulation engine calculates energy consumption with cost opportunities and energy performance of the buildings by using three major subprograms; (i) Space Load Prediction, (ii) Air System Simulation and (iii) Central Plant. The most important subprogram is the Space Load Prediction forecasting space loads based on hourly weather data, building construction, operation details and heat balances of the surfaces and rooms. The buildings geometry data can be entered as an input to the simulation tool but without having any graphical representation of the building geometry. The BLAST is being used for the estimation of the building energy performance and it is also utilized to choose the best retrofitting option among various alternatives. However, as using DOE2, it is also particularly hard to interpret the results with BLAST due to the absence of the graphical representation [31].

2.2.2.3. ECOTECT version 5.50. ECOTECT provides a wide range opportunity such as 3-D modelling interface, solar, thermal, lighting, and acoustic and cost analysis. The prominent advantage of the ECOTECT is that it provides the visual representation of the model. The ECOTECT's interoperability and data exchange option are really extensive due to its capability of importing CAD drawings from BIM tools. The program users can easily change the building geometry to assess the impact of different design alternatives. Hence, different calculation options for energy performance analysis are available in ECOTECT during early design phase including various design scenarios [47, 49].

2.2.2.4. Energy plus. The Energy Plus is a new generation program that was developed based on two energy simulation engines DOE-2 and BLAST and integrated with loads and systems simulation approach as stated earlier. The Energy Plus has important energy performance prediction capabilities such as time steps less than an hour and having modular systems with a heat balance-based zone simulation. The Energy

Plus provides a more accurate estimation of room and surface temperatures, for this reason it is better than DOE-2 and BLAST energy simulation engines in term of thermal behavior result parameters. In the prediction of thermal zones, the Energy Plus takes the temperature differences between spaces, equipment and space boundaries such as walls into account. In recent years, innovative functions have been added into the EnergyPlus which are multi-zone airflow, electric power simulation including fuel cells, distributed energy systems and detail reporting of building water usage. While its simulation engine is more powerful than other developed simulation tools such as DOE-2 and BLAST, the graphical representation is also not available in EnergyPlus. However, it has a model import function by using IDF text to enter the building properties [44, 47, 50].

2.2.2.5. Green building studio. The Green Building Studio (GBS) is web-based energy analysis software that allows designers and architects to predict energy performance, carbon emission and cost analysis of a building. The GBS uses the DOE-2 simulation engine and the developers from Autodesk Company improved the graphical user interface of the simulation engine DOE-2. The building spaces, rooms, number of openings and their sizes are used as building geometry input by the GBS. Therefore, a detailed 3-D geometry is not needed. The GBS has a capability of importing gbXML files to use in energy performance analysis. Apart from this, the Revit architecture tool developed by Autodesk Company can be integrated with the GBS via online without exporting or importing files. This interoperability functionality makes using the GBS easier especially for beginners.

The GBS has wide input choices such as building construction materials, schedules, internal loads, HVAC equipment which are needed for the energy analysis. In order to select the best design option for energy efficiency, the GBS provides various options for choosing structural and architectural materials, HVAC and lighting equipment. At the end of the performance analysis, the comparison of the design alternatives can be listed and compared. As a result, the users can select both more economical and energy efficient design choices for retrofitting the existing and designing the new energy efficient buildings [51].

2.2.2.6. Design builder. The Design Builder is another commonly used building energy simulation tool by the designers. Its last version consists of CAD drawing visualization, default weather templates providing detail temperature information from real building location and high capacity thermal behavior calculation options. The Design Builder has a very advanced graphical user interface that has been integrated with the Energy Plus simulation engine to run the energy performance analysis of a building. Along with the designer and engineers, the energy assessors have been using to define the energy rate of a building based on Energy Performance Certificate (EPC) regulations. The Design Builder includes a core 3-D modelling tool and 9 modules that are collected in the software to enable users to perform precise energy analysis and predict energy consumption for any building. The modules of the Design Builder are; 3-D modeling tool, visualization, certification, simulation, daylighting, HVAC, cost, LEED, optimization, Computational Fluid Dynamics (CFD).

When taken all 9 modules of the software into consideration, some prominent properties of the Design Builder can be listed as follows;

- Prediction of the total building energy consumption
- Simulation of thermal zones ventilated naturally
- Representation of electric conservation from lighting due to the use of natural daylight
- Estimation of natural daylighting distribution in the spaces by daylighting modules
- Representation of site layout and solar shading
- Analyzing heating and cooling energy requirements by means of HVAC module
- Detail design of HVAC and natural ventilation systems within a room using CFD module
- Displaying certification reports based on UK, Ireland, France and Portugal building energy standards via certification module

- Simulating the electricity consumption in detail based on the home devices or spaces lighting.
- There are so many templates related to intended use of building, occupancy schedule, occupant intensity in a building, weather and location databases that can be used in flexible [44, 52].

2.2.3. The advantages and drawbacks of the energy simulation tools

The building energy simulation tools enable users to obtain quick and comprehensive results regarding energy performance and energy consumption of existing or new buildings by accounting of thermodynamic principles and simple assumptions. The building geometries, internal loads and external loads can be assigned to the software as an input such as electrical devices and lighting, HVAC systems and equipment, external loads weather and location data, utility rate and cost, building intended use and schedules. In addition, because of obtaining energy performance results in a short time, the users can generate different scenarios to achieve the optimum solution in energy efficiency and cost effectiveness. Using energy simulation tools are especially important to get cost effective solutions quickly which are required by the facility managers for retrofitting the existing buildings. The designers also aim to achieve quick and simple energy analysis results by using the energy performance software during all the design stages. Furthermore, the development of graphical user interface built on the simulation engines to run the energy performance enhances the design options. Along with the visual representation of the buildings, the energy simulation results can be understood and interpreted more easily. By using real time weather and location data from site, additional calculations are not necessary for external load definitions [43, 44, 46].

Even though the energy simulation tools facilitate the energy performance analysis of a building, there is a gap between actual and estimated energy consumption observed of the buildings according to many studies conducted so far [18, 53-55]. Actually, the energy performance analysis is based on the default weather conditions. However, there is always a possibility of having wrong analysis when the conditions are changed. Also, the thermal calculation settings in the simulation tools are more complex compared to default settings assigned in the simulation tools, so the conclusions can be different matched to real energy consumption. The internal loads are based on the assumptions as well as thermodynamic calculation settings. The internal loads are selected from fixed templates in the simulation tools. For example, if you are analyzing the energy performance of a hotel building at a random place, you should identify the room as a hotel room by using the default settings. However, the usage density and energy consumption behavior in hotels show differences based on geographical locations, so the default settings of the energy usage could not be identical for different hotels. Another reason of the gap between actual and predicted energy consumption is neglecting the differences in user behavior. Most of the simulation tools accept that the users have constant schedule in the buildings, so the analysis is based on default user behavior assumptions as other technical inputs. As a consequence, the reason of the energy consumption discrepancies between actual and estimated is considered as due to both technical and behavioral assumptions of user energy consumption in the buildings [19, 20, 56].

2.3. User Energy Cansumption

In spite of the importance of the user energy consumption patterns in the buildings, the behaviors' of residents are simulated by default settings and the occupancy schedules are fixed depending on the building type templates by the simulation tools. The indicator parameters of the occupant behavior have been minimized or neglected by the simulation tools [18, 20, 21].

The energy consumption of buildings comprises three type of usage; the operational, space utilization and the occupant behavior. The energy usage pattern has great impact on the total building energy consumption due to their indoor activities such as relocation, devices usage, open or close windows, controlling HVAC systems, water consumption, and lighting devices utilization. All mentioned activities influence the building energy consumption directly or indirectly, therefore it is crucial not to neglect the impact of differences in user energy consumption patterns.

Azar and Menassa (2012) state that the impact of the occupant behavior change up to 40% level in the buildings[56]. Another study also shows that the potential energy savings can be achieved from 5% to 30% by changing user energy behavior [18]. Therefore, the impact of the occupant behavior in building energy consumption is significantly important. Similarly another study shows that the variation between two similar buildings in same location was found 20% due to accounting of the occupant behavior differences [15]. Nevertheless, since the user behavior shows differences in energy consumption, the electricity usage has a wide range in the buildings, from 0 to 14.3 kWh/m2 with an average of 2.3 kWh/m^2 [55]. Furthermore, “it has been estimated in various studies that behavioral factors explain about 30% of the variance in overall heating consumption and 50% in cooling consumption, and that overall energy savings of 10-20% due to simple behavioral adjustments are a reasonable expectation” [57]. In detail aspects of the user energy behavior, the energy consumption depends on two important parameters in the buildings, the occupancy schedule concerning with absence of presence of people and all the indoor activities also depending on the absence of the residents.

2.3.1. The Occupancy Schedule in Energy Consumption

Before looking into the occupant indoor activities, first of all their absence or presence should be initially considered. It is a fact that the user energy consumption patterns cannot be considered without reflecting the presence of people in the buildings. More accurate occupancy schedule will provide to achieve more realistic energy consumption prediction for the buildings. Thus far, there are various research that have been conducted to observe the importance and effectiveness of occupancy schedule for buildings in total energy consumption [21, 53, 58]. The objective of these studies is to explain the differences found between predicted and actual energy performance for the buildings.

Yao and Steemers (2004) stated that an office room assigning different occupancy schedules were analyzed to present the influences of the occupancy in energy performance [53]. The average energy consumption based on the five scenarios was calculated and compared with the real consumption. The energy consumption intensity among the analysis results was different due to office occupancy schedules.

To simulate the user behavior and occupancy in the energy simulation tools, two models were integrated in another case study [19]. In this study, the researchers integrated the energy behavior model, the User Simulation of Space Utilization (USSU) and the Sub-Hourly Occupancy Control (SHOCC), into the building performance simulation tool, ESP-r. The USSU model presenting presence of occupants was used with SHOCC - model including user presence and interaction with the building which was applied in a simple office room. Moreover, ESP-r was selected to use for whole building simulation program to execute the dynamic simulations of a building model. Accordingly, some energy performance parameters such as the presence of the occupants have an influence on the variation between actual and estimated energy consumption [19].

Wasilowski and Reinhart (2009) observed the differences between the actual and predicted energy consumption of an existing education building located in Cambridge, MA, USA [20]. In order to define the customized parameters for input, the researchers inspected Harvard University building and conducted a survey to learn the occupancy schedules of the students via online questionnaire and also gathered information from university facility managers. The average occupancy schedule based on the survey was identified and assigned to the simulation tool with supplementary information collected from the site. The energy model of the university building was developed by using the DesignBuilder which is a simulation and design tool. Researchers conducted two separate analysis; one with default values automatically assigned by the tool and the other analysis with the customized values. At the end of the study, the results showed that the actual and predicted energy consumption values of heating and cooling systems were similar due to the central HVAC system. However, the measured and predicted energy consumption turned out to be different by 30%- 35%. Wasilowski and Reinhart (2009) demonstrated that the customization of the occupancy schedule with other energy consumption information such as device usage density or occupant behavior in the simulation tools could change the energy performance results especially for electricity consumption [20].

2.3.2. The Occupant Activities in Energy Consumption

Another aspect of the differences in measured and predicted energy consumption in the buildings is related with the occupant activities. As the user energy consumption pattern has a major role in the discrepancy between design estimation and actual energy use, many studies have been aimed to mitigate the energy prediction gap in recent years [19, 54, 56]. Many researcher developed agent based algorithms to present the actual energy consumption by the occupants [56, 58]. Besides, the eco-feedback studies were conducted to reduce total building energy consumption by changing the user behaviors [15, 16, 59]. The studies about gathering real user information from building site have been executed in two ways, qualitatively and quantitative [9, 20, 55, 60]. The qualitative studies were conducted by questionnaires to obtain energy consumption behavior information from the residents. The quantitative works were executed by monitoring real energy consumption of the users. Thus, research on monitoring and providing feedback emphasize the importance of occupants‘ energy usage behaviors in analyzing the building energy performance of existing buildings and the prediction of energy demand for new buildings during design process. However, one should remember that the human behavior is complicated and estimating the behavior is challenging [61, 62].

In order to present the importance of the user behavior in the prediction of energy consumption, another research focused on the impact of the occupant behavior in lighting usage [21]. In this research, several occupant behavior options were developed by using the automatic and manual control of blind and lighting systems to estimate the potential savings of a daylight dimming system. All the simulation results showed that the energy savings can be increased by 10% due to occupant behavior. Therefore, if the occupant behavior is neglected, the potential energy savings for buildings could be overestimated which leads to make wrong decisions in investment of energy efficient measures.

As an illustration for another occupant behavior study, the user activities in the buildings whether has an impact on the energy use of an office room was inspected in the Lawrence Berkeley National Laboratory [18]. Because of the complexity of user behavior definition, the investigator brought different approaches to identify the user energy consumption patterns in the buildings by clustering the occupants in three groups theoretically based on usual life style. The groups were austerity residents who are active in energy conservation, standard occupants showing average consumption pattern and wasteful ones not taking care about energy use. The properties of groups were assigned to the simulation tools based on defined criteria for a simple office independently. After performing the energy analysis of three cluster models, the findings from the study displayed that the austerity occupants consumed 50% less energy, whereas the residents identified as wasteful used 90% more energy compared to the standard users accepted as a control group in the study [18].

The research mentioned earlier present that there is a gap between actual and predicted energy usage. The most prominent reason of this issue has been accepted as simplifying or neglecting the user energy consumption behavior in the simulations. In order to close the gap between simulated and measured energy performance of the buildings, many studies have focused on this phenomenon. However, classifying the users based on their occupancy and indoor activities have not been done by conducting questionnaire till now. In this thesis, my objective is to categorize the students living in dormitories located at Bogazici University Kilyos Campus via survey questions and identify the features of each clustered group depending on their general occupancy and energy consumption tendency. With this study, the segmented student groups will show a wide range of difference in energy consumption that is aimed. Also, the energy performance of the dormitory buildings based on the survey information is expected to be different compared to analysis done with default settings.

3. RESEARCH METHEDOLOGY

The prominent reason of the differences found between the predicted and actual energy consumption of the buildings is neglecting the user energy consumption behavior [18, 20, 56]. In order to close the gap between the real and estimated energy performance of the dormitory buildings at Bogaziçi University Kilyos Campus, the energy user behavior will be classified. Then, the occupant energy attitudes will be imported into the energy simulation tool, DesingBuilder, in order to accurately predict the energy performance of 1st and 3rd Kilyos dormitories. The research setting, data collection, energy modeling and data analysis processes will be introduced in the next methodology sections in detail.

3.1. Research Setting

This study was conducted on Saritepe Campus located in Kilyos which is on the north side of Istanbul and Black Sea coast. The campus has seven buildings with 25040 m^2 flat area; three of these buildings are dormitories presented in Figure 3.2, being used by foreign language school students and campus staffs. There are approximately 800 English preparation class students that have been living on Kampus. Besides, most of faculties of the Foreign Language School are also living in apartments on Kilyos Campus. Therefore, the life standards of the campus have been tried to increase since 2001. All English preparation class students came from different cities are living in the campus dormitories presented in Table 3.1; 1^{st} dormitory including north and south wings for females (384 students capacity), 2^{nd} dormitory for males (364 students capacity) and the 3^{rd} dormitory (400 students capacity) for both male and female have been in service at the beginning of the 2015.

Table 3.1. Kilyos Dormitories.

Kilyos Dormitories	Capacity (Students)	Dormitory Type
1^{st} Dormitory	384	Female
2^{nd} Dormitory	364	Male
3^{rd} Dormitory	400	Male and Female

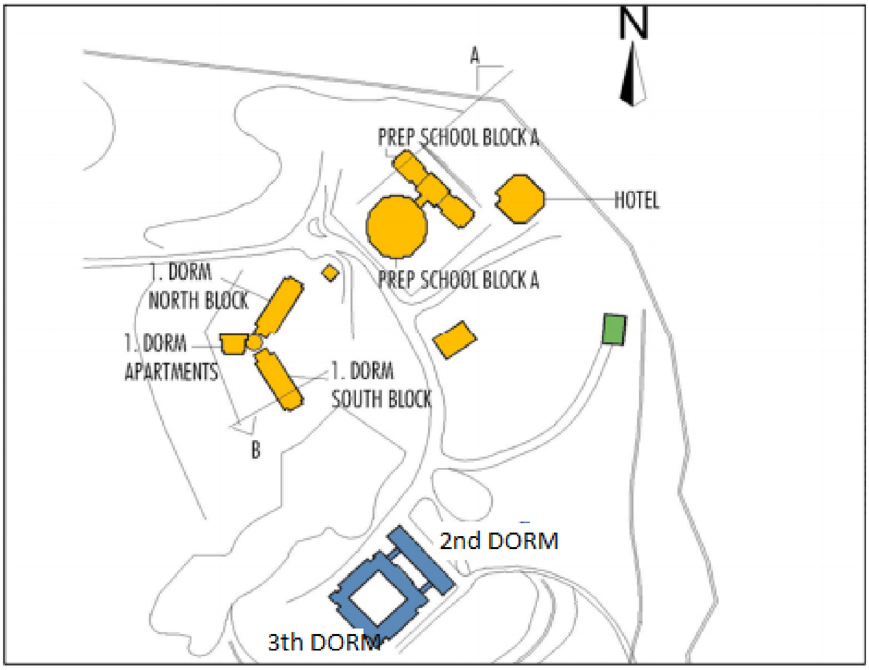


Figure 3.1. Bogaziçi University Kilyos Campus Site Layout.

Since the campus is located far away from the city center, there are various social facilities that have been provided to the students. Apart from this, the campus has been aimed to achieve green campus statue to increase life standards by the application of various energy efficiency projects. For example, the wind turbine that was installed as a part of the Bogaziçi University Wind Power Plant (BÜRES) project on Bogaziçi University Saritepe Campus started to generate electricity on December 27, 2014, making it the only campus in the world that "meets the whole of its electricity demands from its own wind power plant"[63]. Hence, the innovative developments in the energy field on the campus can make contribution to clean environmental with high attendance of the students to the projects.

The students have preset school schedule for their English preparation education and the dormitories are located near the foreign language school building. Generally, most of the students spent time in their rooms because of transportation difficulties to the city center. Also, since the weather conditions around the campus site is very windy and cool during the winter season, the students generally prefer spend their time in the rooms. The lecture schedule of the English preparation classes can be seen in Table 3.2.

Table 3.2. Kilyos Campus Foreign Language School Schedule.

Level	First Block	Second Block	Third Block	Launch	Fourth Block	Fifth Block
Beginner (A-Days)	9:45 - 11:00 75 Min	11:15 - 12:30 75 Min	12:45 - 14:00 75 Min	45 Min	14:45 - 15:30 45 Min	15:45-16:45 60 Min
Beginner (B-Days)	9:45 - 11:00 75 Min	11:15 - 12:30 75 Min	12:45 - 14:00 75 Min			
Pre-Intermediate (A- Days)	9:45 - 11:00 75 Min	11:15 - 12:30 75 Min	12:45 - 14:00 75 Min	45 Min	14:45 -16:00 75 Min	
Pre-Intermediate (B- Days)	9:45 - 11:00 75 Min	11:15 - 12:30 75 Min	12:45 - 14:00 75 Min			
Intermediate (A-Days)	9:45 - 11:00 75 Min	11:15 - 12:30 75 Min	12:45 - 14:00 75 Min			
Intermediate (B-Days)	9:45 - 11:00 75 Min	11:15 - 12:30 75 Min	12:45 - 14:00 75 Min			
Advanced	9:45 - 11:00 75 Min	11:15 - 12:30 75 Min	12:45 - 14:00 75 Min			

Each student dormitory has a variety of facilities with all the comfort of home such as TV rooms, free wireless internet, PC laboratories, ironing and laundry rooms, fitness centers, study rooms, vending machines and kitchens. The town shops are 15 minutes away by shuttle; students can take shuttle service to access the stores. Accordingly, it is estimated that around 700 students usually stay on campus during weekday daytime.

3.2. Data Collection

The qualitative survey approach was adopted to define the energy behavior of the students staying on campus. In addition, instead of using an online survey, a paper based survey was preferred. The return rate for online surveys usually stay 30%

- 50% levels [64, 65], but more students‘ information were required to identify their energy attitudes accurately. Before designing the survey questions, a site visit was conducted to identify the energy consuming appliances such as kitchen devices, lighting system, heating and cooling systems was done. Also, the interview with the dormitory administrators was done to learn the student general life style and appliances usage tendencies. At the end of the observation process, the draft of the survey questions was prepared by utilizing different segmentation papers [50-53]. The studies included with some specific questions were scanned to prepare my survey questions. Most of the questions were changed depending on my search field. The first part of the survey, the demographic questions were asked to profile the students staying at the dormitories. The second part of the survey aims to identify how long students stay in their rooms based on weekend, weekdays, evenings and daylight times. The questions related with time spending in room takes into account the lecture schedules given in Figure 3.3. After that, the electricity consumption patterns were specified by asking various questions such as frequencies of electricity devices utilization, laundry facilities and lighting usage density during the daytime. Besides, the questions related to heating and cooling utilization preferences were excluded from the survey. The last section of the questionnaire was generated as understanding the students' general thoughts related with the energy consumption and environmental issues. As a result, 35 questions were asked to collect data about the students' general attitude of electricity consumption and their daily preferences (Appendix A).

After designing the survey questions, to get the required permission from the foreign school administration, the advisor of thesis contacted with coordinator of the Kilyos Campus. Then, he was contacted with the administrator of the Foreign Language School. At the end of the bureaucratic processes, the required official permission was obtained.

The data collection was conducted by going to each prep class at the beginning and end of the lectures. The general information about survey questions was given to the lecturers and students. The questionnaire took less than 10 minutes to complete as expected. No personal identification information was required in the questionnaire and the answers have been kept strictly confidential and evaluated only by the researcher. The three sessions of data collection took place on consecutive days during class sessions. At the end of the data collection process, the survey was done with 529 students hat shows the respond rate roughly 70% really higher than online methods.

3.3. Energy Modeling Of the Dormitories

To begin with, the first dormitory just for female students and third dormitory used by both males and females were selected to use in energy performance analysis. Since the density of usage is higher in these two dorms, the analysis results are expected to be more precise. Before energy modeling of the dorm buildings, the architectural BIM tool, Revit, was utilized to develop the 3D models of the dormitories. The 2D models were obtained from Bogazici University Construction Works Administration as digital drawings in DWG format. The geometry of the dormitories was developed based on these 2D models by using Revit. Later 3D models were integrated with the energy simulation tool. The 3D view of two dormitories in Revit was provided in Figure 3.2 and Figure 3.3.

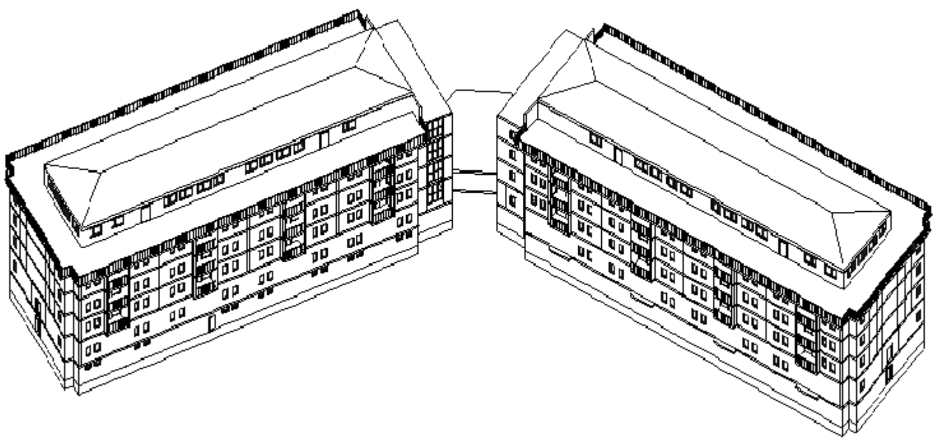


Figure 3.2. 1^{st} Dormitory in Revit (Female).

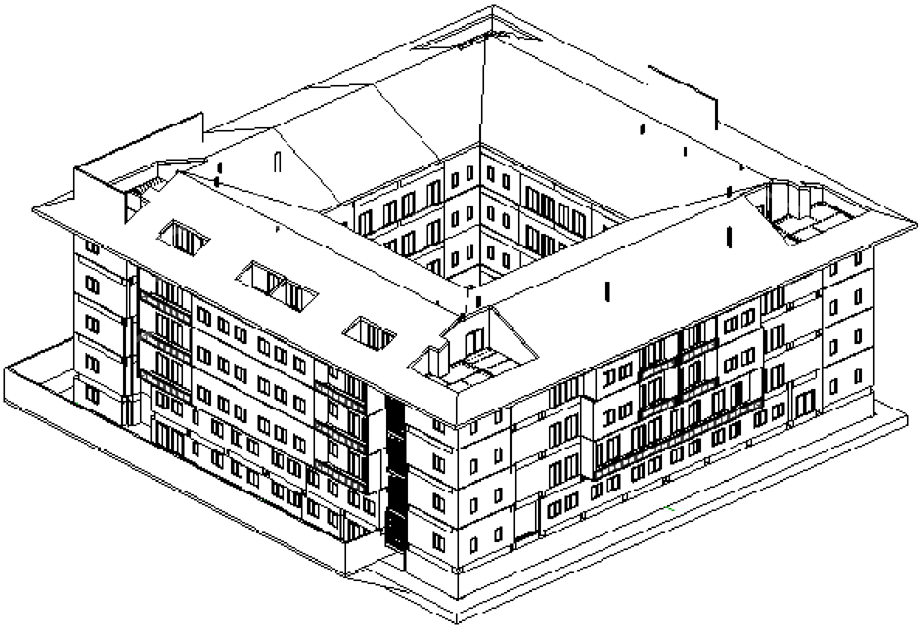


Figure 3.3. 3^{rd} Dormitory in Revit (Mixed).

The DesignBuilder, as stated earlier, was selected due to its interoperation capabilities with architectural programs. Apart from this, the DesignBuilder has more detail input settings for HVAC, lighting systems and occupancy schedules. The equipment usage based on the occupancy can be elaborately arranged. Especially electricity consumption from the lighting can be adjusted with various flexible choices. In addition, the DesignBuilder has many weather and occupancy schedule templates, so the building inputs can be assigned depending on intended use. The DesignBuilder analyzes the energy performance of the building by using spaces and surfaces. Therefore, the room assignment into the simulation tool has a crucial role in the assessment of the energy consumption. The general processes of the energy modeling scheme can be seen in Figure 3.4.

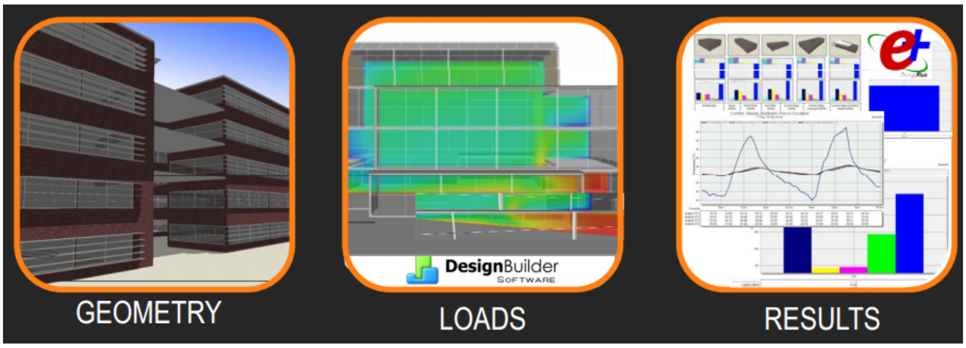


Figure 3.4. General DesignBuilder Energy Modeling Process.

For the first and third dormitory room assignments, the faculty apartments and dormitory halls were excluded from the energy consumption analysis. Also, the other common areas such as laundry and ironing rooms, kitchens and bathrooms were identified individually. Since the students were classified based on the energy consumption preferences and the students from all the clusters use these kind of common areas together, including the common places into the energy performance analysis was not meaningful. The electricity consumption from facility rooms was basically distributed to the defined rooms. Therefore, the consumed electricity was estimated just for the bedrooms, kitchens and bathrooms.

A DesignBuilder icon is available in the Revit module section to transfer the 3D models. In other words, the 3D geometry models are integrated into the DesignBuilder by using the transfer module in the Revit software. The energy model of the dormitories designed in the Revit was exported to the DesignBuilder. Then, the energy simulation tool was ready to regulate the inputs such as lighting, electricity devices usage and occupancy schedules to analyze the energy performance of the buildings. The energy models of two dormitories in DesignBuilder were presented in Figure 3.5 and Figure 3.6.

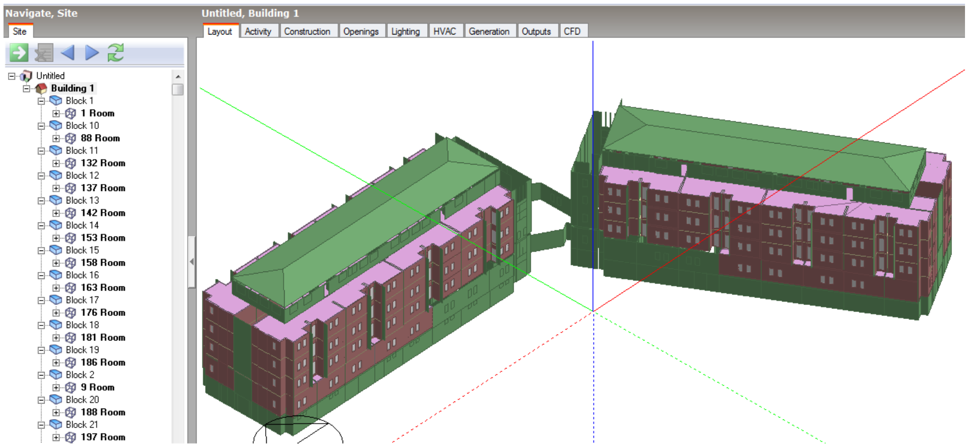


Figure 3.5. 1^{st} Dormitory 3D View in DesignBuilder.

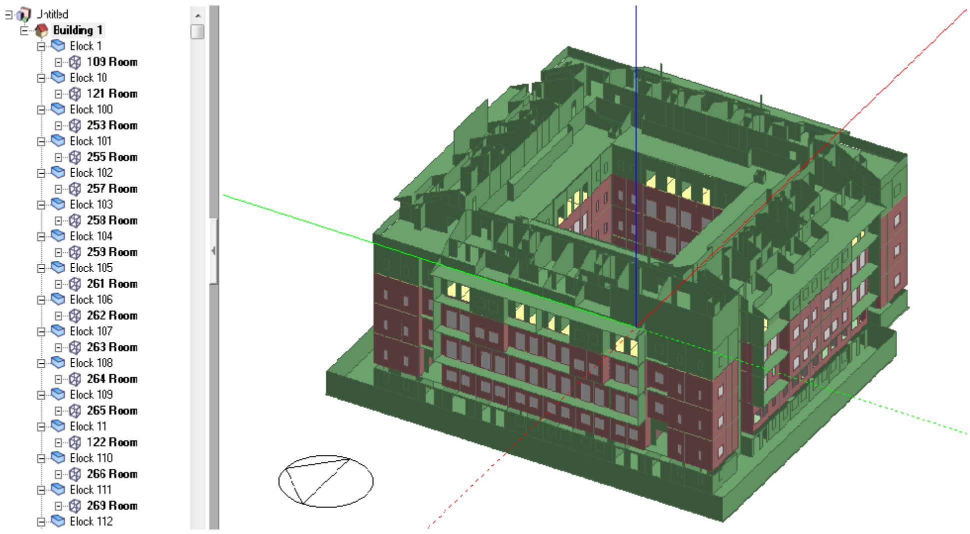


Figure 3.6. 3^{rd} Dormitory 3D View in DesignBuilder.

3.4. Data Analysis

To conduct the energy analysis of the dormitory buildings, two different processes were utilized. First one was the classification of the students' energy consumption behavior. In order to segment the students based on the energy user behavior, a questionnaire was developed and conducted on the Bogazici University Kilyos Campus. The obtained survey answers from the students were analyzed by using factor and cluster analysis techniques to classify the students according to electricity consumption preferences and time spending in the rooms.

The second process was the energy modeling of the dormitories. To generate the energy models, the 3D geometry of the buildings were prepared in the architectural tool, Revit. Then, the architectural models were integrated into the energy simulation tool, the DesignBuilder. At the end of this process, the energy performance analysis of the dormitory buildings was conducted in the DesignBuilder. The steps of the energy analysis are provided in Figure 3.7.

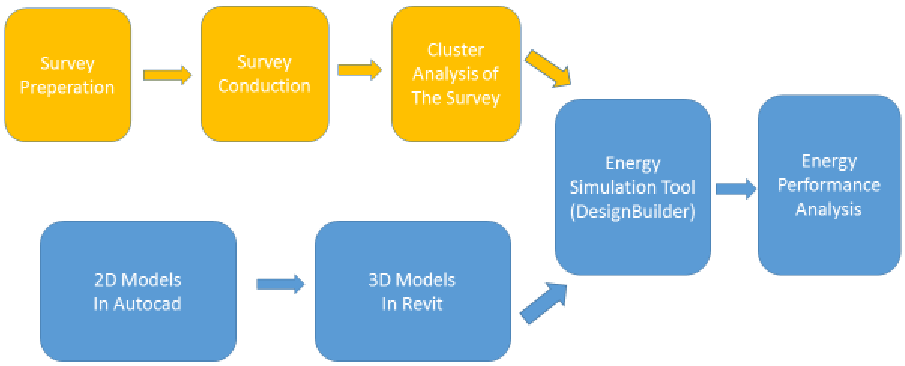


Figure 3.7. The Energy Performance Analysis Steps.

After completing the survey analysis and 3D modeling of the dormitory buildings, the analyze process was started to conduct. The statistical analysis was performed by using SPSS software (version 22). At the end of the data collection, the survey answers were entered into the SPSS step by step for each case. The next step was to investigate the survey analysis techniques to obtain precise conclusion in classifying the students based on the user energy behavior.

Various clustering methods were found in the academic studies related to the data classification [65-68]. Sütterlin and colleagues (2011) classified the energy consumers by using cluster analysis method based on two main subject; energy efficient measures and energy-related behavioral characteristic [65]. Finisterra and colleagues (2008) focused on the segmentation of the green product consumers to develop suitable strategies [66]. They used the demographic such as general information about participants and psychographic variables including behavioral criteria such as people's activities, interests and opinions as classification variables. The data obtained were analyzed by Multivariate Statistical Analysis constituting factor analysis, cluster analysis and discriminant analysis. At the end of the analysis, the segmented groups were characterized in detail. Pedersen (2008) conducted a survey to classify the households based on the electricity patterns [67]. The survey questions included 60 attitudinal and behavioral questions concerning electricity and conservation. The k-means cluster analysis method was utilized to segment the residents. The analysis results show that the households were classified into 6 groups and the clusters were characterized in detail. Ji and colleagues (2014) carried out a study to provide descriptions for Chinese teenagers who are Renren, social network users [68]. They conducted a survey at even middle schools in Beijing. The general linear model provided by SPSS was used to identify the social network, Renren, users. Among all the alternative methods, the cluster analysis method was selected as the best approach to classify and define the energy behavior of the students in my study. As it is difficult to define the energy behavior of each student, the students were classified into groups based on energy behavior. Consequently, the clustering methods could give precise information to understand the electricity consumption preferences of the students who belong to different groups [65, 67].

The analysis techniques, factor analysis and cluster analysis, were conducted. The survey data analysis is a crucial leg of this study since the energy consumption attitudes of the students were assigned to the simulation tool based on the cluster identifications. The factor analysis was the first step to validate the reliability of the survey questions and the data reduction. The survey dependent variables were reduced by factor analysis. It is often used to identify a small number of latent variables that explain most of the variance embedded in a larger number of observed variables. Then, the cluster analysis was applied using the factor analysis results to define the segmentation of the respondents. The cluster analysis enables to group the students based on their consumption behavior. The cluster analysis was conducted in two steps. First one was hierarchical cluster analysis and the second was non-hierarchical analysis k-means clustering method. In the first step, the hierarchical approach could give prior knowledge about how many clusters would be available accurately for classifying. Then, with prior knowledge from hierarchical analysis, the k-mean cluster analysis method was applied. In the k-mean analysis technique, the software required definite cluster numbers from the users. Therefore, the most accurate way to classify the students according to the electricity consumption preferences and time spending in rooms could be using hierarchical and cluster analysis approach. Since the validation of the cluster analysis is important to show the differences among each groups based on dependent variables, two-way MANOVA test was applied on the segmented groups based on electricity consumption preferences and spent time in rooms. At the end of the cluster analysis using k-means analysis, the classified student groups were identified as cluster A, B and C.

To calculate the electricity consumption of the dormitories, the DesingBuilder is required internal load values. By using the load parameters, both the total room consumption and the lighting electricity consumption were estimated for the dormitories. The internal loads were selected according to the survey results. In the dormitories, the students consume electricity from lighting system, electrical equipment such as kitchen appliances and notebooks and also other building facilities such as ironing, washing/drying machines and fitness centers. The laundry rooms or other communal areas were not included in the energy models, but the electricity consumption of these spaces was distributed to the student rooms. There is one or two facility rooms in the dormitories and it could not be defined which student groups use the facilities more than the other groups. In the DesignBuilder activity and lighting tab, the internal load values can be entered manually. There are various choices to identify the internal loads, but the computer, miscellaneous, catering and lighting parts were selected as the internal loads to predict the electricity consumption in the dormitories. For each student groups classified based on their energy behavior, the fix internal loads and flexible equipment and lighting schedules were used based on the survey answers. Since the study was focused on the consumed electricity just in bedrooms, kitchen and bathrooms by the students, the HVAC system equipment such as fans, air conditions or pump electricity consumption was neglected. Due to the fact that the students live in the dormitories during winter and spring seasons, the all winter energy simulation period from first October to end of the March was used. The energy simulation settings can be arranged under activity and lighting tab presented in Figure 3.8 in the DesignBuilder.

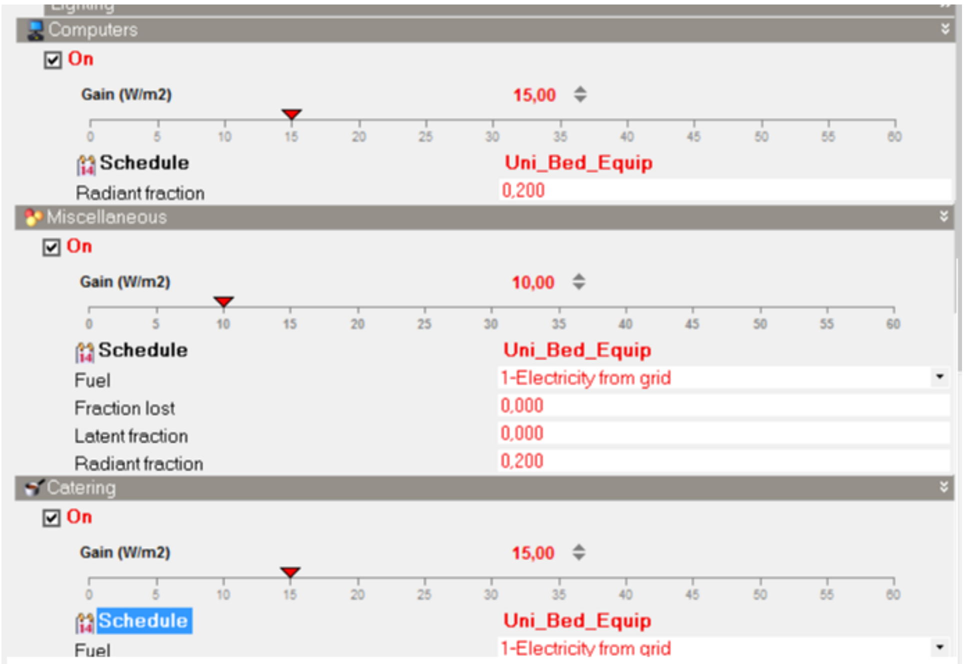


Figure 3.8. The DesingBuilder Internal Loads in Activity Tab.

Table 3.3. Internal Loads in the DesignBuilder and Survey [69].

Internal Loads	Load (W/m^2)	Related Equipment	Related Survey Questions
Lighting	12	Room Lighting Sytems	Q11- Q12
Computer	15	Notebooks Laptop	Q14-Q15
Catering	15	Kitchen Appliances	Q16
Miscallenous	10	Ironing, Laundry Rooms, Fitness Center, Vending Machine	Q17-Q18-Q19-Q20

The internal load values for lighting, computer, catering devices and miscellaneous that indicates the electricity consumption density in wattage per square area as presented in the Table 3.3 was obtained from ASHRAE 90.1 regulation and The Chartered Institution of Building Services Engineers (CIBSE) Guide for environmental design and real executions [49-50-51]. The assigned values were used as an input under the activity and lighting tab in DesignBuilder to calculate the electricity consumption of the lighting, catering devices, laptops and laundry facilities.

The distribution percentage of each group in the dorm buildings was calculated by the SPSS. Then, the properties of the clustered groups were assigned based on the distribution ratio to the rooms in DesignBuilder for each selected dormitory. The devices utilization and lighting schedules and occupancy schedules were assigned for each student group by using activity and lighting modules. Also, the equipment and lighting schedules were arranged depending on the equipment and lighting usage density. Therefore, the impact of the different equipment usage density in three groups on the energy consumption can be observed accurately.

In the simulation tools, DesignBuilder, has default templates to analyze the energy performance of the buildings. The default schedules such as lighting utilization schedules based on the general building operation are provided by simulation engine to the users. Therefore, the users do not need define any occupancy or devices usage schedules and select provided by the simulation tools any preset template according to the buildings The default input settings and schedules are built on the ASHRAE 90.1 standard versions. The ASHRAE 90.1 version 2010 regulation was utilized for default setting analysis of the dormitory buildings. In order to observe the electricity consumption differences among all the cluster, the Cluster C was thought as staying at all dormitory rooms. The energy performance analysis of the dormitories was conducted by assigning the Cluster C energy user behavior to the all rooms. The same energy performance analysis method was applied to the dormitories for both Cluster A and B. Therefore, the differences in electricity consumption of the dormitories can be accurately observed based on the electricity consumption patterns of the clusters. Another electricity consumption estimation method for the buildings was that all the clusters were considered as living together in the dormitory buildings. The electricity consumption behaviors of the clusters were defined to the rooms in the simulation tool according to real distribution rate of the student groups. Hence, the real approach in the prediction of the electricity consumption was conducted by using the energy user behavior of all clusters together. The Green Building Studio also was used to predict the default energy consumption of the dormitories and compare other results. The Green Building Studio (GBS) do not provide any schedules for electricity devices usage. While the DesignBuilder perform the energy analysis based on the different schedules, the energy consumption analysis is done by using just occupancy schedules in the GBS. Also, there are few occupancy schedules to conduct an energy performance analysis in the GBS. The GBs electricity consumption analysis results can be compared to the default setting analysis in the DesignBuilder.

4. RESULTS

4.1. Survey Analysis Findings

As stated in the methodology section, an exploratory factor analysis was used to simplify the interpretation of the variables. Each of the factors was depicted by means of several items used in the questionnaire. The factor analysis used to determine the factors that were relevant to the study originated new nine variables. These new variables then were used as inputs in later cluster analysis. The new component variables show 83.33% variances of all the dependent fourteen variables, survey questions, related to electricity consumption behavior and time spent in the rooms. Table 4.2 provides that the results obtained from factor analysis and new dependent variables. For instance, the first new variable is constituted by time spend questions concerning with daytime for weekend, nighttime for weekdays and weekends. From the Table 4.2 below, it can be also seen that the inter-correlations among the nine measures of the students' electricity consumption attitude and time spent in the rooms. To reduce the dependent variables by using factor analysis. The principal component analysis method was utilized. Also, the results of the Kaiser-Mayer-Olkin (KMO) - Bartlett's test in Table 4.1 illustrates that the measuring of sampling adequacy is enough to do survey analysis. Besides, as the significance value is under 0.05, the null hypothesis was rejected which means that the variances do not have normal distribution and relationship among the variables.

Table 4.1. Kaiser-Meyer-Olkin and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.539
Bartlett's Test	Approx. Chi-Square	765.628
	df	78
	Sig.	0.000

Table 4.2. Factor Analysis New Component Variables.

Questions	Component								
	1	2	3	4	5	6	7	8	9
spend time in room daytime for weekdays						0.9			
spend time in room daytime for weekend	0.737								
spend time in room nighttime for weekday	0.634								
spend time in room nighttime for weekend	0.921								
frequency of turning off lights when room unoccupied		0.819							
frequency of using lights during daytime							0.934		
frequency of using laptop								0.985	
frequency of turning of the electricity devices when not in use		0.805							
frequency of using cook and house appliances					0.915				
frequency of using washing/drying machine			0.823						
frequency of using vending machines									0.941
frequency of going to fitness center				0.954					
frequency of using ironing room			0.566						

Once the variable reduction process had been completed and the new variables had been defined by the factor analysis, both hierarchical and non-hierarchical cluster analysis were conducted. The generated component variables as presented in Table 4.3 are named according to the related questions.

Table 4.3. The Component Variables.

New Component Variables	Name of The Component Variables
1	Time spent in the rooms (daytime for weekends and nighttime for all days)
2	Turning off the electrical devices
3	Washing/drying machine
4	Fitness center
5	Kitchen devices
6	Time spent in the rooms during daytime for weekdays
7	Using lights during daytime
8	Laptop
9	Vending machines

In order to obtain prior knowledge about optimum cluster numbers, the hierarchical analysis was initially done. In the hierarchical analysis by using Ward's method and Squared Euclidian Distance method, the increasing value of the coefficient in every analysis step was inspected in the agglomeration schedule. If the coefficients increase in unexpected value for next step, after this step there is new cluster that has been generated in the analysis. In our agglomeration schedule, the coefficient indicated an unexpected increasing value after step number of 526. After analyzing the percentage variation of the agglomeration coefficient, it was decided to opt for three-cluster solution. When 526 steps were excluded from all 529 analysis steps, the definite initial cluster number for k-mean cluster analysis was calculated in Equation 4.1. This number of cluster does not give the precise solution for cluster analysis, but the initial knowledge just provides an idea related to optimum cluster numbers for k-means cluster analysis.

$$\begin{aligned} &AllAnalysisSteps\,(529) - \\ &NormalCoefficientAglomerationSteps\,(526) = 3Cluster \end{aligned} \tag{4.1}$$

With obtaining the idea about optimum cluster number from hierarchical analysis, the k-means cluster analysis was conducted in order to achieve definite result in cluster numbers. The obtained cluster number from hierarchical analysis was assigned to the k-means analysis. Therefore, the k-means cluster analysis was conducted based on the three clusters. Firstly, the initial cluster centers were determined by using variables obtained from Ander-Rubin factor scores saved as new nine variables after factor analysis before. The cluster centers were iterated and updated in each analysis step. The initial cluster centers illustrated in Table 4.2 were generated according to the factor analysis component nine variables given left column. The cluster centers were calculated depending on the mean of the variables.

Table 4.4. The Number Cases in Each Cluster.

Cluster Numbers	A	200
	B	171
	C	158
Total		529

The findings show that first cluster defined as Cluster A has 200 students, the second one defined as Cluster B has 171 and the third one defined as Cluster C was constituted by 158 students. Total, the collected 529 data from survey is illustrated in the Table 4.4.

In order to validate whether the clustered groups show differences among each other, two-way MANOVA test was applied on the segmented groups. The mean values of the dependent variables related with answers of spent time in rooms and electricity consumption attitude questions were calculated for two groups. By observing the results in column Significance of Table 4.6, it can be seen that these allowed us to reject the null hypothesis of equal means among the groups, and to accept the alternative hypothesis, as the groups displayed different means. Also, the Wilk's Lambda statistical results in Table 4.6 explain that there are differences between the group mean values and variation within these groups. Besides, as can be seen from the Table 4.5, the mean values of the electricity consumption behavior show differences among each cluster. The Cluster 1 defined as Cluster A and Cluster 2 defined as Cluster B is nearly similar in time spend in the rooms.

Table 4.5. Descriptive Statistics of Each Cluster.

Related Questions	Cluster Number of Case	Mean	Std. Deviation	N
time spent in the rooms	A	31.000	0.65356	200
	B	22.222	0.69157	171
	C	30.506	0.82543	158
	Total	28.015	0.82375	529
electricity behavior	A	25.872	0.41475	200
	B	23.112	0.38464	171
	C	27.778	0.46112	158
	Total	25.549	0.45845	529

Table 4.6. Two Way-Manova Test Results.

Effect		Value	F	Hypothesis df	Error df	Sig.
k-mean cluster	Pillai's Trace	0.359	57.618	4.000	1,052.000	0.000
	Wilks' Lambda	0.649	63.303(a)	4.000	1,050.000	0.000
	Hotelling's Trace	0.527	69.071	4.000	1,048.000	0.000
	Roy's Largest Root	0.501	131.733(b)	2.000	526.000	0.000

In order to decide whether the cluster groups show differences between each other, the Wilks' Lambda test values were taken into account in the second row, k-mean cluster which is the last conducted k-means cluster analysis presented in Table 4.1. The significance value is under 0.05, so the null hypothesis is rejected. Wilks' lambda is used to test the null hypothesis stated as the margins of all the independent variables are equal across groups of the dependent variable. Therefore, the mean values are useful basis for predicting the group to which a case belongs, and thus there is a relationship between the independent variables and the dependent variable. As a consequence, the clusters show difference among each other and the independent variables have significant impact on the clusters.

Table 4.7. Homogeneity of Variances.

Related Questions	F	Sig.
Time spent in the rooms	4.463	0.012
Electricity behavior	3.200	0.042

Due to the fact that the significance value is under 0.05 (0.012<0.05 and 0.042<0.05), the null hypothesis, the variances show homogeneity, was rejected (Table 4.7). The F column presented in Table 4.7 show the significance of the dependent variables. Therefore, the Tamhane's test should be considered to observe the relationship among clusters.

According to the Tamhane's test results presented in Table 4.8, if the significance values are considered, the Cluster A and B show differences based on the time spent in rooms. Also, the significance value which is under 0.05 for cluster 2 and 3 shows the significant difference between the groups. However, the significance value is over 0.05 between cluster 1 and 3, so these two clusters did not show differences depending on the time spent in dormitory room. Furthermore, there is significant difference in the electricity behavior among three clusters stated in Tamhane's test results in Table 4.8. As can be seen in Sig. column for electricity usage attitudes, all the significance values are under 0.05. The two-way MANOVA test results revealed that three - cluster solution in the k-means analysis gives the precise solution to define the cluster numbers.

Table 4.8. Two-Way Manova Test Results in Multiple Comparisons.

Dependent Variable		(I) Cluster Number of Case	(J) Cluster Number of Case	Sig.
time spent in the rooms	Tukey HSD	A	B	0.000
			C	0.796
		B	A	0.000
			C	0.000
		C	A	0.796
			B	0.000
	Tamhane	A	B	0.000
			C	0.902
		B	A	0.000
			C	0.000
		C	A	0.902
			B	0.000
electricity behavior	Tukey HSD	A	B	0.000
			C	0.000
		B	A	0.000
			C	0.000
		C	A	0.000
			B	0.000
	Tamhane	A	B	0.000
			C	0.000
		B	A	0.000
			C	0.000
		C	A	0.000
			B	0.000

The mean values of the time spent in room of the students according to three groups were displayed as in Table 4.9. The Cluster B has a smaller mean value compared to Cluster A and C presented in Table 4.9. Also, the mean value of each clusters based on the time spent in room was given in mean plot Figure 4.1.

Table 4.9. The Mean Values of Each Cluster in Time Spend in Room.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	B	171	22.222	
	C	158		30.506
	A	200		31.000
	Sig.		1.000	0.798

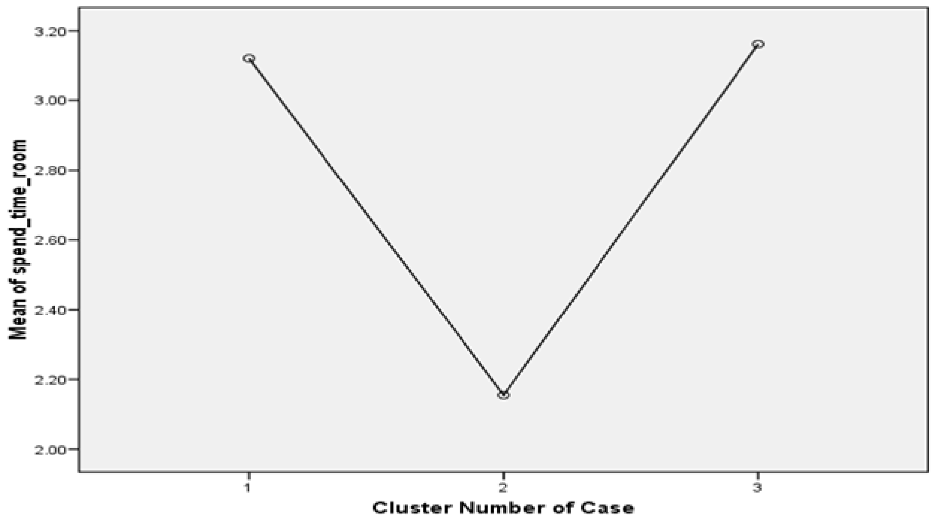


Figure 4.1. The Mean Values Plot of Each Cluster in Time Spend in Room.

When the electricity consumption preferences of the clusters are compared according to the Tamhane's test result in Table 4.8, one can conclude that all three clusters show differences among each other. The mean values of each cluster based on the electricity consumption behavior are illustrated in Table 4.10. The mean values show the significant differences among three clusters according to the electricity consumption preferences.

Table 4.10. The Mean Values of Each Cluster in Electricity Consumption Behavior.

	Cluster Number of Case	N	Subset		
			2	3	1
Tukey HSD	B	171	23.112		
	A	200		25.872	
	C	158			27.778
	Sig.		1.000	1.000	1.000

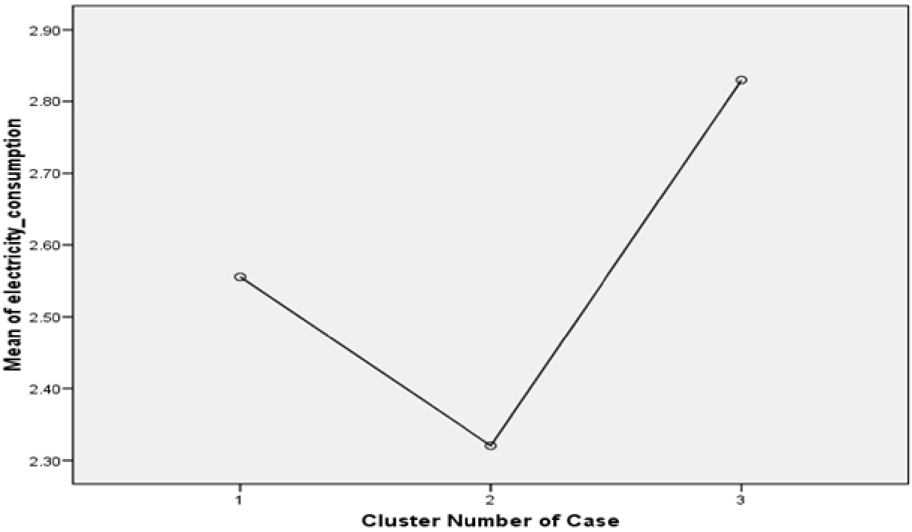


Figure 4.2. The Mean Values Plot of Each Cluster in Electricity Consumption Behavior.

As a consequence of the survey analysis in the SPSS, the students were classified into three clusters as Cluster A, B and C based on their answers to the survey questions about the time spending in rooms (Survey Q7-8-9-10 in Appendix A) and electricity consumption preferences (Survey Q11-12-13-14-15-16-17-18-19-20 in Appendix A).

According to the two-way MANOVA analysis result, the frequency of turning lights when room unoccupied for each cluster was provided in Table 4.11. The table below illustrates that the Cluster A and B have nearly similar mean values in turning off the lights when room is unoccupied compared to Cluster C.

Table 4.11. The Mean Values of Each Cluster in Turning Off the Lights When Room Is Unused.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	A	200	15.700	
	B	171	16.023	
	C	158		29.810
	Sig.		0.926	1.000

The results from the two-way MANOVA test show that the mean values of using lights during daytime do not have major differences between the Cluster B and C rather than the Cluster A presented in Table 4.12.

Table 4.12. The Mean Values of Each Cluster in Using the Lights During The Daytime.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	B	171	21.462	
	C	158	23.228	
	A	200		28.000
	Sig.		0.233	1.000

As shown in table 4.13, the mean values of the laptop usage for the Cluster A and C are almost similar and higher than the Cluster B. The mean values of computer usage are higher than other dependent variables.

Table 4.13. The Mean Values of Each Cluster in Laptop Usage.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	B	171	29.942	
	A	200		37.000
	C	158		37.025
	Sig.		1.000	1.000

Table 4.14 provides an overview about mean values of turning of the electricity devices when not in use. There is not crucial differences between the Cluster A and B, but their mean values are smaller than the Cluster C.

Table 4.14. The Mean Values of Each Cluster in Catering and Using House Devices.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	B	171	17.719	
	A	200	19.300	
	C	158		29.304
	Sig.		0.25	1.000

From the Table 4.15 presented as below it can concluded that the mean values of the Cluster B and C are roughly similar in catering and using house appliances. However, the mean value of the Cluster A is higher than the other clusters. In general, the mean values are higher in catering and using electrical devices compared to the other dependent variables.

Table 4.15. The Mean Values of Each Cluster in Catering and Using House Devices.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	C	158	35.886	
	B	171	36.608	
	A	200		42.250
	Sig.		0.861	1.000

It can be seen from the results in Table 4.16 that the mean value of the Cluster B in using washing/drying machines is 2.25 which is little smaller than the Cluster A and C. In general view, the mean values of the laundry facility utilizations by the groups are under the average mean values from all the dependent variables.

Table 4.16. The Mean Values of Each Cluster in Using Washing/Drying Machines.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	B	171	22.573	
	A	200		25.800
	C	158		27.532
	Sig.		1.000	0.166

The results of the two-way MANOVA provides that the mean value of going to the fitness center for Cluster B is 2.03, the lowest value according to the Cluster A and C presented in Table 4.17. The Cluster A's mean value in going to the fitness center is the highest value compared to the other clusters.

Table 4.17. The Mean Values of Each Cluster in Going to the Fitness Center.

	Cluster Number of Case	N	Subset	
			2	1
Tukey HSD	B	171	20.351	
	C	158		23.861
	A	200		26.400
	Sig.		1.000	0.188

4.1.1. Cluster A

The properties of students belonging to Cluster A, 200 students, are between the Cluster B and C in the energy efficient behaviors. The Cluster A students spend more time in their rooms as Cluster C, but their electricity consumption preferences are more energy efficient compared to Cluster C. On the other hand, the electricity consumption behavior of the Cluster A is not energy efficient compared to Cluster B. The students of Cluster A generally spend their time in dormitory rooms. The Cluster A occupants usually turn of the lights when room is unoccupied, but they sometimes use the lighting during the daylight time. The frequency of using laptop, cooking and kitchen devices are higher and they switch off the electrical devices when not in use. The usage of other dormitory facilities such as laundry rooms, vending machines and ironing rooms are not frequently used by the Cluster A students. An example illustration of occupancy tab from DB is presented in Figure 4.3.

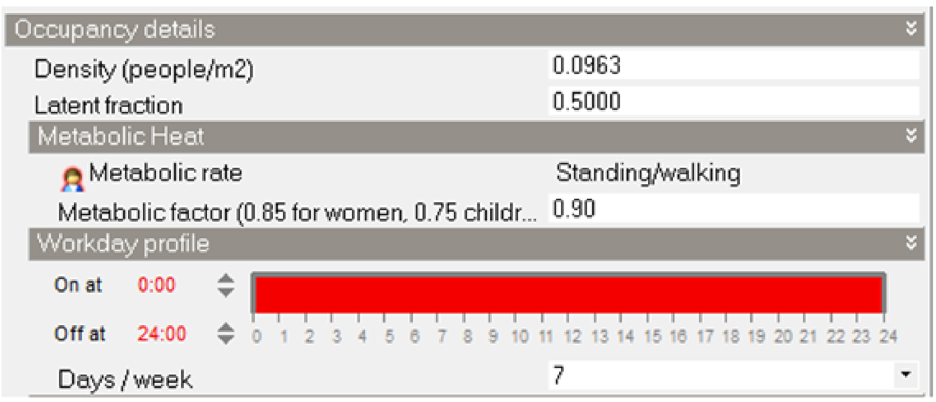


Figure 4.3. Occupancy Tab in DesignBuilder.

The occupancy schedule of the Cluster A was generated based on the time spend in their rooms achieved from survey analysis illustrated in Figure 4.4. The members of the Cluster A spend their time at outside just in English preparation classes between 12.30 -15.30 hours at the weekdays. In addition, they spend all their time in the rooms at the weekends as presented weekly occupancy schedule in Figure 4.5. In all the below figures, the intervals per hour displays that the breakdown of the occupancy or the devices usage density according to the time zones.

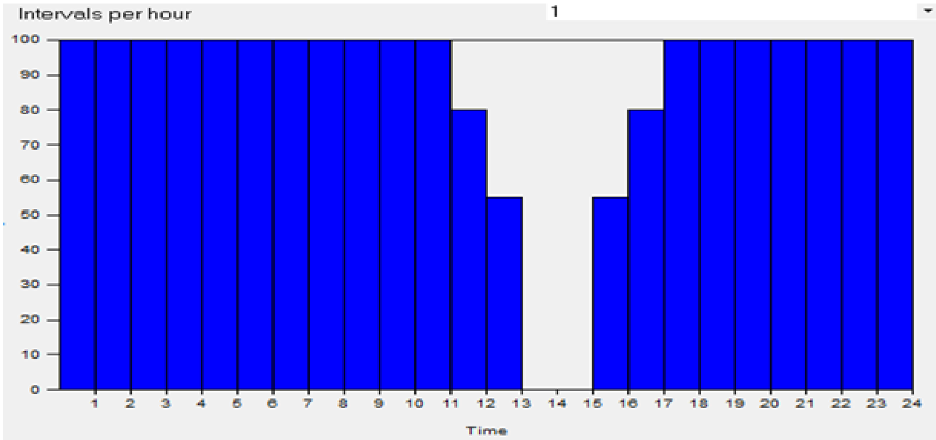


Figure 4.4. Cluster A Daily Occupancy Schedule at the Weekdays.

Design Days

Design day definition method: 1-End use defaults

Use end-use default: 2-Occupancy

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Feb	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Mar	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Apr	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
May	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Jun	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Jul	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Aug	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Sep	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Oct	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Nov	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On
Dec	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	Cluster A Occ	On	On

Figure 4.5. Cluster A Occupancy Weekly Schedule.

The computer usage schedules at the weekdays and weekends for the Cluster A provided in Figure 4.6 and Figure 4.7. The Cluster members are considered that they use their computers before and after the lecture times at the weekdays and from morning times to the night times at the weekends. The schedules were assigned to the weekdays and weekends in the weekly schedule table presented in Figure 4.8.

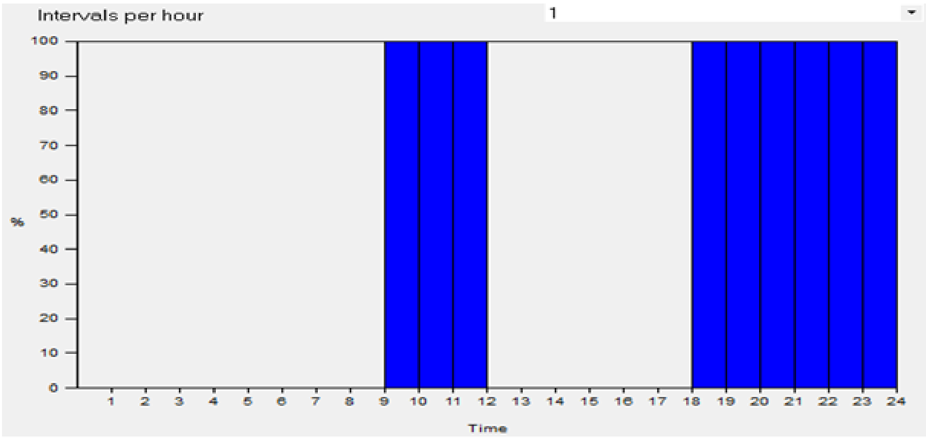


Figure 4.6. Cluster A Computer Usage Weekdays Schedule.

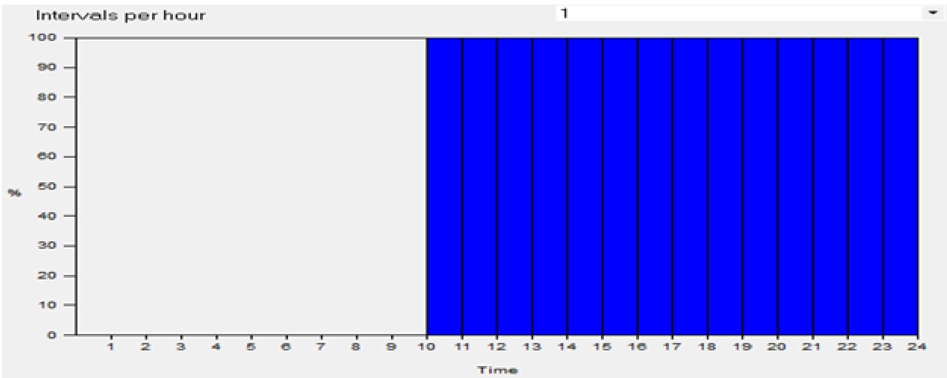


Figure 4.7. Cluster A Computer Usage Weekend Schedule.

Design Days

Design day definition method: 1-End use defaults

Use end-use default: 4-Equipment

Profiles

M...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Feb	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Mar	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Apr	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
May	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Jun	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Jul	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Aug	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Sep	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Oct	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Nov	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Dec	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend

Figure 4.8. Cluster A Computer Weekly Schedule.

Due to the fact that the Cluster A members usually cook and use the kitchen devices according to the survey analysis, the students prepare breakfast and use kitchen devices between 9.00-11.00 hours and cook in the evening between 19.00-22.00 hours at the weekdays illustrated in Figure 4.9. They also are assumed that cook in the afternoon time at the weekends presented in Figure 4.10. The weekdays and weekends schedules were assigned to the weekly catering schedule provided in Figure 4.11.

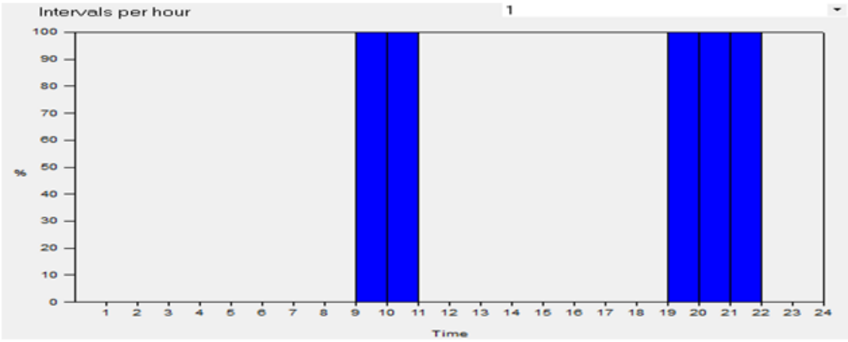


Figure 4.9. Cluster A Catering Weekdays Schedule.

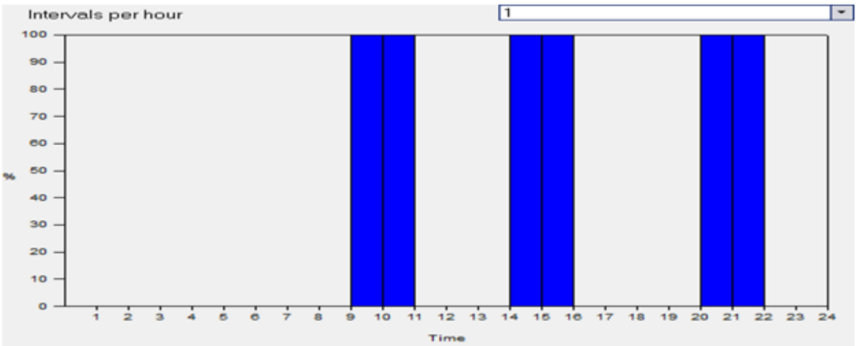
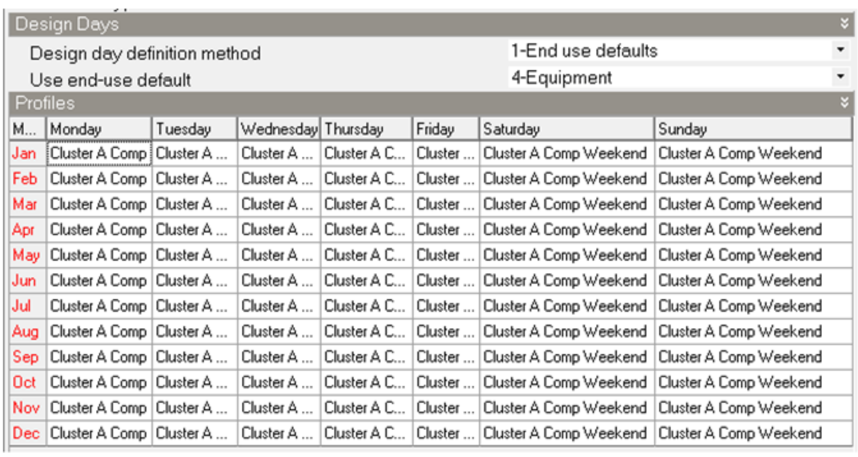


Figure 4.10. Cluster A Catering Weekend Schedule.



M...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Feb	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Mar	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Apr	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
May	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Jun	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Jul	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Aug	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Sep	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Oct	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Nov	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend
Dec	Cluster A Comp	Cluster A ...	Cluster A ...	Cluster A C...	Cluster ...	Cluster A Comp Weekend	Cluster A Comp Weekend

Figure 4.11. Cluster A Catering Weekly Schedule.

The results obtained from the two-way MANOVA analysis show that the Cluster A residents were assumed as using the laundry facilities such as washing/drying machines and ironing rooms twice a week displayed in the weekly laundry schedule, Figure 4.13. The breakdown of the laundry facility utilization in the daytime was considered that the students belonging to the Cluster A sometimes use the laundry rooms in the morning and sometimes in the evenings presented in Figure 4.12.

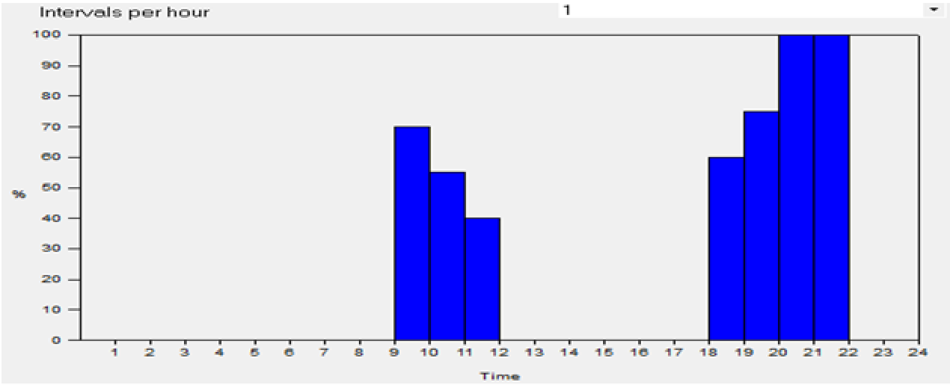


Figure 4.12. Cluster A Daily Laundry Schedule.

Design Days

Design day definition method	1-End use defaults
Use end-use default	4-Equipment

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Feb	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Mar	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Apr	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
May	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Jun	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Jul	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Aug	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Sep	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Oct	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Nov	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off
Dec	Off	Off	Cluster A Laund	Off	Off	Cluster A Laund	Off

Figure 4.13. Cluster A Laundry Weekly Schedule.

The mean values of the two-way MANOVA analysis results revealed that the occupants of the Cluster A use the lighting during the occupancy times. Therefore, the residents were assumed that they use the lighting before and after the lecture times which is presented in Figure 4.14 as a weekday schedule. At the weekend the use the lighting as well as weekday schedule, but more density compared to the weekdays provided in Figure 4.15. The weekdays and weekend lighting usage were defined into the weekly lighting schedule illustrated in Figure 4.16. Besides, the lighting is switched off by the Cluster A members when the room is unoccupied which means that the lighting control option is selected in the lighting tab. Overall, the intervals per hour in the schedules generated by using survey results are based on the general assumptions.

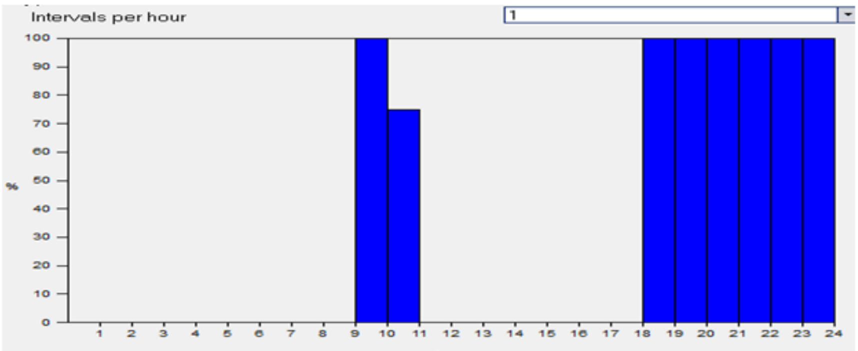


Figure 4.14. Cluster A Lighting Weekdays Schedule.

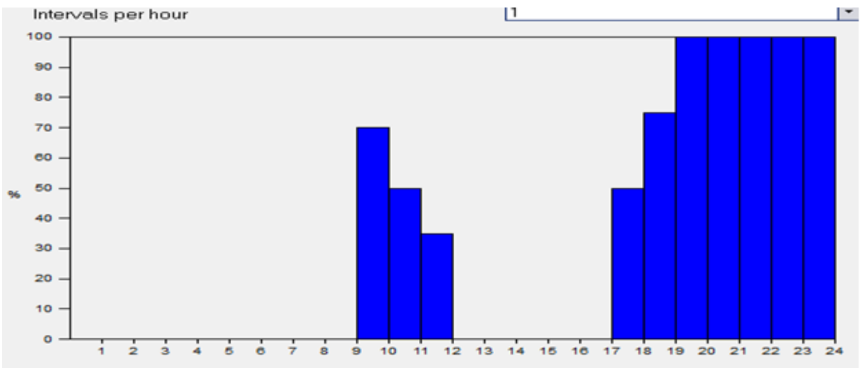
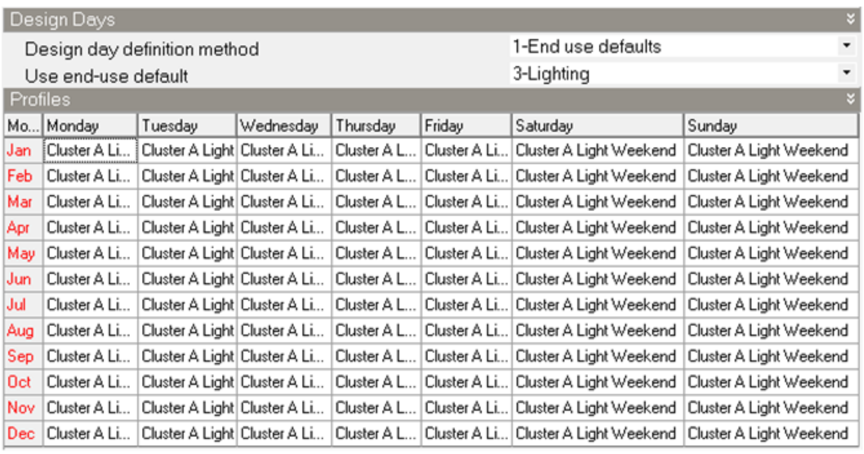


Figure 4.15. Cluster A Lighting Weekend Schedule.



Design Days

Design day definition method	1-End use defaults
Use end-use default	3-Lighting

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Feb	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Mar	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Apr	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
May	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Jun	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Jul	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Aug	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Sep	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Oct	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Nov	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend
Dec	Cluster A Li...	Cluster A Light	Cluster A Li...	Cluster A L...	Cluster A Li...	Cluster A Light Weekend	Cluster A Light Weekend

Figure 4.16. Cluster A Lighting Weekly Schedule.

4.1.2. Cluster B

The Cluster B with 171 students represents more green consumers due to students' energy efficient preferences compared to Cluster A and C. Besides, they spend less time in the dormitory rooms with respect to other clusters. The students belonging to Cluster B usually turn off the lights when the room is unoccupied and they do not use the lights during daylight time. They also use notebooks less than other clusters. Moreover, they general do not plug in the electrical devices when not in use. For Cluster B, the utilization of the kitchen devices are little more than Cluster C, but the Cluster A use more kitchen devices than Cluster B. The laundry facilities, vending machines and fitness center are utilized in the least level by the Cluster B students.

According to the mean values of the dependent variables related with time spend in room, the residents of the Cluster C occupancy schedule was assumed as below Figure 4.17. Since the members of the Cluster C spend less time in the dormitory rooms, they are considered as staying at outside around from 10 am to 9 pm. In addition to the lecture hours, they were thought as spending their time at outside for different outdoor activities. Besides, they also are assumed as not staying in the dormitory on Sundays which is presented in Figure 4.18. The daily occupancy schedules were assigned to the weekly occupancy schedule.

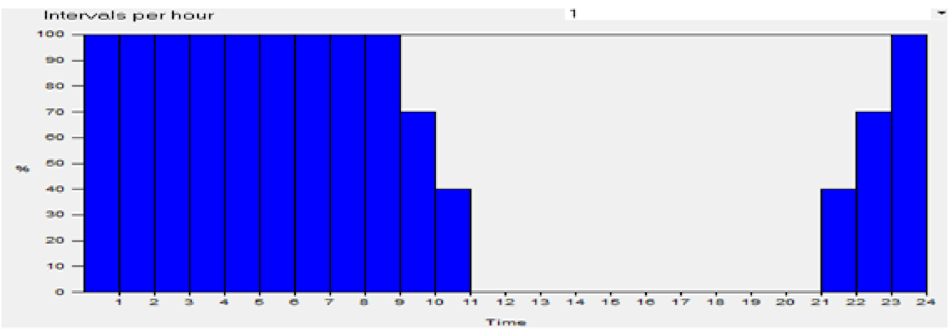


Figure 4.17. Cluster B Daily Occupancy Schedule.

Design Days	
Design day definition method	1-End use defaults
Use end-use default	2-Occupancy

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Feb	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Mar	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Apr	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
May	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Jun	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Jul	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Aug	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Sep	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Oct	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Nov	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off
Dec	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Cluster B Occ	Off

Figure 4.18. Cluster B Weekly Occupancy Schedule.

The obtained results from the cluster analysis revealed that the students belonging to the Cluster B use rarely their laptops compared to the other groups. The members of the Cluster B sometimes use their notebooks before the lecture times in the morning and usually use them around from 8.00 pm to 11.00 pm illustrated in Figure 4.19. In the other words, the laptop usage density was assumed as a lowest level for Cluster B. Besides, due to the absence of the Cluster B residents on Sunday, the computer usage in weekly schedule was set off provided in Figure 4.20.

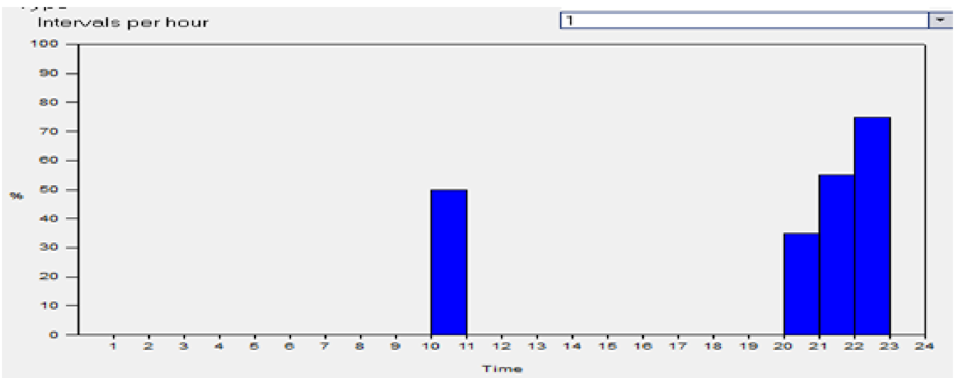


Figure 4.19. Cluster B Daily Computer Usage Schedule.

Design Days

Design day definition method: 1-End use defaults

Use end-use default: 4-Equipment

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Feb	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Mar	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Apr	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
May	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Jun	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Jul	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Aug	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Sep	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Oct	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Nov	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off
Dec	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Cluster B Comp	Off

Figure 4.20. Cluster B Computer Usage Weekly Schedule.

The below Figure 4.21 indicates that the catering and using kitchen devices density in the rooms of the Cluster B is lower than Cluster A. Therefore, the catering schedule of the Cluster B occupants was assumed that they cook more than twice a week represented in Figure 4.22. In the daily catering schedule, they sometimes make a breakfast in their kitchen before lecture hours and prepare a dinner in the evening. Due to the absences of the Cluster B residents on Sunday in the dormitories, their catering schedule was set as off on those days. The daily catering schedule was assigned to the weekly schedule according to the density of cooking.

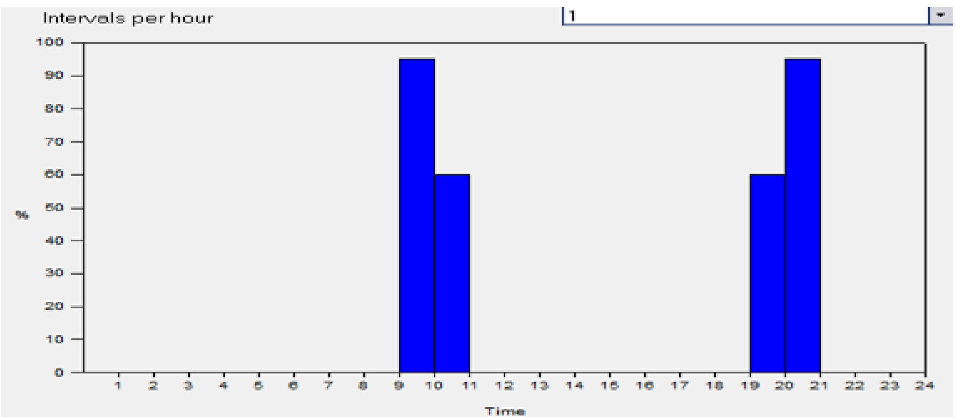


Figure 4.21. Cluster B Daily Catering Schedule.

Design Days

Design day definition method: 1-End use defaults

Use end-use default: 4-Equipment

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Feb	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Mar	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Apr	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
May	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Jun	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Jul	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Aug	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Sep	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Oct	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Nov	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off
Dec	Cluster B Cat	Off	Cluster B Cat	Off	Cluster B Cat	Cluster B Cat	Off

Figure 4.22. Cluster B Catering Weekly Schedule.

The results of the survey analysis show that the laundry facilities such as washing/drying machines and ironing rooms are used at least level. Hence, the equipment schedule of the laundry rooms were assumed as a minimum level provided in below Figure 4.23. In the assumed daily laundry schedule, they generally use the laundry rooms around after 19.00 pm. The occupants of the Cluster B use the laundry rooms once a week represented in Figure 4.24. The density of the laundry facility utilization is lowest among all the clusters.

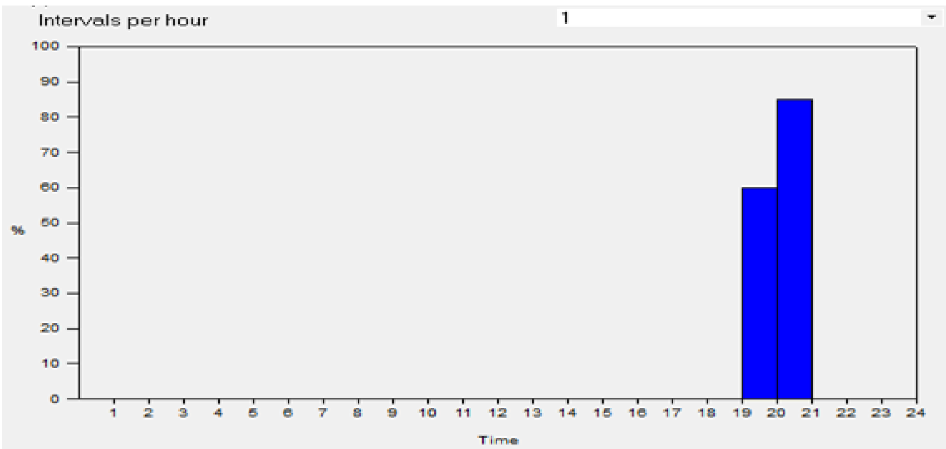


Figure 4.23. Cluster B Daily Laundry Schedule.

Design Days

Design day definition method: 1-End use defaults

Use end-use default: 4-Equipment

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Off	Off	Off	Off	Off	Cluster B Laund	Off
Feb	Off	Off	Off	Off	Off	Cluster B Laund	Off
Mar	Off	Off	Off	Off	Off	Cluster B Laund	Off
Apr	Off	Off	Off	Off	Off	Cluster B Laund	Off
May	Off	Off	Off	Off	Off	Cluster B Laund	Off
Jun	Off	Off	Off	Off	Off	Cluster B Laund	Off
Jul	Off	Off	Off	Off	Off	Cluster B Laund	Off
Aug	Off	Off	Off	Off	Off	Cluster B Laund	Off
Sep	Off	Off	Off	Off	Off	Cluster B Laund	Off
Oct	Off	Off	Off	Off	Off	Cluster B Laund	Off
Nov	Off	Off	Off	Off	Off	Cluster B Laund	Off
Dec	Off	Off	Off	Off	Off	Cluster B Laund	Off

Figure 4.24. Cluster B Laundry Weekly Schedule.

The lighting system is just turned on during the nighttime by the Cluster B students which are represented in Figure 4.25. Since they use their rooms around after 19.00 pm, the lighting schedule was started around these hours. They also usually turned off the lights during the daytime which was reflected to the daily lighting schedules. In addition, the Figure 4.26 provides the weekly lighting schedule. As the absence of the Cluster B students on Sundays, the lighting schedule was set as off.

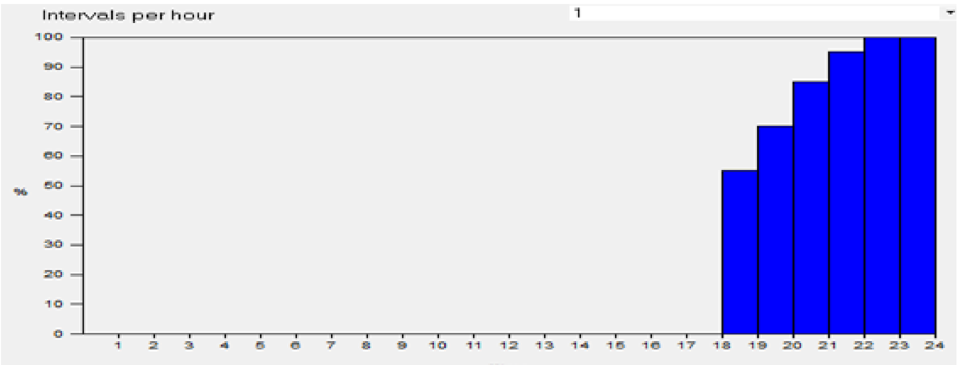


Figure 4.25. Cluster B Daily Lighting Schedule.

Design Days

Design day definition method: 1-End use defaults

Use end-use default: 3-Lighting

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Feb	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Mar	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Apr	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
May	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Jun	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Jul	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Aug	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Sep	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Oct	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Nov	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off
Dec	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Cluster B light	Off

Figure 4.26. Cluster B Lighting Weekly Schedule.

4.1.3. Cluster C

The Cluster C with 158 students is considered as non-green energy consumption behavior. The Cluster C students spend more time in their rooms and their electricity preferences are not energy efficient. Their time spending in rooms is similar to Cluster A students, but their density of electricity usage is more than other two clusters. They sometimes turn on the lights when room is unoccupied and they use the lights during the day time. Their laptop usage density is higher than other two clusters and they do not turn off the electrical devices when not in use. On the other hand, the usage of kitchen devices of the Cluster C students is nearly similar to Cluster B students and is less than Cluster A students. The utilization level of the other facilities such as laundry room, vending machine and fitness centers are between the Cluster B and Cluster C.

Due to the fact that the occupancy of the Cluster C residents in the dormitory rooms is nearly similar to the Cluster A, the occupancy schedule was assumed as presented in Figure 4.27. They were just considered as staying at the outside during the lecture hours. They do not stay in the rooms around between 11.00 and 16.00 which was assumed according to the survey analysis. They also spend their time in the rooms during the weekends. The Saturdays and Sundays were set on in the weekend time spend schedule. The daily room occupancy schedule of the Cluster C was assigned to the weekly occupancy schedule illustrated in Figure 4.28.

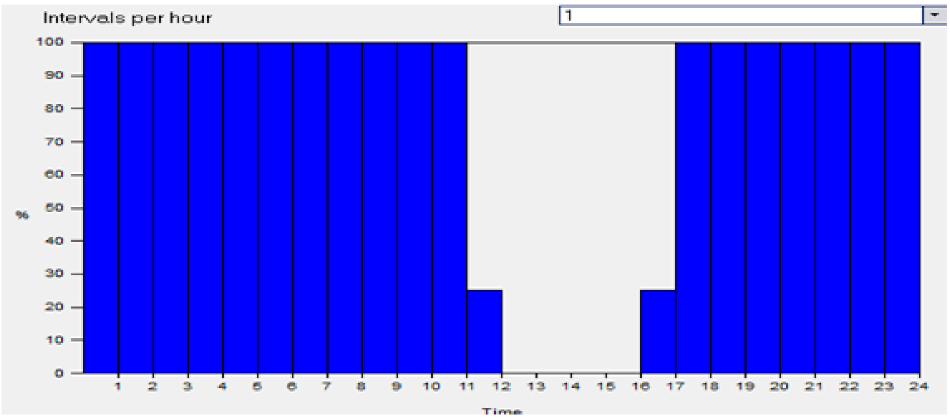


Figure 4.27. Cluster C Daily Occupancy Schedule.

Design Days

Design day definition method	1-End use defaults
Use end-use default	2-Occupancy

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Feb	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Mar	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Apr	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
May	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Jun	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Jul	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Aug	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Sep	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Oct	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Nov	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On
Dec	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	Cluster C Occ	On	On

Figure 4.28. Cluster C Occupancy Weekly Schedule.

The members of the Cluster C laptop usage schedule were assumed as below Figure 4.29. The laptop usage of the Cluster C is the densest among the groups according to the cluster analysis results. Thus, their notebooks were assumed as working all day hours, so the schedule was set on for all days illustrated in Figure 4.30. The daily schedule was assigned to the weekly laptop usage schedule.

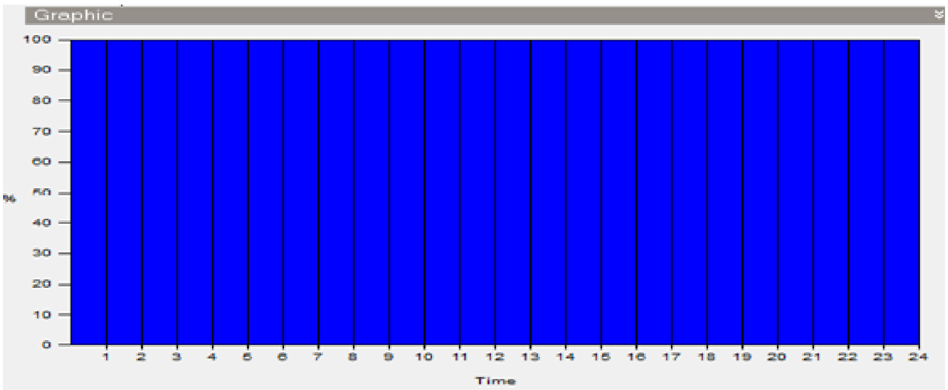


Figure 4.29. Cluster C Daily Computer Usage Schedule.

Design Days

Design day definition method	1-End use defaults
Use end-use default	4-Equipment

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	On	On	On	On	On	On	On
Feb	On	On	On	On	On	On	On
Mar	On	On	On	On	On	On	On
Apr	On	On	On	On	On	On	On
May	On	On	On	On	On	On	On
Jun	On	On	On	On	On	On	On
Jul	On	On	On	On	On	On	On
Aug	On	On	On	On	On	On	On
Sep	On	On	On	On	On	On	On
Oct	On	On	On	On	On	On	On
Nov	On	On	On	On	On	On	On
Dec	On	On	On	On	On	On	On

Figure 4.30. Cluster C Computer Usage Weekly Schedule.

The catering schedules of the Cluster C occupants were based on the Cluster B catering schedules because of similarities between two groups. However, since the occupancy of the Cluster C residents is higher than the Cluster B, the cooking density of the Cluster C was considered higher than Cluster B provided in Figure 4.31. The daily catering schedule was assigned to the weekly schedules for all days can be seen in Figure 4.32.

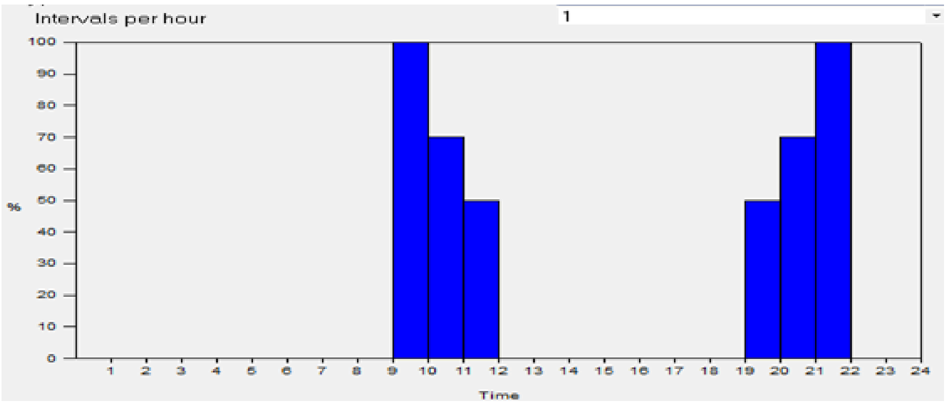
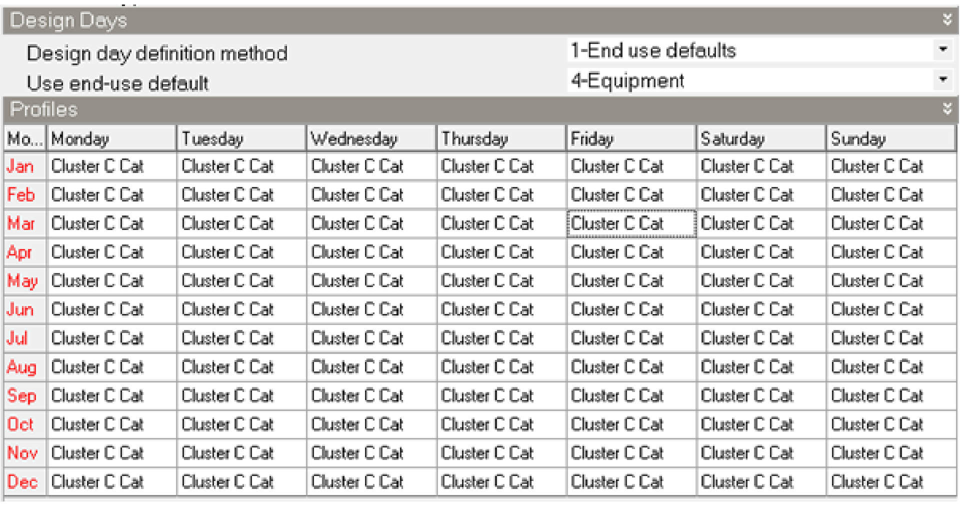


Figure 4.31. Cluster C Daily Catering Schedule.



Design Days

Design day definition method	1-End use defaults
Use end-use default	4-Equipment

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Feb	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Mar	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Apr	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
May	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Jun	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Jul	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Aug	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Sep	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Oct	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Nov	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat
Dec	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat	Cluster C Cat

Figure 4.32. Cluster C Catering Weekly Schedule.

The laundry schedule given in Figure 4.33 was built on the Cluster A and B laundry schedules. The Cluster C occupants use the laundry room twice a week illustrated in Figure 4.34 as the Cluster A members mentioned earlier and more than Cluster B. Also, the occupancy schedule is considered that has impact on the facility utilization density.

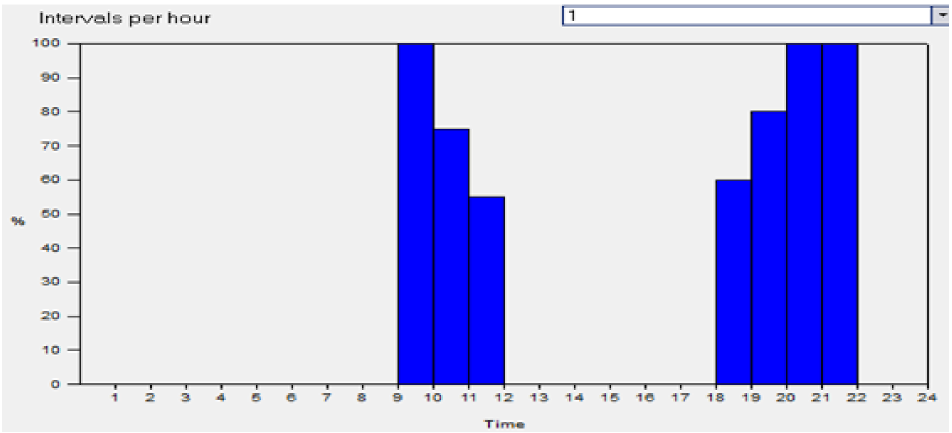


Figure 4.33. Cluster C Daily Laundry Schedule.

Design Days

Design day definition method	1-End use defaults
Use end-use default	4-Equipment

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Feb	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Mar	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Apr	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
May	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Jun	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Jul	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Aug	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Sep	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Oct	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Nov	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off
Dec	Off	Off	Cluster C Laund	Off	Off	Cluster C Laund	Off

Figure 4.34. Cluster C Laundry Weekly Schedule.

According to the cluster analysis and two-way MANOVA test results, the members of the Cluster C use the lighting more than other groups. Also, they turn on the lights during the daytime without considering the sun light. Therefore, their lighting schedule was assumed as below Figure 4.35. The lights are used in the evening times started around from 16.00 to 01.00 that was considered. They use the lights in the morning hours around between 9.00 and 12.30 during the day time. Furthermore, the task light devices are used by the Cluster C residents considered. The daily schedule assigned to the all weekdays and weekends presented in Figure 4.36.

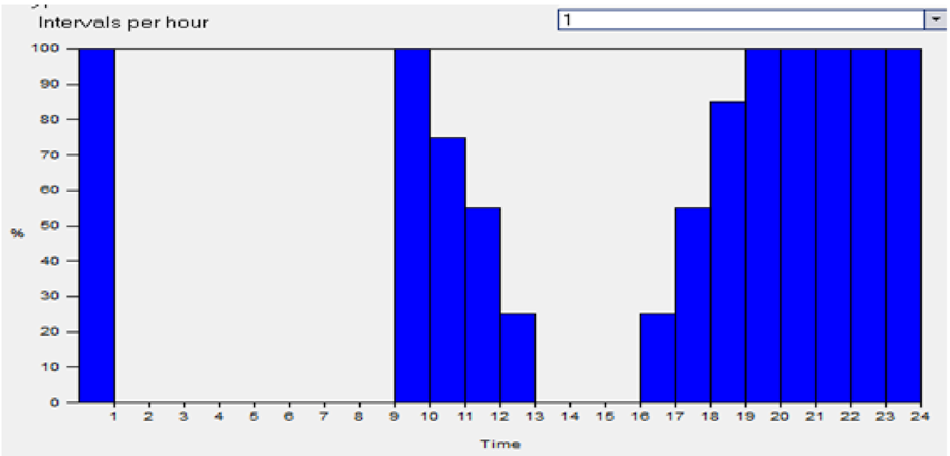


Figure 4.35. Cluster C Daily Lighting Schedule.

Design Days

Design day definition method: 1-End use defaults

Use end-use default: 3-Lighting

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Feb	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Mar	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Apr	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
May	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Jun	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Jul	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Aug	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Sep	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Oct	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Nov	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light
Dec	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light	Cluster C Light

Figure 4.36. Cluster C Lighting Weekly Schedule.

4.2. The Energy Simulation Results

The electricity consumption in the rooms of two dormitory buildings were estimated based on a period between 1 October and 31 March by the DesignBuilder. First of all, the main assumption of the analysis is that all the students in each of the dormitory were considered as belonging to just one cluster. Therefore, one cluster energy consumption properties were assigned to the all dormitory rooms. In addition, all cluster groups were assigned to each dormitory building based on the actual distribution ratio achieved from survey analysis. In addition, the default settings were used in order to perform the energy performance of the dormitories by the DesignBuilder and the Green Building Studio. In total, there are 6 energy performance analysis results for each dormitory building.

4.2.1. The Electricity Consumption and Carbon Emission of 3th Dormitory Building

The electricity consumption of the dormitories assuming that all the students staying in the dormitory belong to just one cluster was calculated. Thus, the energy user behavior properties of one cluster were only assigned to the entire building. This assumed analysis method was conducted for each cluster in two dormitories. In addition, the electricity consumption analysis of the dormitories was done based on the default settings provided by the DB and GBS. In one of the analysis, the actual number of students in each cluster was assigned as illustrated in the Figure 4.17. In other words, the real case is also simulated. However in that case, the average value for those rooms with students was taken, more than one type of user behavior.

The distribution rate of the clusters in the dormitory is presented in Figure 4.18. 219 students from 3rd dormitory answered the survey questions which were analyzed by using the SPSS. In the 3^{rd} dormitory, 81 (37%) students belong to Cluster A, 79 (36.1%) students are in Cluster B and the rest of 59 (26.9%) students are in Cluster C. In the 3^{rd} dormitory, 280 rooms were identified in the DesignBuilder including bedrooms, kitchens and bathrooms as living spaces.

Table 4.18. Distribution Rate of the Clusters.

		Cluster Number of Case			Total
		A	B	C	
students' dormitory	1. Dorm (female)	75	52	58	185
		40.5 %	28.1 %	31.4 %	100.0 %
	2. dorm (male)	44	40	41	125
		35.2 %	32.0 %	32.8 %	100.0 %
	3. Dorm (mixed)	81	79	59	219
		37.0 %	36.1 %	26.9 %	100.0 %
Total		200	171	158	529
		37.8 %	32.3 %	29.9 %	100.0 %

In order to show the analysis results with default settings, both the DB and the GBS were utilized. Both of the soft-wares are based on the ASHRAE 90.1 regulations in their default settings.

The electricity consumption and carbon emission are calculated for Cluster A assuming that the third dormitory building is just occupied by Cluster A members. The electricity consumption is estimated as 249.22 MWh and the carbon emission is 170.71 ton as illustrated in Figure 4.37. The consumed electricity in all the room by electrical devices is 182.79 MWh and electricity consumption by lighting is 66.43 MWh.

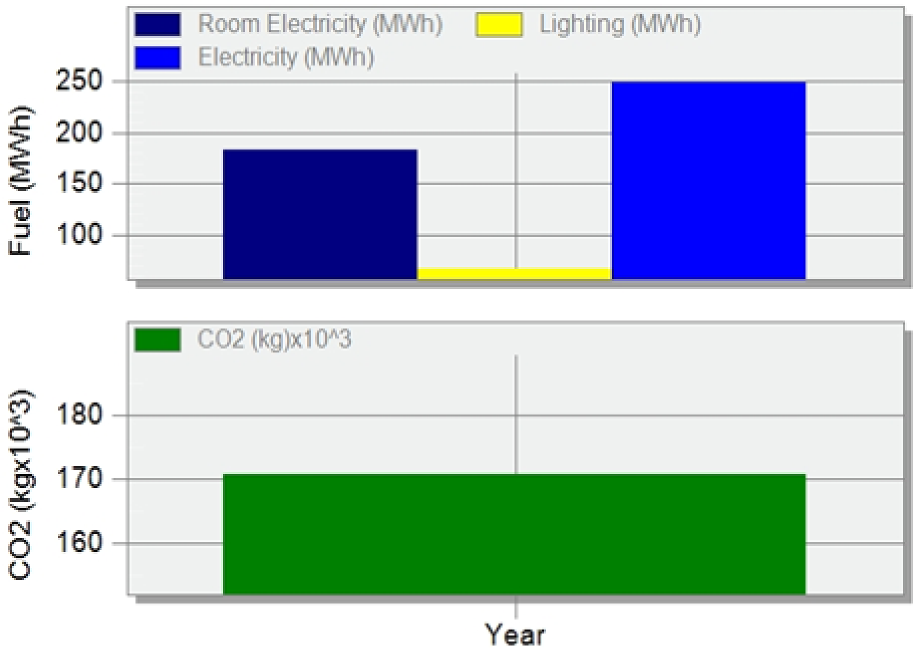


Figure 4.37. Cluster A Electricity Consumption and CO_2 Emission.

According to the energy performance analysis result of the 3rd dormitory building, this time considering that the building is only occupied by the members of the Cluster B, the entire electricity consumption is 84.68 MWh for six months as provided in Figure 4.38. In addition, the carbon emission is estimated to be 58 ton for the six-month period. The electricity consumption due to using electrical devices is 43.43 MWh and consumed electricity by lighting is 41.25 MWh.

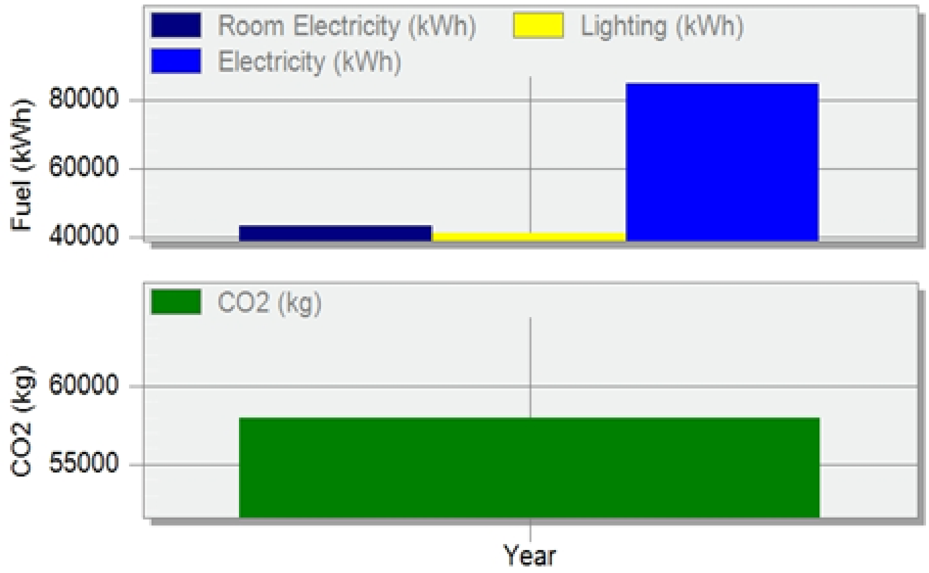


Figure 4.38. Cluster B Electricity Consumption and CO_2 Emission.

The results obtained from the energy performance analysis show that the electricity consumption of the entire building when all the occupants assigned as the member of Cluster C is 461.67 MWh for six months (Figure 4.39). The carbon emission is estimated to be 316.24 ton. The consumed electricity by electrical devices in the rooms is 327.42 MWh and the lighting electricity consumption is predicted to be 134.25MWh.

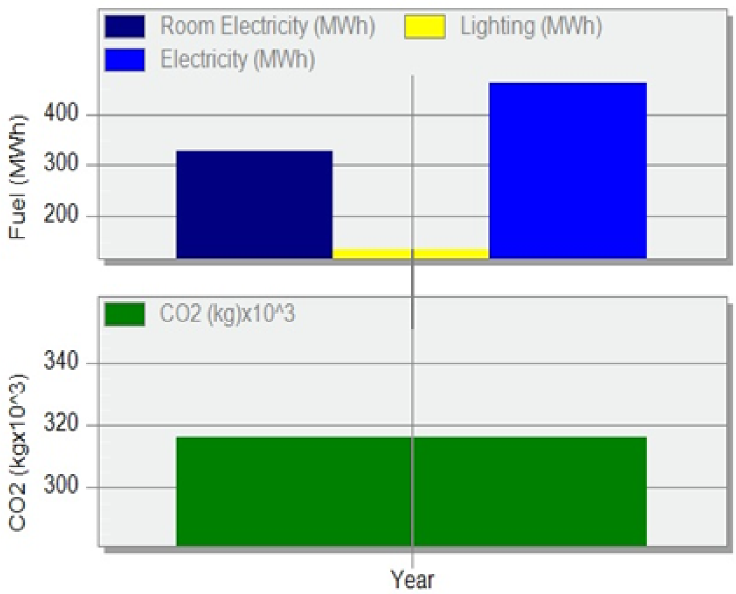


Figure 4.39. Cluster C Electricity Consumption and CO_2 Emission.

As shown in Figure 4.40, the electricity consumption for six months is calculated as 237.35 MWh assuming that the number of student in each cluster is distributed as it is in real life. Accordingly, the carbon emission is calculated to be 162.58 ton. The electricity consumption of the electrical devices and lighting system are 163.43 MWh and 73.92 MWh respectively.

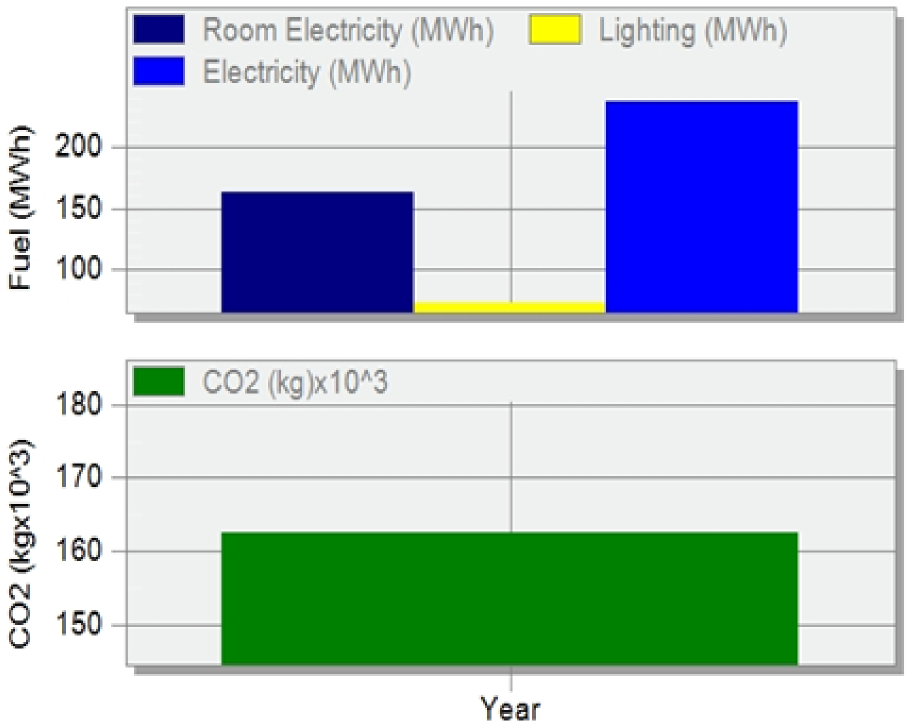


Figure 4.40. Distributed Electricity Consumption and CO_2 Emission.

The result of the conducted analysis by using DB default setting based on the ASHRAE 90.1 regulation shows us that the electricity consumption is 338.30 MWh for winter period given in Figure 4.41. The carbon emission is predicted to be 231.74 ton. The estimated electricity consumption by accounting electrical devices in the rooms is 203.98 MWh and the lighting electricity consumption is 134.32 MWh.

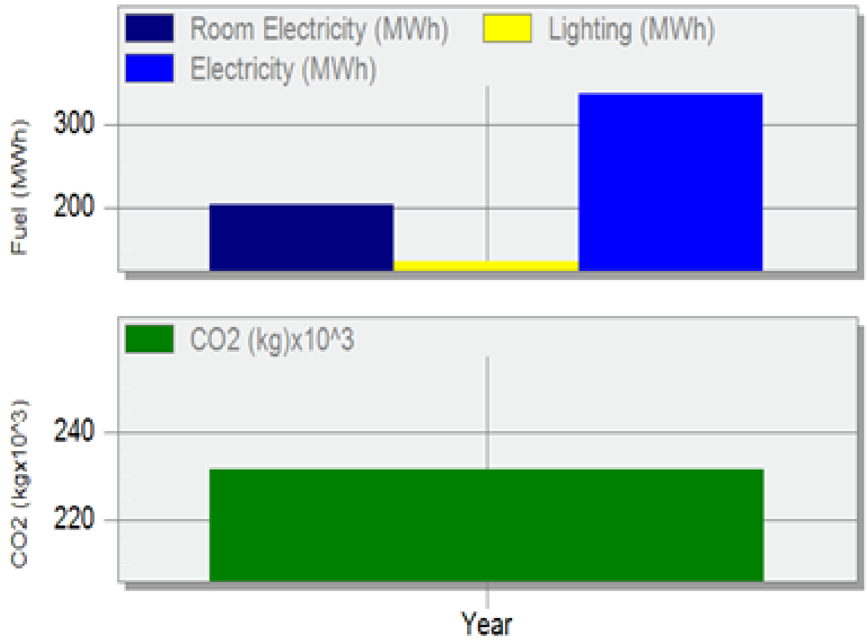


Figure 4.41. DesignBuilder Default Analysis Electricity Consumption and CO_2 Emission.

As presented in the Figure 4.18, the electricity consumption for six months is estimated to be 144.3 MWh by Green Building Studio. The lighting electricity consumption is predicted as 75.09 MWh and the electricity utilization from electrical devices is 69.21 MWh.

Table 4.19. Green Building Studio Default Analysis Electricity Consumption.

	INTERIORLIGHTS: ELECTRICITY [kWh]	INTERIOREQUIPMENT: ELECTRICITY [kWh]
January	12791	11782
February	11553	10638
March	12791	11893
April	-	-
May	-	-
June	-	-
July	-	-
August	-	-
September	-	-
October	12791	11915
November	12379	11357
December	12791	11628
Annual Sum or Average	75096	69213
Total		144309

4.2.2. The Electricity Consumption and Carbon Emission of 1st Dormitory Building

In the first dormitory, there were 185 students that answered the survey questions. Also, 214 rooms including bedrooms, kitchens and bathrooms were defined into the DesignBuilder in order to estimate the electricity consumption in the first dormitory. The Cluster A students constitute 40.5% of the total residents in the first dormitory as indicated in Figure 4.19. There are 52 students belonging to the Cluster B and 58 students from the Cluster C that stay in the first dormitory.

Table 4.20. Distribution Rate of the Clusters.

		Cluster Number of Case			Total
		A	B	C	
students' dormitory	1. Dorm (female)	75	52	58	185
		40.5 %	28.1 %	31.4 %	100.0 %
	2. dorm (male)	44	40	41	125
		35.2 %	32.0 %	32.8 %	100.0 %
	3. Dorm (mixed)	81	79	59	219
		37.0 %	36.1 %	26.9 %	100.0 %
Total		200	171	158	529
		37.8 %	32.3 %	29.9 %	100.0 %

According to the energy performance analysis of the first dormitory building, the electricity consumption of the entire building considering as all the students belong to Custer A is 227.15 MWh from 1 October to 31 March as presented in the Figure 4.42. The carbon emission, the electricity consumption by using electrical devices and lighting are 155.60 tons, 165.48 MWh and 61.67 MWh.

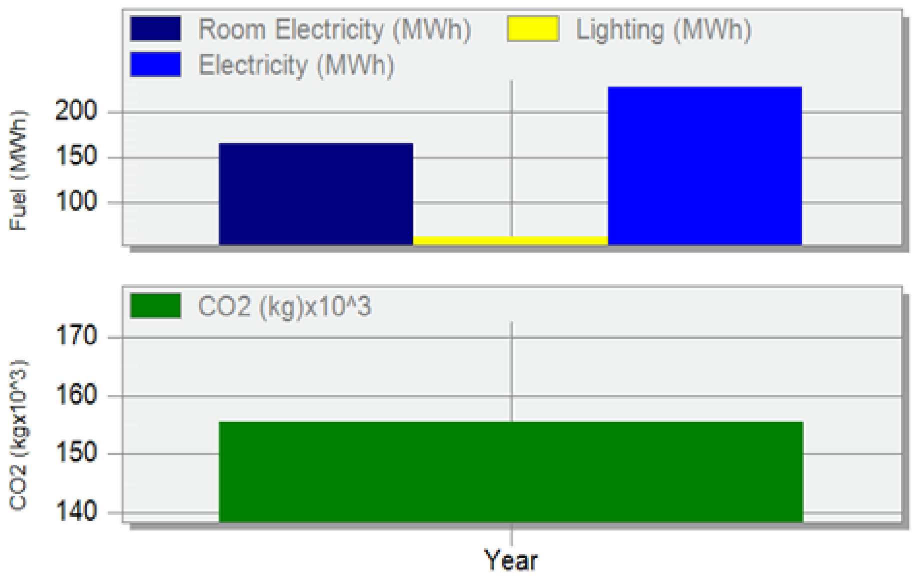


Figure 4.42. Cluster A Electricity Consumption and CO_2 Emission.

As illustrated in the Figure 4.43, the electricity consumption of the entire building assuming as all the students belong to the Cluster B is 71.63 MWh and carbon emission is predicted to be 49,069 MWh for six months. The consumed electricity by the electrical devices is estimated to be 37.25 MWh and the electricity consumption by using the lighting is 34.37 MWh.

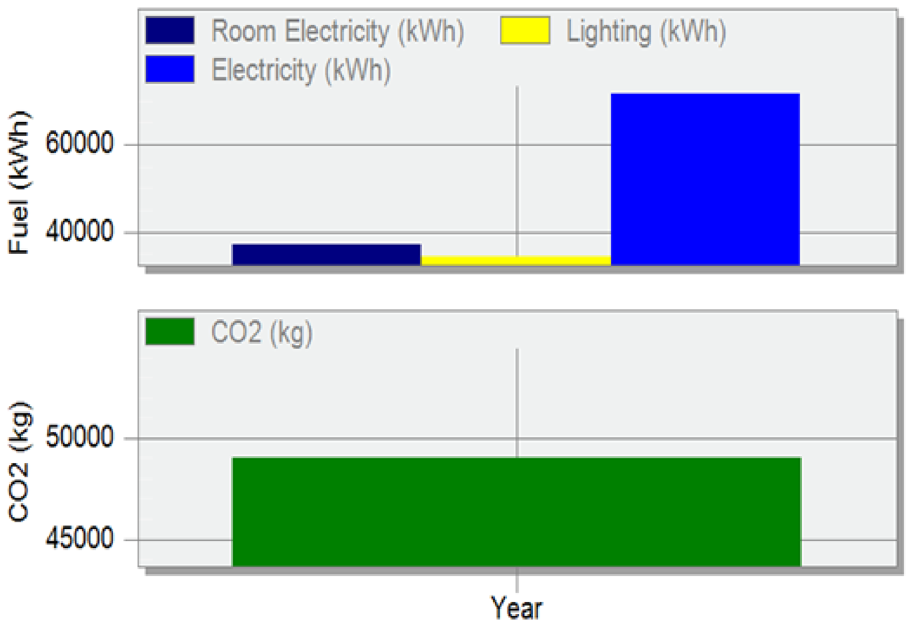


Figure 4.43. Cluster B Electricity Consumption and CO_2 Emission.

The electricity consumption of the dormitory building assumed that rooms are only occupied by the Cluster C members is 407.54 MWh as presented in the Figure 4.44 and carbon emission is calculated as 279.16 ton. The electricity consumption by the electrical devices in the rooms is 292.76 MWh and lighting electricity usage is 114.78 MWh.

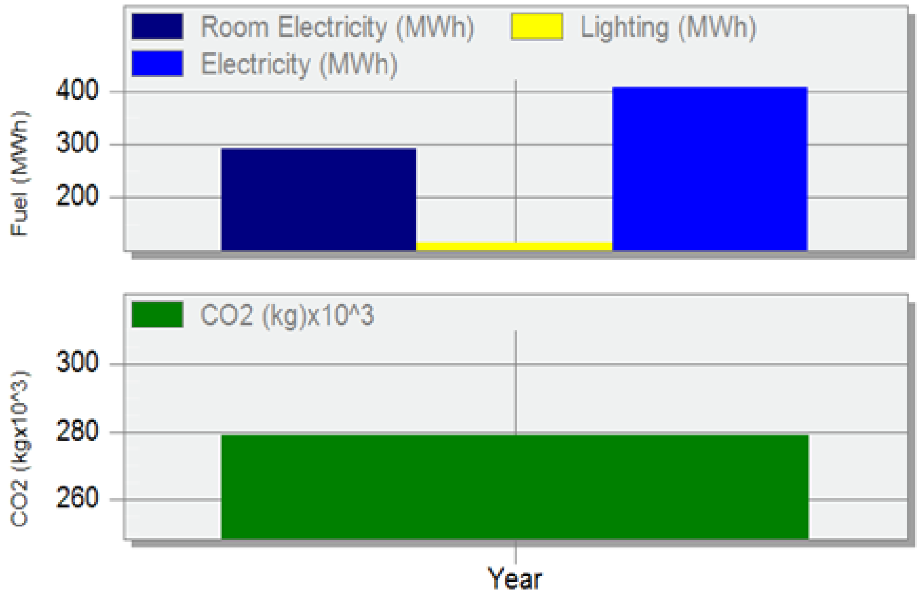


Figure 4.44. Cluster C Electricity Consumption and CO_2 Emission.

The energy performance analysis of the dormitory building with the real distribution rate shows that the electricity consumption is 242.71 MWh and carbo emission is 166.26 ton for six months presented in the Figure 4.45. The electricity consumption from electrical devices is estimated to be 171.08 MWh and lighting electricity consumption is predicted as 71.63 MWh.

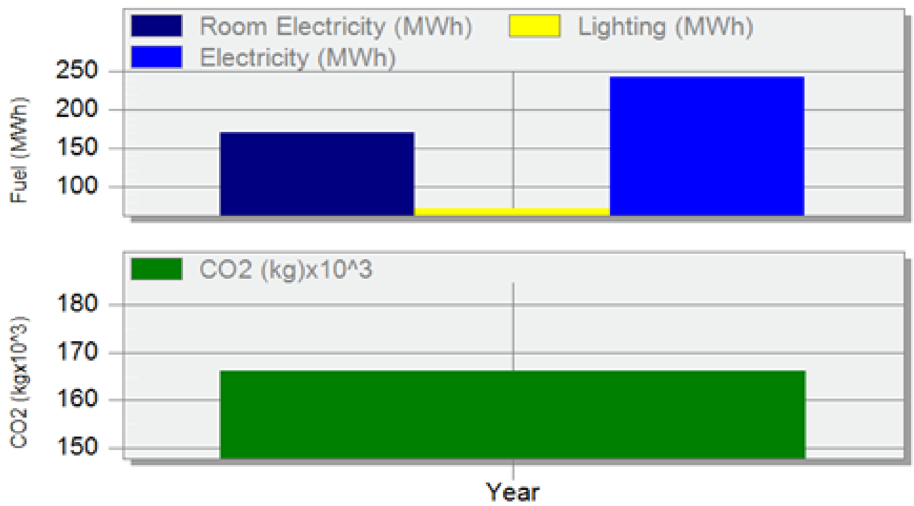


Figure 4.45. Distributed Electricity Consumption and CO_2 Emission.

The results obtained from the energy performance analysis based on the default settings of the DesignBuilder show that the electricity consumption is estimated to be 306.71 MWh and carbon emission is 210.10 ton for six months as illustrated in the Figure 4.46. The consumed electricity by the electrical devices in the rooms is 185.13 MWh and lighting electricity consumption is 121.58 MWh.

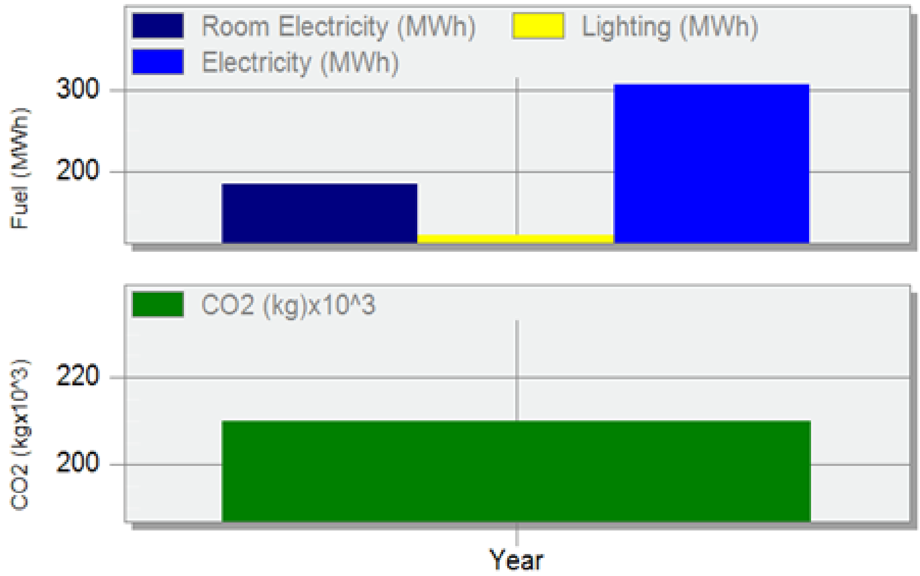


Figure 4.46. DesignBuilder Default Analysis Electricity Consumption and CO_2 Emission.

As resented in the Table 4.21, the electricity consumption of the first dormitory building is estimated to be 88.30 MWh for six months by using the Green building Studio, another popular energy simulation tool. The electricity usage of the interior lights is 45.50 MWh and room electricity consumption by using electrical devices is predicted to be 42.80 MWh.

Table 4.21. Green Building Studio Default Analysis Electricity Consumption Monthly.

	INTERIORLIGHTS: ELECTRICITY [kWh]	INTERIOREQUIPMENT: ELECTRICITY [kWh]
January	7750	7286
February	7000	6577
March	7750	7378
April	-	-
May	-	-
June	-	-
July	-	-
August	-	-
September	-	-
October	7750	7397
November	7500	7013
December	7750	7156
Annual Sum or Average	45500	42807
Total		88307

5. DISCUSSIONS

In this thesis, the impact of the residents' electricity consumption preferences and time spending in rooms on the electricity consumption was demonstrated. The predicted energy performance of the dormitories has a wide range because of considering the energy user behaviors in different ways. In order to analyze the energy performance of the buildings in a precise way, the energy consumption attitudes of the residents should be integrated to the energy simulation tools in a systematic approach. The most accurate way of analyzing the user behavior is through collecting data with the energy consumption monitoring systems, yet these systems are expensive. Therefore, an alternative method is necessary to define the energy consumption attitudes of the occupants. In this sense, a survey was conducted on the Boğaziçi University Kilyos Campus to define the energy consumption behaviors of the students living in the dormitories. The survey results show that the students are able to be classified based on their electricity consumption preferences and time spent in the rooms by asking related questions. According to the KMO and Bartlett Test, the number of the survey data was sufficient to analyze the collected survey answers since the adequacy number is over 0.5. It is challenging to define each student's energy user behavior in the energy analysis model, so the students were grouped by using the cluster analysis according to their energy behavior and time spent in their room. Many studies classified the residents living in the households based on the energy related behavioral characteristics [65, 67]. There are different survey analysis methods such as general linear regression models and segmentation techniques that have been prominently conducted. The segmentation studies shows variety on how the properties of the energy consumer types can be defined in a precise way. According to the survey analysis, the students living on Bogaziçi Kilyos Campus dormitories could be divided into three different groups based on their electricity consumption behavior and time spent in the rooms. At the end of the k-means cluster analysis, the classified groups were defined as Cluster A, B and C. Then, the analysis results of all the survey questions related to electricity usage attitude and time spending in the rooms show that each group indicates differences in the electricity utilization attitudes. However, Cluster A and Cluster C occupants are nearly similar in time spending in the rooms with respect to Cluster B students.

In this study, there are 6 energy performance analyses that were conducted for each dormitory based on a period between 1 October and 31 March by the DesignBuilder. In order to demonstrate the changing range of values in electricity consumption depending on user types, all the students in the dormitories were considered as the Cluster A members in the first analysis. Then, all the students in the dormitories were considered as the Cluster B and C members in the second and third analysis. Therefore, the energy user behaviors of one cluster were just assigned to the all dormitory rooms in different analysis. In addition, all the groups were assigned to the dormitory buildings based on the actual distribution ratio as in real life achieved from survey analysis. In addition, the default settings were used in order to perform the energy performance of the dormitories by using the DesignBuilder and the Green Building Studio. The results of all the energy performance analysis demonstrate that there are major differences among the clusters and analysis of the default settings provided by the DB and GBS in the electricity consumption.

According to the previous research, the energy user consumption behaviors have major impact on the building energy consumption [18, 20]. Hence, there are differences that have been occurred between the estimated and actual energy consumption by using energy simulation tools [21]. According to energy performance analysis, the entire dormitory buildings just occupied by the Cluster C members assumed as more time spent in the rooms and having non-energy efficient behaviors consume more electricity with respect to the other clusters. The electricity consumption of the buildings assuming that the dormitories are just occupied by the Cluster C members is estimated to be 461.67 MWh in the third dormitory and is predicted to be 407.54 MWh in the first dormitory. Also, the carbon emission of the dormitory buildings considering as the buildings are just occupied by the Cluster C members is the highest, 279.19 ton in the first dorm and 316.24 ton in the third dorm.

The electricity consumption of the entire buildings when all the occupants assigned as Cluster B members having energy efficient behaviors in electricity consumption is 84.68 MWh in the third dormitory and 71.63 MWh in the first dormitory. The electricity consumption and carbon emission analysis results of the dormitories considered as only occupied by the Cluster B residents are the least with respect to the other groups.

The Cluster A occupants were assigned to the DesignBuilder as a consumer type between the students belonging to the Cluster B and C in energy efficient behaviors. Hence, the electricity consumption of the entire dormitory buildings when all the students assigned as Cluster A members are 249.22 MWh in the third dormitory and 227.15 MWh in the first dormitory between the Cluster B and C members in electricity consumption.

The results show that the electricity consumption and carbon emission can be different in crucial levels by accounting of user energy consumption in the energy performance analysis. When taken the electricity consumption differences between the Cluster B and C members into account, the impact of the occupants' indoor activities and devices usage schedules on the electricity consumption can be observed in precise. If all the dormitory building is used by Cluster C students, the electricity consumption is roughly 6 times more than Cluster B members when they use the entire dormitory building both in the first and in the third dorms as provided in the Table 5.1 and Table 5.2. In addition, the electricity consumption of the Cluster A residents assumed as occupying all the dormitory buildings is about 3 times more than Cluster B in two dormitories as illustrated in the Table 5.1 and Table 5.2.

Table 5.1. First Dormitory Results.

1. Dormitory	Annual Electricity Consumption (MWh)	Annual Carbon Emission (ton)
Cluster A	227,15	155,60
Cluster B	71,63	49,06
Cluster C	407,54	279,16
Clusters with actual distribution ratio	242,71	166,26
DesignBuilder Default	306,71	210,10
Green Building Studio Default	88,37	-

Table 5.2. Third Dormitory Results.

3. Dormitory	Electricity Consumption (MWh)	Annual Carbon Emission (ton)
Cluster A	249,22	170,71
Cluster B	84,68	58,00
Cluster C	461,67	316,24
Clusters with actual distribution ratio	237,35	162,58
DesignBuilder Default	338,30	231,74
Green Building Studio Default	145,30	

In addition, the results of the default setting analysis by using the DesignBuilder and the Green Building Studio demonstrate that there is no accurate estimation in the electricity consumption. The differences in the electricity consumption between analysis of all the cluster members distributed into the rooms as real life and analysis of the default settings provided by the DB and GBS strengthen this assessment. When the occupant behaviors are considered in the estimation of the electricity consumption, the analysis results based on the default settings are overestimated compared to when the all clusters assigned to the rooms as actual time.

Another important point is that there is a big fluctuation among the results in electricity consumption of the dormitories. The fluctuation of the energy performance results in each dormitory can be seen in Figure 5.1 and Figure 5.2. Especially, the electricity consumption results based on the default settings, the major differences between the Cluster B and C can be seen in the Figure 5.1 and Figure 5.2 because of accounting of students' electricity consumption behaviors. In addition, the fluctuation in the estimated electricity consumption shows the potential electricity savings when changing the energy user behaviors in the dormitories.

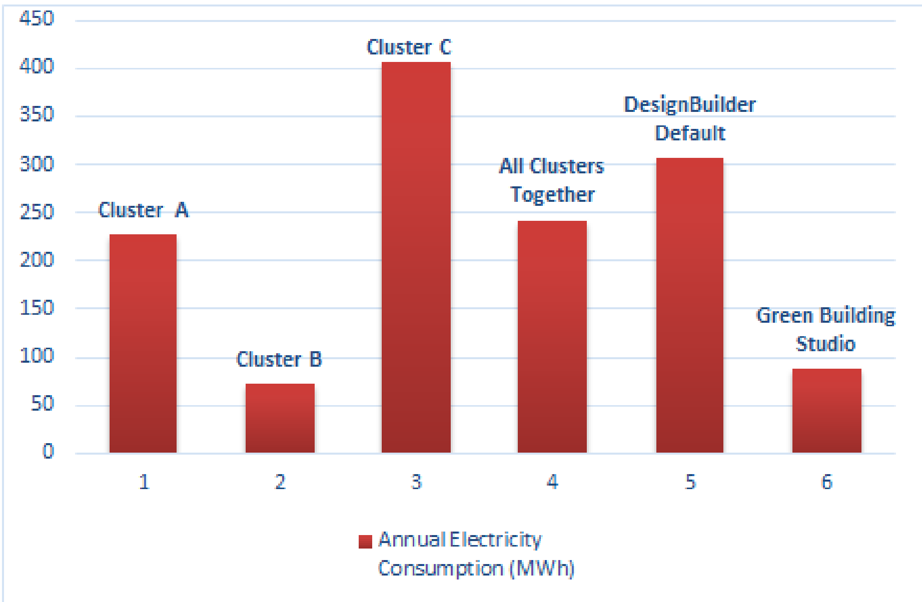


Figure 5.1. 1^{st} Dormitory Electricity Consumption Results.

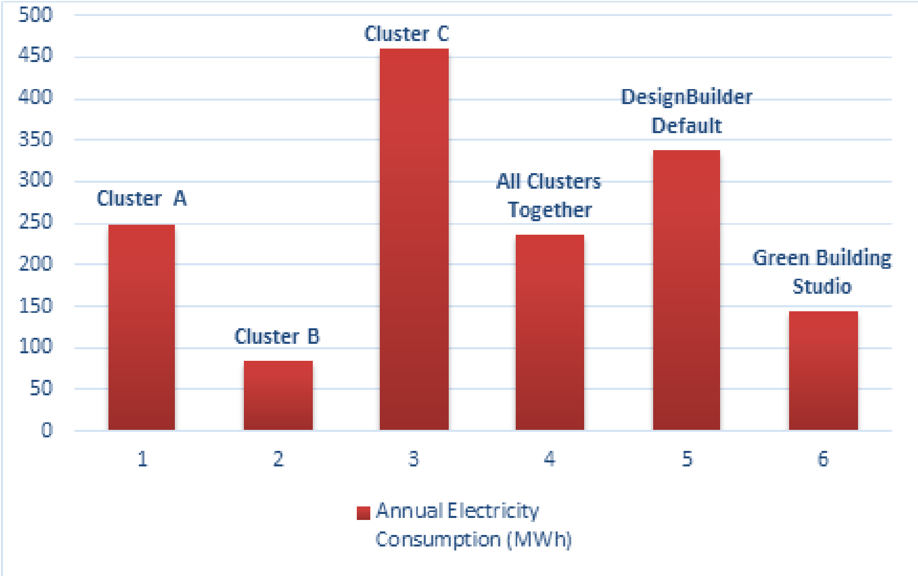


Figure 5.2. 3^{rd} Dormitory Electricity Consumption Results.

This kind of variations in the predicted electricity consumption could impact the energy efficient applications and strategies executed to reduce the electricity consumption. There are two type buildings that have been applied the energy efficient applications; the existing and new ones. The retrofitting projects have been conducted in the existing buildings to increase the energy efficiency. In this study, it was aimed to imply that the retrofitting applications should be decided on the consumer types. Especially, the decision of the energy efficient strategies has been built on the assumptions in the energy efficiency. From the Figure 5.1 and Figure 5.2, it can be concluded that the energy conservation ratios could be show differences according to the energy consumer groups.

The initial investment of the energy efficient measures has been decided according to the return rates. Therefore, it is a crucial point how much energy will be conserved in the future if the retrofitting measures are implemented. The potential energy saving calculations is based on the general assumption in the financial analysis. However, the conservation rates can be different when considering the energy user behaviors. Camlıbel (2011) applied several energy efficient measures to observe the financial return gain by using heuristic model [5]. The Net Present Value (NPV) defined as sum of the present values of incoming and outgoing cash flows over a period time was calculated to observe the financial gain of the energy efficient measures. However, the conservation of the energy efficient applications was calculated on the assumptions without considering energy consumer behaviors. As can be seen in Figure 5.1 and 5.2, the estimated energy saving could be different according to the energy consumer attitudes. The assumptions in the energy saving calculation could not be accurate. Thus, the decision of the energy efficient applications may be directed to the wrong way in energy efficiency. As a consequence, the accounting of the energy user behavior is an inevitable way to estimate the precise potential energy saving and consumption.

When considering the different results between the electricity consumption of the dormitories estimated by using default settings and electricity consumption of the buildings that all the cluster members stay together as real life, the neglecting of the energy consumer behaviors in the energy consumption could not provide precise results. The fluctuation in the electricity consumption according to different consumer types as presented in the Figure 5.1 and Figure 5.2 proves this assessment. The energy consumption of the buildings could not be stable because of the energy user behaviors.

There are different solutions that can be provided according to the consumer types in energy efficiency. As an illustration, the energy efficient bulbs could be more effective to reduce electricity consumption for Cluster C students because their lighting usage is more than the other clusters.

Another solution type could be placing the students based on the electricity consumption attitudes to the rooms in the dormitories. Therefore, the rooms can be allocated based on the clusters such as Cluster A, B and C. Also, the feedback system enabling the occupants to the real time electricity consumption information in units can be provided according to the different clusters. For example, if the electricity consumption of the Cluster B occupants is observed by the Cluster C residents, this could have positive impact on the electricity conservation of the Cluster C occupants due to peer pressure. The return rates in energy efficiency will be higher in those rooms with respect to the other clusters.

During the design process of a new building, the prior knowledge about what kind of energy consumers stay in the building is a crucial point. The designers can choose the optimum solution in the daylighting efficiency such as using wide windows or relocating the building towards the south direction

Another important point is related with the existing buildings. Before the retrofitting the existing buildings, the energy efficiency applications should be decided according to the energy consumer types in the buildings. Therefore, the designers such as engineers and architects need information about the energy consumption behavior of the residents. It is fact that the gaining from energy efficient implementations could be different according to the energy consumer types. As a result, the provided survey approach can be implemented in the retrofitting projects for the existing buildings. Before determining the energy efficient measures, the decision makers can conduct a survey to define the energy user behaviors of the occupants. The strategies could be developed according to the identified energy consumption attitudes in the retrofitting projects. For example, if the occupants in the existing buildings do not turn off the lights when not in use during the day hours, then the sensor lightening system can be implemented. Thus, the electricity consumption of lightening system can be reduced significantly. However, if the residents are sensitive in turning off the lights, the implementation of the sensor lightening system could be an unnecessary financial investment.

In addition to identifying the energy user behavior, the reasons of energy consumption attitudes should be understood. Therefore, the design of the buildings can be differentiated according to these reasons. Especially, the architectural design choices are important in the energy consumption behavior. For example, the window sizes have impact on the lighting consumption in the buildings. The daylighting design strategy is important to reduce the electricity consumption of lighting. Also, the architectural design strategies are crucial in the passive systems of the buildings such as HVAC, heater pump and building insulation. Although the energy user behaviors have more impact on the electricity consumption of the building through active systems such as lighting or equipment usage, the energy consumption behavior of the residents also influence the total energy consumption of the building through passive systems during the operational phase.

The offered survey approach is proposed as a framework to be integrated into the simulation tools. This study does not aim to develop a new module to implement into the simulation tools. The achieved results from survey analysis can be integrated into the energy simulation tools manually.

Similar to the findings of studies conducted by Wasilowski (2009) [18] and Hong (2013) [20] which are related with the impact of the energy user behaviors on the energy consumption, the potential electricity conservation by just changing the electricity consumption attitudes is also presented in this study. There is a significant difference in the electricity consumption among the consumer types having different electrical devices usage schedules. In addition, the energy analysis results with default settings are not able to provide an accurate energy performance of the buildings because of ignoring the electrical devices and lighting usage schedules in detail. The energy consumption of the buildings estimated by using the default settings of the simulation tools have been predicted on just preset occupancy schedules.

In summary, this study shows the impact of the user behavior on the energy consumption theoretically. By using a survey approach, the energy user behaviors were classified and assigned to the DB before performing the energy analysis. At the energy performance analysis, it is difficult to obtain accurate results in the energy consumption of the dormitory buildings. The energy consumption behavior of the each resident could not be identified and assigned into the energy simulation tools precisely. Therefore, this research provides a theoretical approach to estimate the precise energy consumption of the buildings by conducting a survey to define the general energy user behaviors. Before determining the energy efficient measures for the existing buildings, this kind of information about energy consumption behaviors of the occupants could change the direction of the energy efficient implementations.

6. LIMITATIONS AND FUTURE RESEARCH

Although the study shows the significant results concerning the impact of the electricity usage attitudes on the electricity consumption, there are some limitations that can be observed in the research.

First off all, the estimated energy analysis results were not compared with the real electricity consumption in the dormitories. The electricity bills have been provided for all the entire campus buildings. Therefore, the electricity consumption of each dormitory cannot be individually obtained. Due to the fact the impact of electricity user behavior was the main focus in the dormitories, the total building electricity consumption including HVAC system was neglected. Moreover, because of using a central heating system in the dormitories, the electricity consumption of the HVAC system was excluded during energy performance analysis.

Another important limitation is that the common areas in the dormitories such as laundry rooms, fitness centers, PC laboratories, bathrooms, kitchens and ironing rooms could not be individually identified in the energy model since they are utilized by all the clusters together. The energy model of the common areas could not be assigned to the simulation tool based on the one typical consumer type. Thus, the electricity consumption of these common places was distributed to the defined rooms.

The answer of the survey questions may not represent the real electricity consumption behavior and time spending in the rooms of the students. For instance, one student answers the questions as an energy efficient consumer, but his energy consumption behaviors could be different in practice with respect to the survey answers. The results of the survey analysis can be considered as a theoretical approach to define the energy consumer types. However, the energy user behaviors are important what the occupants' energy consumption behavior in practice.

The most crucial limitation is that students belonging to different clusters share the same room which leads to overlapping problem in the energy simulation. According to the cluster analysis, many students from the different clusters live together in the same rooms. In order to solve this issue, the students belonging to different clusters were assumed as living different rooms based on the consumer types. However, this energy model method may not give the accurate energy performance of the buildings. For example, the occupants from the Cluster B and C live together in the same room, so the Cluster B energy efficient behaviors could not be important due to Cluster C non-energy efficient attitudes. To prevent the overlap problem during energy performance analysis, an agent-based model might be developed in the future works. Therefore, the energy user behavior of the students can be individually estimated in the dormitories by using different algorithms. Also, the developed model can be integrated to the energy simulation tools to predict the accurate energy consumption of the buildings based on the real indoor activities of the residents.

Based upon the findings of this study, the next-plan is to develop an agent-based simulation model to estimate the energy user behavior accurately in the buildings in the future study. In addition, this model is planned to be integrated to the energy simulation tool to predict energy consumption of the buildings in more real approach.

7. CONCLUSION

The findings of the study confirm that there is a crucial link between energy user behavior and building energy consumption. By accounting of the occupants' energy consumption behavior, the results show major differences among groups having different electricity consumption attitudes.

Before the energy performance analysis of the dormitory buildings, a qualitative survey was conducted on Boğazici University Kilyos Campus in order to define students' behaviors in electricity consumption and time spending in the rooms. At the end of the survey analysis, the students are classified into three accurate groups defined as Cluster A, B and C. The cluster and factor analysis techniques were used to analyze the survey data. The different electrical devices and lighting usage schedules with occupancy were defined for each cluster based on the answer of the survey questions. Based upon the segmentation of the students based on the energy user behavior, the electricity consumption of the 1st and 3rd dormitories was estimated by using energy simulation tool, DesignBuilder. The results show that Cluster C students assumed as staying in the entire dormitories, who have non-efficient electricity utilization attitudes, consume six times more than Cluster B students considered that the entire dormitory only is occupied by the Cluster B members.

The electricity consumption of the dormitories based on the default settings by using DB and the GBS shows significant differences with respect to analysis of all the clusters assigned to the dormitory buildings with the actual distribution rate. The major fluctuation among the electricity consumption results indicates that the occupants' electricity usage patterns have significant impact on the electricity consumption estimation. Also, the reason of the gap between predicted and actual energy performance can be understood from these findings. By ignoring the occupants' energy behaviors, the discrepancies between the estimated and real energy consumption are inevitable.

In summary, this study provides an initial step in understanding the importance of the energy user behavior in the buildings. The contribution of this study is to indicate the impact of user behavior on the electricity consumption by accounting of the energy user behavior during energy performance analysis. The fluctuation among the results gives a powerful clue about energy saving potential due to changing user energy patterns. The energy efficiency targets in the buildings can be achieved by replacing non-energy efficient activities to the energy efficient ones. Therefore, the potential energy conservation by changing energy user behaviors is indicated. This kind of reducing energy consumption strategies does not require major initial investments. Increasing of the awareness and giving incentives for energy efficient behaviors in the buildings will be important steps to reduce energy consumption in the future.

APPENDIX A: SURVEY QUESTIONS

QUESTIONS						
Section 1 : Description Respondent Profiles						
1	Your dormitory	1. Dorm	2. Dorm	3. Dorm		
2	Gender	Male	Female			
3	Age Range	18-21	21-24	24<		
4	Faculty	Faculty of Arts and Science	Faculty of Economy and Administrative Sciences	Faculty of Education	Faculty of Engineering	The School of Foreign Languages
5	Prep class level	Advanced	Intermediate	Pre-Intermediate	Beginner	
6	Your Room Number					
7	How many students live in your dormitory apartment? ***(Apart means that you are sharing kitchen and bathroom with other roommates)***	1	2	3	4	5 or More

Figure A.1. Description Respondent Profiles Section 1.

Section 2: Student Room Occupancy and Schedule		**Hours**				
7	Average time you spend in your room during daytime (only for weekdays)	0 - 2 hours	2 - 4 hours	4 - 6 hours	6 - 8 hours	8 - 10 hours
8	Average time you spend in your room during daytime (only for weekends)	Never	0 - 2 Hours	2 - 4 hours	4 - 6 hours	6 - 8 hours
9	Average time you spend in your room during nighttime/after sunset (only for weekdays)	0 - 8 hours	08 - 10 hours	10 - 12 hours	12 - 14 hours	14-16 hours
10	Average time you spend in your room during nighttime/after sunset (only for weekends)	Never	0 - 8 hours	08 - 10 hours	10 - 12 hours	12 - 14 hours

Figure A.2. Description Respondent Profiles Section 2.

Section 3 : Energy Behavior of Students		Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Electricity Consumption Behavior						
How often Do You........						
11	turn off lights when the room is vacant?					
12	use the lights during daytime?					
13	use window shading system(curtain) during daytime?					
14	use your laptop?					
15	switch off the electric devices when not in use?					

Figure A.3. Description Respondent Profiles Section 3.

Your Personal Preferences		Never	Every Other Week	Once a Week	Twice a Week	Everyday
How often Do You........						
16	cook and use house appliances? (e.g. electric stove, toaster, kettle, refrigerator)					
17	use the laundry room (washing/drying machines) in the dorm?					
18	use the vending machines?					
19	go to the fitness center?					
20	use the ironing room?					

Figure A.4. Your Personal Preferences.

REFERENCES

1. World Energy Council, *World Energy Sources*, New York, 2013.

2. United Nations Environment Programme, *Buildings and Climate Change A Summary For Decision Makers*, London, 2009.

3. BP Oil & Gas Company, *BP Statistical Review of World Energy*, 2014,

4. The United Nations Framework Convention on Climate Change, "Kyoto Protocol", http://unfccc.int/kyoto - protocol/items-/2830.php [accessed June, 2015].

5. Camlibel, M.E., ‘An Integrated Optimization Model Towards Energy Efficiency For Existing Buildings - A Case Study For Bogazici University Kilyos Campus, Ph.D. Thesis, Bogazici University, 2011.

6. Energy U.S Information Administration. "Short Term Energy Outlook", http://www.eia.gov/forecasts/steo/report/prices.cfm [accessed June, 2015].

7. Perez-Lombard, L., J. Ortiz, and C. Pout, "A Review on Buildings Energy Consumption Information", *Energy and Buildings*, Vol. 40, No. 3, pp. 394-398, 2008.

8. Boyano, A., P. Hernandez, and O. Wolf, "Energy Demands and Potential Savings in European Office Buildings: Case Studies Based on EnergyPlus Simulations", *Energy and Buildings*, Vol. 65, pp. 19-28, 2013.

9. Tavares Paulo Filipe de Almeida Ferreira Martins, and Antonio Manuel de Oliveira Gomes, "Energy Efficient Building Design Using Sensitivity Analysis - A Case Study", *Energy and Buildings*, Vol. 39, No. 1, pp. 23-31, 2007.

10. Keskin, T., *Binalar Sektörü Mevcut Durum Değerlendirmesi Raporu*, Ministry of Forest and Water Affairs, Climate Change Department, İstanbul, 2010.

11. Türk Mühendis ve Mimarlar Odaları Birliği, *Dünyada ve Türkiyede Enerji Verimliliği Raporu*, İstanbul, 2012.

12. Lopes, M.A.R., C.H. Antunes, and N. Martins, "Energy Behaviours as Promoters of Energy Efficiency: A 21st Century Review", *Renewable and Sustainable Energy Reviews*, Vol. 16, No. 6, pp. 4095-4104, 2012.

13. United Nations Development Programme, Promoting Energy Efficiency in Buildings - Turkey, United Nations, New York, 2013.

14. The Ministry of Environment and Urbanisation, "Binalarda Enerji Verimliliği - Istaistikler", http://www.bep.gov.tr/BEPTRWEB/istatistikler. aspx [accessed June, 2015].

15. Peschiera, G. and J.E. Taylor, "The Impact of Peer Network Position on Electricity Consumption in Building Occupant Networks Utilizing Energy Feedback Systems", *Energy and Buildings*, Vol. 49, pp. 584-590, 2012.

16. Gulbinas, R. and J.E. Taylor, "Effects of Real-Time Eco-Feedback and Organizational Network Dynamics on Energy Efficient Behavior in Commercial Buildings", *Energy and Buildings*, Vol. 84, pp. 493-500, 2014.

17. Jain, R.K., J.E. Taylor, and P.J. Culligan, "Investigating the Impact Eco-Feedback Information Representation has on Building Occupant Energy Consumption Behavior and Savings", *Energy and Buildings*, Vol. 64, pp. 408-414, 2013.

18. Hong, T. and H.W. Lin, "Occupant Behavior: Impact on Energy Use of Private Offices", Ernest Orlando Lawrence Berkeley National Laboratory, California, 2013.

19. Hoes, P., J.L. M. Hensen, M.G.L.C. Loomans, B. de Vries, and D. Bourgeois, "User Behavior in Whole Building Simulation", *Energy and Buildings*, Vol. 41, No. 3, pp. 295-302, 2009.

20. Wasilowski, H. and C. Reinhart, "Modeling An Existing Building in DesignBuilder-

/EnergyPlus custom Versus Default Inputs”, *Building Simulation*, New York, 2009.

21. Parys, W., D. Saelens, and H. Hens, “Impact of Occupant Behavior On Lighting Use”, *Building Simulation*, Vol. 1, pp. 1143-1150, 2009.

22. Elektrik İsleri Etüt İdaresi, “Binalarda Enerji Performansı Yönetmeliği”, Ankara, 2008.

23. American Society of Heating Refrigerating and Air Conditioning Engineers, “Energy Standard for Buildings Except Low-Rise Residential Buildings”, American Society of Heating Refrigerating and Air Conditioning Engineers, ed., ASHRAE 2007-90.1, Washington, 2007.

24. Allmänna Svenska Elektriska Aktiebolaget - Automation and Power Technologies Inc, *Energy Efficiency in Buidings*, Zurich, 2009.

25. Improving Energy Efficiency in Buildings, “Promoting Energy Efficiency in Buildings”, http://www.surdurulebilirbinalar.net /index.php/en/component/content/article-?id=32 [accessed June, 2015].

26. Kanan, N.Ö. “Binalarda Enerji Verimliliği Konusunda Kamu Projeleri-Binalarda Enerji Performansı Belirlenmesi; 100 Kamu Projesi Örneği”, *Tesisat Mühendisliği Sayı-136*, Vol. 1, pp. 65-70, 2013.

27. Meier, A., T. Olofsson, and R. Lamberts, “What Is An Energy-Efficient Building?”, in IX ENTAC conference, Parana, Brazil, 10th May 2002, Vol. 1, pp. 3-12, 2002.

28.) U.S. Environmental Protection Agency - Energy Star. “Energy strategy for the future”, http://www.energystar.gov/buildings/about-us/research-and-reports/energy- strategy-future [accessed June, 2015].

29. Watson, D.J., D.I. Scrase, and D.L. Stapleton, Transforming the *UK’s Energy System - Policies for the 2020 Renewables Target and Beyond*, University of Sussex, Brighton, 2011.

30. Osmani, M. and A. O'Reilly, "Feasibility of Zero Carbon Homes in England by 2016: A House Builder's Perspective", *Building and Environment*, Vol. 44, No. 9, pp. 1917-1924, 2009.

31. Europen Union Commission Report, *The Energy-Efficient Buildings PPP: Research for Low Energy Consumption Buildings in The EU*, Brussel, 2014.

32. Danny H.W. Li, L. Yang, and J.C. Lam, "Zero Energy Buildings and Sustainable Development Implications - A Review", *Energy*, Vol. 54, pp. 1-10, 2013.

33. Marszal, A.J., P. Heiselberg, J.S. Bourrelle, E. Musall, K. Voss, I. Sartori, and A. Napolitano, "Zero Energy Building - A Review of Definitions and Calculation Methodologies", *Energy and Buildings*, Vol. 43, No. 4, pp. 971-979, 2011.

34. Zero Net Energy Homes, "The Many Benefits of Zero Energy Homes", http://www.zero homes.org/benefits [accessed June, 2015].

35. Nesler, C. and A.S. Palmer, *Absolute Zero Net Zero Energy Commercial Buildings - An Inspiring Vision for Today*, Johnson Controls Inc, New York, 2009.

36. Türkiye Istatistik Kurumu, "Yıllara Göre Nüfus Dagilimi", http://www.-tuik.gov.tr/UstMenu.do?metod=temelist [accessed June, 2015].

37. Özyurt, G. and K. Karabalik, "Enerji Verimliliği, Binaların Enerji Performansı ve Türkiye'deki Durum", *Türkiye Mühendislik Haberleri*, Vol. 1, pp. 32-34, 2009.

38. The Ministry of Energy and Natural Resources, "Enerji Verimliligi - Etutler", http://-www.enerji.gov.tr/tr-TR/Sayfalar/Etutler [accessed June, 2015].

39. Netherlands Enterprise Agency, *Türkiye Green Buildings*, Report, Amsterdam, 2012.

40. Energy Design Resources, "Integrated Design Building", http://energy designresources .com/media/1711/DesignBriefs-design.pdf?tracked=true [accessed June, 2015].

41. United Nations Development Programme, *Enerji Etkin Binalara Ulaşma Yolunda Temel Tasarım Prensipleri*, United Nations, New York, 2013.

42. Sürdürülebilir Binalar, "Integrated Building Design Approach", http://surdurulebilir-binalar.net/subsite/index.php/en/what-is-ibda [accessed June, 2015].

43. Clarke, J.A., *Energy Simulation in Building Design*, 2^{ed}., 2001.

44. Maile, M. Fischer, and V. Bazjanac, *Building Energy Performance Simulation Tools -A Life-Cycle and Interoperable Perspective*, Stanford University, California, 2007.

45. Sam, C., M. Hui, "Energy Performance of Air-conditioned Buildings in Hong Kong", Ph.D. Thesis, Hong Kong, 1996.

46. Waltz, J.P., *Computerized Building Energy Simulation Handbook*: The Fairmont Press Inc, London, 2000.

47. Crawley, D.B., J.W. Hand, M. Kummert, and B.T. Griffith, "Contrasting the Capabilities of Building Energy Performance Simulation Programs", *Building and Environment*, Vol. 43, No. 4, pp. 661-673, 2008.

48. James J. Hirsch and Associates, "DOE2 Building Energy Use and Cost Analysis Software", http://www.doe2.com/ [accessed June, 2015].

49. The U.S Department of Energy, "Building Energy Software Tools Directory- Ecotect", http://apps1.eere.energy.gov/buildings/tools-directory/software. cfm/ID=391-/pagename=alpha-list [accessed June, 2015].

50. The U.S Department of Energy, "Building Energy Software Tools Directory - EnergyPlus", http://apps1.eere.energy.gov/buildings/tools-directory/software. cfm/ID-=287/pagename=alpha-list [accessed June, 2015].

51. Autodesk. "Green Building Studio - Cloud Based Energy Simulation," https://gbs.autodesk.com/GBS/ [accessed June, 2015].

52. DesignBuilder, “DesignBuilder”, http://www.designbuilder.co.uk [accessed June, 2015].

53. Yao, R. and K. Steemers, “A Method of Formulating Energy Load Profile for Domestic Buildings in the UK”, *Energy and Buildings*, Vol. 37, No. 6, pp. 663-671, 2005.

54. Demanuele, C., T. Tweddell, and M. Davies, “Bridging The Gap Between Predicted and Actual Energy Performance in Schools”, New York, 2013.

55. Peng, C., D. Yan, R. Wu, C. Wang, X. Zhou, and Y. Jiang, “Quantitative Description and Simulation of Human Behavior in Residential Buildings”, *Building Simulation*, Vol. 5, No. 2, pp. 85-94, 2011.

56. Azar, E. and C.C. Menassa, “Agent-Based Modeling of Occupants and Their Impact on Energy Use in Commercial Buildings”, *Journal of Computing in Civil Engineering*, Vol. 26, No. 4, pp. 506-518, 2012.

57. Langevin, J., P.L. Gurian, and J. Wen, “Reducing Energy Consumption in Low Income Public Housing: Interviewing Residents About Energy Behaviors”, *Applied Energy*, Vol. 1, No. 102, pp. 1358-1370, 2013.

58. Reinhart, C.F., “LIGHTSWITCH-2002: A Model for Manual and Automated Control of Electric Lighting and Blinds”, *Solar Energy*, Vol. 77, no. 1, pp. 15-28, 2004.

59. Jain R.K., J.E. Taylor, and G. Peschiera, “Assessing Eco-Feedback Interface Usage and Design to Drive Energy Efficiency in Buildings”, *Energy and Buildings*, Vol. 48, pp. 8-17, 2012.

60. Nicol, J.F., “Characteristing Occupant Behavior in Buildings: Towards A Stochastic Model of Ocuupant Use Windows, Lights, Blinds, Heaters and Fans”, *Rio de Janeiro*, Vol. 1, pp. 1073-1078, 2002.

61. Widén, J. and E. Wäckelgård, “A High-Resolution Stochastic Model of Domestic Activity Patterns and Electricity Demand”, *Applied Energy*, Vol. 87, No. 6, pp. 1880-1892, 2010.

62. Bourgeois, D., C. Reinhart, and I. Macdonald, “Adding advanced behavioural models in whole building energy simulation: A study on the total energy impact of manual and automated lighting control”, *Energy and Buildings*, Vol. 38, No. 7, pp. 814-823, 2006.

63. Bogaziçi University, “Elektrik Ihtiyacının Tamamını Kendi Rüzgar Santralinden Karşılayan Dünyadaki İlk Üniversite Kampüsü,” http://haberler.boun.edu. tr/tr/haber [accessed June, 2015].

64. Ek, K. and P. Söderholm, “The Devil is in the Details: Household Electricity Saving Behavior and the Role of information”, *Energy Policy*, Vol. 38, No. 3, pp. 1578-1587, 2010.

65. Sütterlin, B., T.A. Brunner, and M. Siegrist, “Who Puts the Most Energy Into Energy Conservation? A Segmentation of Energy Consumers Based on Energy-Related Behavioral Characteristics”, *Energy Policy*, Vol. 39, No. 12, pp. 8137-8152, 2011.

66. Finisterra do Paço, A.M., M.L. Barata Raposo and W.L. Filho, “Identifying the Green Consumer: A Segmentation Study”, *Journal of Targeting, Measurement and Analysis for Marketing*, Vol. 17, No. 1, pp. 17-25, 2009.

67. Pedersen, M. “Segmenting Residential Customers Energy and Conservation Behaviors”, ACEEE Summer Study on Energy Efficiency in Buildings, Vol. 1, pp. 229-240, 2008.

68. Ji, Y., G.J. Wang, Q. Zhang, and Z.H. Zhu, “Online Social Networking Behaviors Among Chinese Younger and Older Adolescent: The Influences of Age, Gender, Personality, and Attachment Styles”, *Computers in Human Behavior*, Vol. 41, pp. 393-402, 2014.

69. Wilkins, C.K. and M.H. Hosni, “Plug Load Factors”, *ASHRAE Journal*, Vol. 1, pp. 30-34, 2011.