Effect of Occupant Behavior on Thermal Comfort in EMU Student Accommodation Units: Kamacioglu and Prime Living Dormitories

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ABSTRACT

The climate change and the subject of energy efficiency to overcome the man-made harms to our environment are of very important issues today. The building sector and especially the accommodation sector by using energy and their inefficiency in doing so contribute a lot to the existing problem. Many strategies and methods can be applied to reduce the energy consumption rate in buildings and houses but first the main factors and energy consuming elements in a building must be underlined. Among these buildings, dormitories are between the important ones as they accommodate certain range of occupants in terms of age and activity and also their occupational pattern. On the other hand, in the existing studies the importance of student accommodations are overlooked.

This study tries to identify some major factors in the energy consumption of a building, by literature review of the latest publications, and then investigating them in a field study which in this study are Kamacıoğlu dormitory and Prime Living dormitory in EMU campus, finally in the analysis of the results the main weak points of the field study in terms of physical and occupant characteristics are shown and some suggestions are given to the existing problems.

Keywords: Energy Crisis, Climate change, Energy efficiency, Occupant behavior, Dormitories

ÖZ

İklim değişikliği ve enerji verimliliği konusu insanların çevreye verdikleri hasarların üstesinden gelmek amacıyla gündemin en önemli konularının içinde yer alıyorlar. Bina sektörü ve özellikle mesken ve yerleşim sektörü, etkinsiz bir şekilde enerji kullanım nedenleriyle mevcut olan problem ve sıkıntıları daha da kötüleştirmede önemli payı olmaktadır. Bu problemi farklı yaklaşımlar ve yöntemler ile karşılamak ve neticede enerji kullanma oranları düşürüle bilir, ama öncelikle binada olan önemli faktörler ve enerji kullanımını etkileyecek olan elemanlar altı çizilerek vurgulanmalıdır.

Bina sektöründe Öğrenci yerleştirme binaları ve yurtlar özel bir genç etnik grubun sakin olduğu yerler olduğu için önemli binalar sayılıyorlar. Bu özel yurt sakinleri yas ve farklı enerji kullanımına yaklaşım ve davranışlarından dolayı yurtları diğer binalara göre farklı bir pozisyonda bırakıyorlar. Bugüne kadar enerji tasarruf konusunda yapılan araştırmalarda konut binaları ve özellikle yurtlar göz ardı edilmişler.

Bu araştırma mevcut olan araştırmalar ve literatürleri inceleyerek, enerji tüketiminde ana faktörleri tanımlamaya çalışıp, ve ardından bulunan bilgileri DAÜ kampüsünde olan iki yurtta inceleyecektir. Sonuç olarak bulunan bilgileri analiz ederek, yurtlara olan zayıf noktaları bulup ve ardı sıra, bu problemleri alt etmeye önerilerde bulunuyor.

Anahtar kelimeler: Enerji Krizi, İklim Değişikliği Enerji Verimliliği, Kullanıcı Davranışları, Öğrenci Yurdu

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LIST OF ABBREVIATIONS

GHG	Green House Gases
IEA	International Energy Agency
MTOE	Million Tons of Oil Equivalent
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfaction

Chapter 1

INTRODUCTION

1.1 Energy Status Today

The dependence of today’s civilizations and societies to the non-renewable energy sources and the negative influence they have on the environment and climate is a huge threat to humanity and also the global ecosystem. (Climate change is real, 2011). Energy is the crucial factor for socioeconomic progresses, human life and environment quality all over the globe. (ASHREA 1990). One of the major challenges in 21th century is to reduce the impacts of energy consumption on environment and at the same time ensure the energy supply for future generations. Challenges encompassing sustainability in energy sources and energy saving to protect the environment are immense which require major changes and compromises in both the energy supply ways and energy consumption ways. (Allouhi et al, 2015). This requires to study the past and the present in the fields related to energy in order to plan for future. The evidences from all over the world show the ever-growing demand for energy and consequently the increasing impact on environment and climate.

The intimate correlation between the energy sector and economy makes it a necessity to fully understand and manage energy consumption. This understanding needs to be quantified and categorized for every sector and specific end uses. (Shahbaz et al, 2013).

The building sector has significant share in end use energy consumption and the CO_2 emissions, therefore, improving the efficiency of buildings in energy use is an essential factor in reduction of building sectors effect on environment and energy resources. The increasing understanding about the climatic changes and also the increase in energy costs and shortage of non-renewable energy resources along with advancements in technology that allow more possibilities in energy reduction have increased the demand for highly efficient buildings that has reduced energy consumption and lowered operation costs with high quality indoor conditions (Nikolaou et al, 2011). Basically, the building energy efficiency is explained as using less energy in every building operations (as heating and cooling, lighting, hot water supply and other appliances) without any compromise in the occupant's comfort that finally will result in more efficient buildings and less CO_2 emissions (Nikolaou et al, 2011). Other benefits are operational cost reductions in buildings and reduction of harsh impacts on environment. (Ruparathna et al,2016). The buildings impact the environment with the energy consumption thru the building operation time, and the impact of building material lifecycle. Consequently, new movements push the building sector towards designing buildings with better energy performance and sustainable construction (Cook et al, 2009) Nevertheless, newly designed buildings are just a small portion of the built structure and building sector hence it is crucial to develop instructions and principals in order to improve and enhance the existing building efficiency and sustainability (Xing et al, 2011).

The study in the field of building sustainability and efficiency has been a very popular subject among researchers. The efficiency in buildings can be improved through different approaches such as the programs to increase awareness of the users and building operators, improvements in the building management, enhancing buildings with technological advancements in energy efficiency and using renewable sources of energy. All these in practice has to result in great improvements in environmental conditions and enhanced energy consumption objectives for the future. (Mohareb et al, 2014). A sufficient energy reduction and energy efficiency can be achieved with interaction of all behavioral and technical and also organizational improvements (Figure 1). These factors working in interaction with each other can lead the way to optimal efficiency in buildings and result in reduced costs and impacts on environment (Ruparathna et al, 2016).

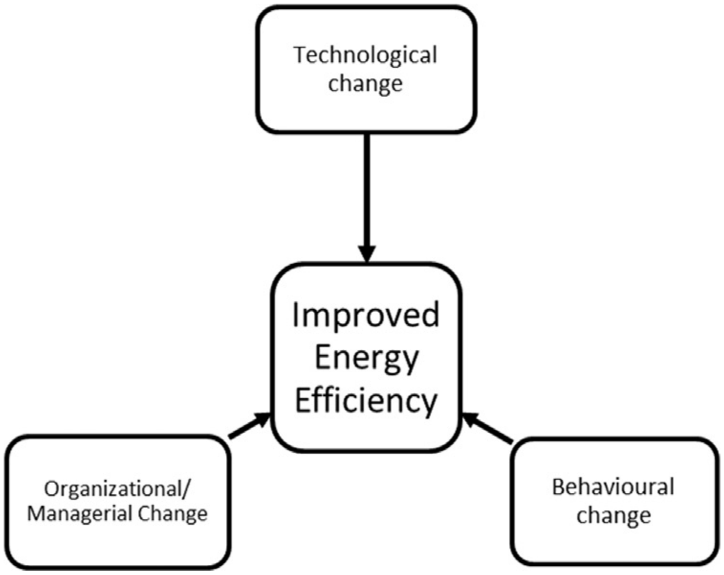


Figure 1: A diagram of factor resulting in energy efficiency (Ruparathna et al, 2016).

This study will investigate the student accommodation units as a specific building sector typology to understand the weak point and find reasonable solutions for the problems.

1.2 Research Problem

Many of the studies encompassing energy efficiency are based around office buildings, institutional buildings and industrial buildings. The studies around the residential and accommodation sector are limited, let alone the dormitory accommodation units. On the other hand, the island of Cyprus is a region that is almost completely dependent on energy imports. Subsequently the energy efficiency of the operating building in every sector can assist to decrease the energy end uses, also help the economy and at the same time reduce the foot print on environment. One of the other problems in the island is the lack of a systematic policy and procedure to insure improving efficiency in buildings. Accordingly, a lack of management and dynamic actions towards more efficiency in buildings are evident.

1.3 Aim and Focus

First, this study will attempt to review the accurate and recent papers and research all over the world to identify the main struggles in the building efficiency and the latest achievements in the field and also identify the most effective approaches and multi-disciplinary methods towards energy efficiency.

The second objective in this study is to observe and investigate the main week points in the efficiency of the dormitory buildings in EMU university via questionnaire, observations and interview. Suggest suitable solutions and procedures in order to increase efficiency in the dormitory buildings.

1.4 Methodology

The methodology of this study is based on survey and problem solving methods. Firstly, it will seek to underline the energy crisis in the world and underline the crucial factors in energy efficiency and the energy efficiency in buildings by literature review and study of recent papers and publications. In second phase, it will investigate the field study using observation techniques, questionnaire survey and interviews. At the end the collected data will be analyzed and synthesized in other to derive solutions to the problem and conclusions.

1.5 Data Collection Techniques

The data collection techniques in this study includes literature review of the latest publications to identify the important factors in energy reduction of buildings; the second phase includes field study and observation using photographs, notes, sketches and measurements, to find the existing situation and problems in the field. Then a questionnaire including 20 close ended questions will be distributed among forty users of the selected dormitories in EMU. And at the end the obtained data will be evaluated by visualizing the relevant data on graphs and charts and analyze them for the results.

1.6 Study Limitations

Since new building consist only a small portion of the existing built structure and likewise in the existing built structures of EMU, this study will be limited and focused to the existing building context. Accordingly, the content of the thesis the, observations and data are in line with the existing building and existing potential of improvement in building performances. On the other hand, according to the information obtained from the dormitories the main occupancy of the dormitories is during the academic year (September to May) that correspond to the cold seasons mainly, therefore this thesis will be mainly focused and limited to the heating activities of the dormitories.

Chapter 2

ENERGY

2.1 Energy Crisis

The very fast expansion in global energy consumption has raised many concerns relating to the shortage of resources, harmful environmental impacts and difficulties in supplies. From the start of industrial revolution, sea water levels, eco systems, the water resources, agriculture all have been effected in a way that influence human societies negatively. Among the environmental impacts, damage to the ozone layer, the global warming and consequently the climate changes, heavy air pollution and alike problems can be named. The energy consumption and emissions has grown around 50% in the last two decades and are still increasing with 2% rate annually. (Yau, 2013). In this manner IEA (international energy agency) publishes continues reports periodically on the energy status internationally. In one the latest reports that shows that the energy use and also CO_2 emission worldwide has been increased close to two and a half times from 1971 to 2015 (IEA, 2017) (Figure1and 2).

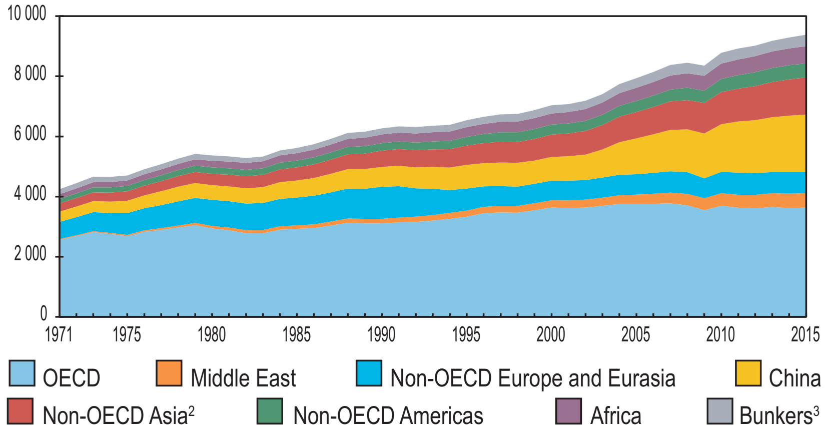


Figure 2: World Total final energy consumption by region from 1971 to 2015, source: IEA 2017 key world energy statistics.

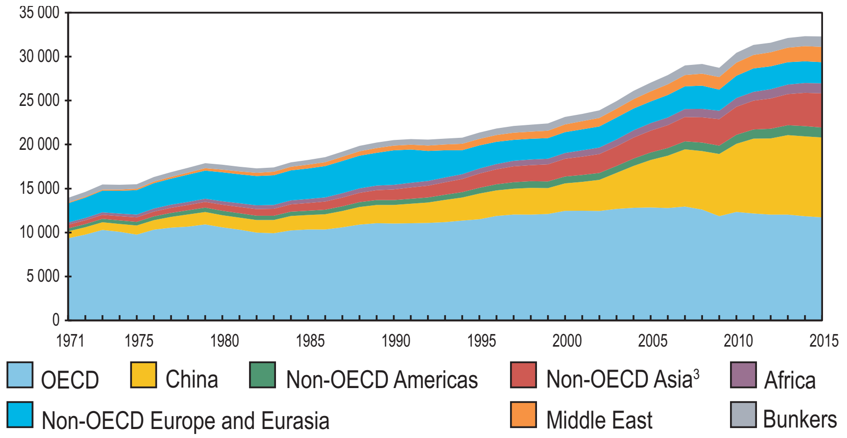


Figure 3: World CO_2 emissions from 1971 to 2015, source: IEA 2017 key world energy statistics

The main reason in the everyday increase of energy demand lies in the global economic development and growth. This global demand has grown by 150% since the 1971 and is measured by TPES (total primary energy supply). As shown in the Figure 4 below provided by IEA this energy is still very dependent to the fossil fuels all over the world, which result in emission of greenhouse gases to atmosphere.

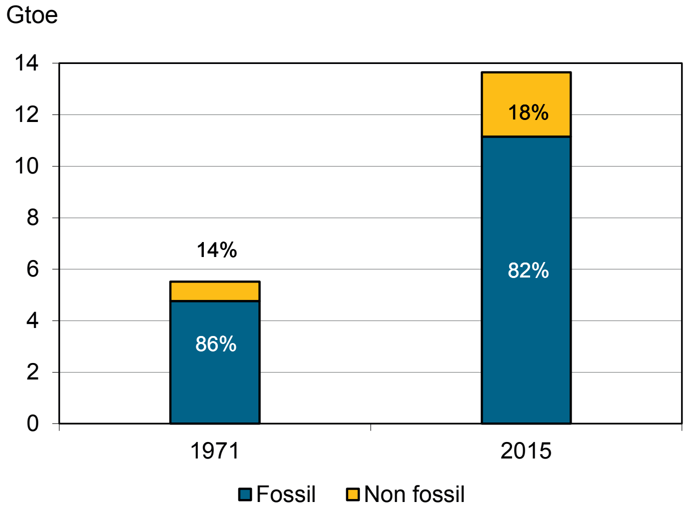


Figure 4: World Primary Energy Supply, (IEA, 2017)

2.2 Green House Gasses (GHG)

Researchers have witnessed that the density of CO_2 gas in the atmosphere have increased significantly from the pre-industrial time until now, from 280 to 403 parts per million in 2016. This is almost 40% more from the mid 18th century. Apart from CO_2, concentration of methane gas and also nitrogen oxide have increased considerably.

Many activities by human kind produces GHG but among them all the activities to produce energy has the biggest effect on GHG emissions. Agriculture is placed next with smaller shares of greenhouse gasses that are mainly Methane ($CH_{4)}$ and Nitrogen Oxide (N_2O), and then are the industrial activities that produce fluorinated gas and N_2O. (IEA, 2017).

The main GHG emerging from the energy sector is resulted from the fuel combustion and the oxidation of carbon and in the result the formation of CO_2 gas. Despite the emerging of the new energy sources that are considered clean without any GHG emissions specially in the electricity generation sector that is responsible of worldwide figure (including, hydropower, solar energies, nuclear energy generation, and other renewable). The percentage of fossil fuels in the global energy generation has remained the same in the last fourthly years. More than 80% of the world energy is produced by using fossil fuels including coal, oil and natural gasses (Suganthi, et al, 2012). As a result, the greenhouse gasses have increased in the atmosphere severely that have cause the climatic changes and global warming all around the world with negative impacts on human health, society and economy on every level from regional to global (Liang, 2013);(Pan, 2012).

Despite all the efforts to decrease the CO2 emissions in the last four decades, the annuals emissions have increased by more than 100% (IEA, 2013). These increases are estimated to continue to a point that in year 2020 there will be 36 million tons of Co_2 emissions and by year 2050 this will be double if precautions and appropriate policies and measures are not applied (Smith, 2013);(Wada, 2012).It is important to take actions in order to reduce the emissions, since without any actions the average temperature will increase up to 41°C (under the A1FI scenario obtained from Intergovernmental Panel on Climate Change’s fourth assessment report);(Coley, 2012).

2.3 Energy Use in Buildings

Approximately 40% of total global energy is consumed by the buildings which shows the fact that buildings have a considerable share in total global energy market. It is predicted that the demand of energy by the buildings will resume to raise in decades to come. (Xing, 2011);(Ibn, Mohammad, 2013). The demand for energy has grown around 1.8% in buildings in last 40 years, (IEA, 2013) and it is expected to grow from

1790 Mtoe (116.8 EJ) in 2010 to over 4400 Mtoe (184.2 EJ) by 2050, with most of this growth being from developing countries (IEA 2013). Additionally, buildings are also accountable for one third of greenhouse gases emitted globally (Robert, 2012). It is a fact that buildings performances can achieve considerable enhancement can help reduce the CO_2 emissions considerably (Kesicki, 2012). The residential sector is considered to be a big portion of the buildings with great potentials in saving energy.

2.3.1 Energy in Residential Sector

The residential sector is accountable for using one third of total energy consumption in buildings. It is to be said that residential buildings have great potential to reduce this by increasing efficiency in energy use (IEA, 2013). Figure 5 below show the share of residential sectors energy use in overall global energy use. The residential buildings are responsible for 20% in developed to 30% of the end uses in developing countries (Yau, 2013). The residential sector energy demand is both evident in present time and also in future (Kelly, 2012).

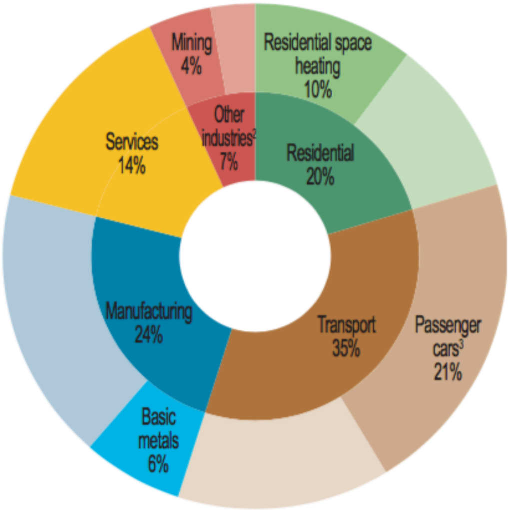


Figure 5: End use energy share of Residential sector (IEA, 2017).

The building share in the crisis of global warming is prominent. The residential sector alone has had 6% direct (PBL, 2013) and 11 % indirect(Electricity) CO_2 emission worldwide, this puts the residential buildings in 4th place among all the responsible factors for this crisis (Figure 6) ;(IEA, 2017).

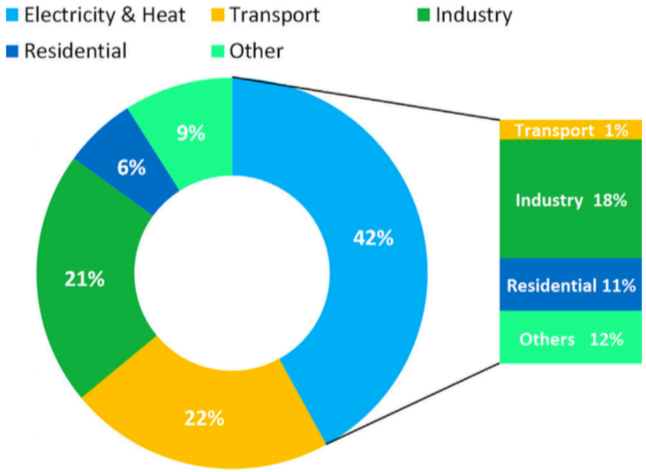


Figure 6: CO2 emitters. (IEA, 2017)

Energy resources used to provide energy for residential buildings can be separated to categories as shown in Figure 7 below: Natural gas, Oil, coal, Traditional biomass, modern renewables like wind power and solar panel and commercial biofuel.

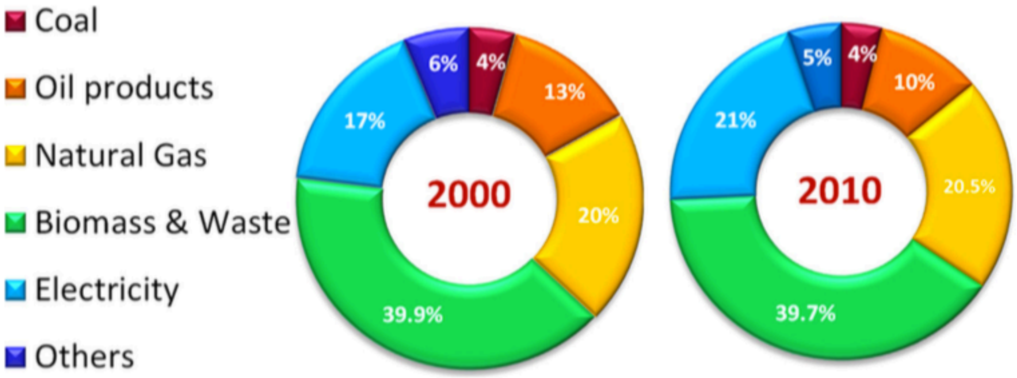


Figure 7: Energy sources used in residential sector (IEA, 2013).

Around 40% of the entire energy use of the residential sector is occupied by traditional biofuels mostly relative in developing an undeveloped world. Next are the fossil fuels that compromise 35% the total energy source and are mostly used in developed countries (IEA, 2013) ;(IEA, 2011). By 20% the electricity is third for overall energy consumption.

The energy used in the residential sector includes all the activities that consume energy except the amount that the occupants use for transportation purposes. In the International Energy Agency (IEA) report, almost half of the total energy use in accommodation units is for the purpose of space heating. These energy end uses can be described as follows (IEA, 2017).

Space Heating:

This includes any effort that results in heating the space using energy sources. They can be divided in two categories: A) central heating B) Dedicated area or room heating

A) Central Heating: These systems are able to heat up the whole living spaces, they include hot water steam pumps radiators or wall furnaces etc.

B) Area / Room Heaters: These systems are divided into several sub systems as electric heaters, fire places, stoves that work with oil or other product as coal or wood.

In some cases, a combination of units is used to heat a space. For example, electrical heaters are used when the central heating is insufficient. These heating systems can use all kind of fuels and energy sources, like electricity, fossil fuels, biomasses, and solar energy.

Space Cooling:

Space cooling activities are all the facilities that are equipped in order to cool the living areas, and are divided into two separate groups: A) Central cooling B) Area or room dedicated cooling

A) Central Cooling: These systems are used together with the ducts which these ducts are also used by the central heating units.

B) Area / Room Cooling: These systems are split units and wall air conditioning units (Evaporative systems), these systems reduce the air temperature by evaporation of water. Mainly the cooling units in residential building use electricity as main energy source.

Water Heating:

Also, named as domestic hot water, provides the occupants with hot water needed for all kind of uses like shower, washing etc. These are a variety of systems that are tank based or thankless. This system can also be combined with the space heating systems. Natural gas is usually the main energy source for the water heaters, then there are electricity and solar thermal energy that is being used increasingly in more countries around the world.

Lighting:

The total energy used to illumination purposes in interior and exterior of the residential units is considered as lighting. Today this is mainly provided by electricity. For more than a century incandescent lamps have been used for this purpose. These lighting bulbs are slowly giving their place for more efficient and low energy fittings for instance, LEDs, Fluorescent lamps and CFLs (Compact Florescent lamps). The regulations to use efficient lighting systems is passing in more countries by time. The off-grid lighting systems that are operated by the energy generated from solar panels will be more protruding in future.

Cooking:

This includes the energy used in household to prepare meals, the unit range from induction systems to three-stone stoves and ovens. The energy source they use are from natural gas. Electricity, biofuel, LPG (Liquefied petroleum gas) and coal.

Household Appliances:

The appliances used in residential units are split into two sets: the large appliances and the others. The large appliances are also called the white ones or white goods. The other categories are the other small devices and appliances. The white appliances are usually describing as bellow:

- Freezers and refrigerators
- Washing machines: dishes and cloths
- The driers
- TV systems (entertainment devices considered)
- Personal computers and IT equipment
- And others (vacuum cleaner, coffee maker, hair drier, microwave, etc.)

The shares of the end use in entire energy consumption of residential building is shown in the Figure 8 below:

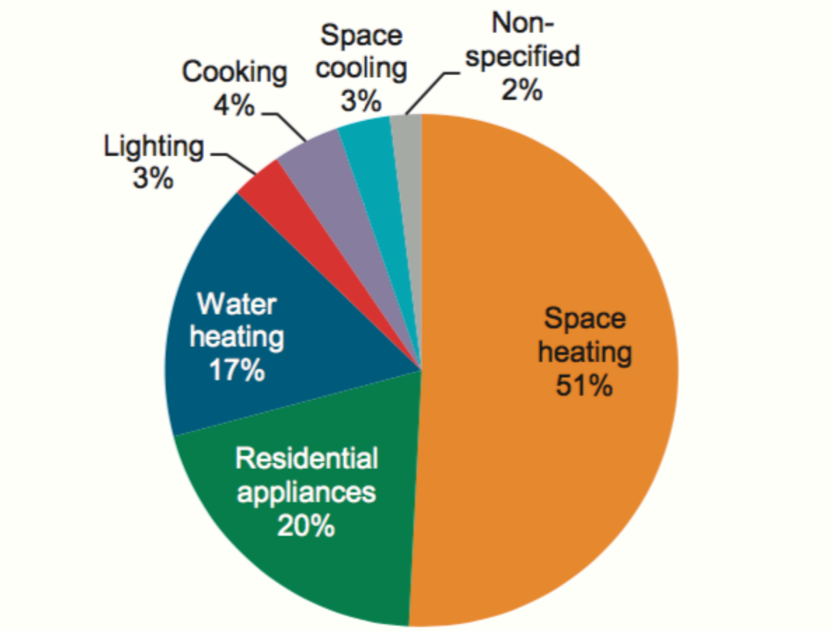


Figure 8: Residential units share in consumption by end use (IEA, 2017)

2.4 Energy Efficiency

Energy efficiency is the main basis for decreased energy use and evolutions to cost effectiveness, and all countries have the potential to take it into consideration. In order to lessen the energy bill, it is essential to take proper actions and apply strong policies covering energy efficiency goals which are reduction in air pollution, achieving security in energy sources, and escalation in energy accessibility (IEA, 2017). Enhancements and improvements in the energy efficiency specially for the purpose of space heating has happened in all the countries of IEA with employing better insulation, also enhancement is existing buildings by refurbishment of the old equipment and improvement in the insulation. These efforts have been tracked by IEA agency and have shown a considerable reduction in almost all countries. Figure 9 bellow shows comparison in consumption since year 2000 that shows up to 30% of reduction.

Figure 9: Energy per floor area of residential spaces since 2000 to 2014 (IEA, 2017)

Accordingly, through these improvements there are a series of benefit that can be achieved, among them the development in macroeconomics, the wellbeing and improved health of society, the increase in budget for people, the productivity in industries and the enhancement in energy supply (IEA, 2017). Following figure (Figure 10) illustrates some the benefits achieved by energy efficiency

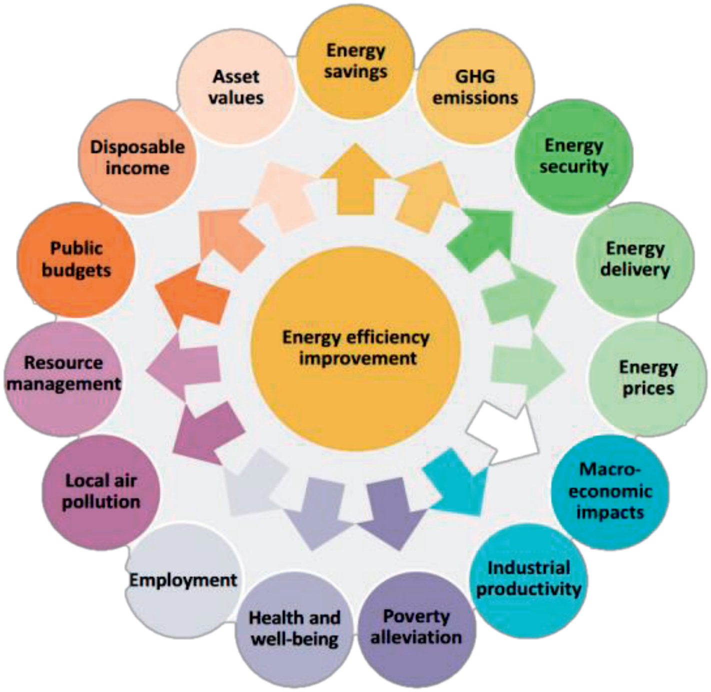


Figure 10: Multiple benefits of energy efficiency (IEA, 2017).

Chapter 3

ENERGY EFFICIENCY AND THERMAL COMFORT

3.1 Building Energy Efficiency

The increasing energy use in the building sector is closely related with the growth in population worldwide and consequently the growth of households and other buildings that is expected to grow more the 28% by the year 2035. The major consumers in builds are the HVAC units, the lighting fixtures and any electrically operated motors. Figure bellow shows the major end uses classification (mainly in US) for residential and commercial building sectors.

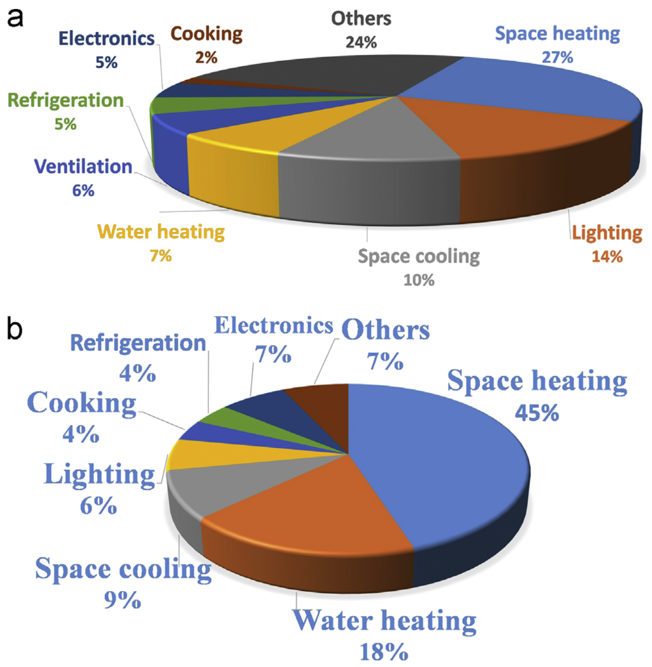


Figure 11: Energy end uses in residential(a) and commercial(b) buildings (U.S. Department of Energy2012).

Nearly 70% of the total building end uses are related to four end uses of space heating, space cooling, hot water supply and the lighting fixtures. The remaining 30 percent is due to the electronic equipment, kitchen equipment. The different approaches towards achieving energy efficiency in building can be divided in these basic groups (Diakaki, 2008):

- The building envelope: enhancements and improvements on insulation, the color of the material, low heat conductive window frames doors, shading elements, the thermal mass increase, the shape of building.
- The considerations to reduce the load on cooling and heating (Using passive approaches for heating and cooling, controlling the solar gain with measures like shading elements orientation, glazing types.)
- Utilization of the renewable energy sources (Solar radiation, PV panels, geothermal, wind, tide, hybrid systems.)
- The application of smart energy controlling and management systems like sensors and monitoring systems, control systems etc.
- Improvements in comfort levels for indoor areas along with reduction in energy needs (Improving HVAC systems, Maintenance of operating systems, Passive ventilation measures, Heat recovery systems, use of integrated systems i.e.: integration of hot water supply with space cooling)
- The application of efficient equipment and lighting systems (LED and CFL light bulbs, High efficiency electric equipment).

There have been many advancements and improvements in the field of existing buildings energy efficiency. The publications and researches show and suggest productive methods, techniques and technologies to assist in reduction of energy use in buildings and improvements in environmental conditions (Ruparathna, 2016). The components used in the building and the equipped systems are very important in total efficiency of a buildings. Below the approaches effective of the efficiency of building components will be discussed (Lombard, 2011).

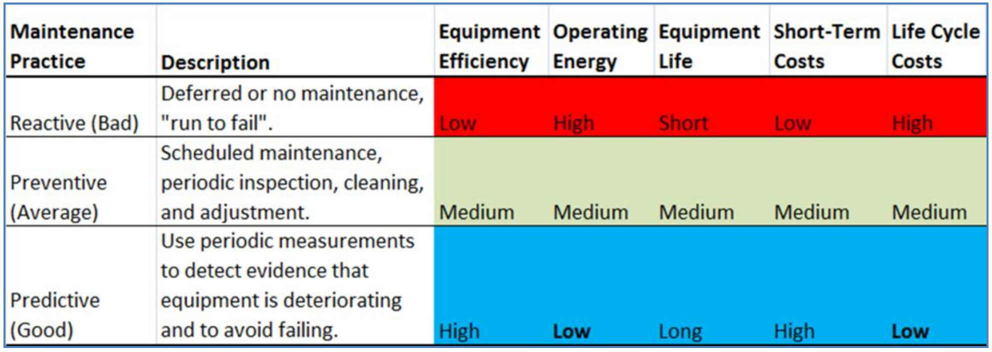
3.1.1 Heating, Cooling and Ventilation

The highest energy consuming items in buildings are HVAC (Heating, ventilation, and air conditioning) units. (Peters et al, 2008). The effective factor on the HVAC systems energy use is the temperature setting in indoor space, the window type and ratio and internal load. Additionally, all of these parameters are dependent to the type of the building and also the climate. Accordingly, increasing the efficiency in the HVAC unit reduces the energy usage in buildings considerably. (Lin H-W, 2013). Research has shown that the appropriate selection in the HVAC systems can reduce the energy usage in buildings up to one forth without disturbing the comfort conditions (Zhao, 2009).

Maintenance of the energy consuming units specially the HVAC system play an important role in buildings energy performance. Different maintenance patterns and approaches of the HVAC systems in buildings can lead to very different energy usages in them. The lack of sufficiently maintained will result in drastic performance degradation in the unit. For instance, not calibrated sensors in these units would cause the equipment to lose its ability to satisfy the thermal needs of the spaces. The maintenance regularities and approaches can be divided into three divisions. A) The Proactive maintenance that is referred to a monitoring of the unit efficiency and regular scheduled maintenance, here the problems and malfunctions are monitored identified and fixed before any breakdown happiness’s. B) The preventive maintenance approach that is consist of scheduled and regular maintenance of the units. In this approach a pre-determined maintenance are done, for instance replaced the filters in 6 months or cleaning the units every season. C) Reactive maintenance the is referred to maintenances that happen irregularly or none at all. This kind of maintenance is when the equipment is already broken, and are fixed due to complaints from the users. It is mainly happening in under staffed and underfunded facilities.

The following table shows the relation between these approaches in maintenance and the effects that have on, efficiency of the devices, operational energy, the life span of equipment, short term costs, and long term cost (Life cycle costs).

Table 1: HVAC systems maintenance types and consequences (Wang et al, 2013).



Maintenance Practice	Description	Equipment Efficiency	Operating Energy	Equipment Life	Short-Term Costs	Life Cycle Costs
Reactive (Bad)	Deferred or no maintenance, "run to fail".	Low	High	Short	Low	High
Preventive (Average)	Scheduled maintenance, periodic inspection, cleaning, and adjustment.	Medium	Medium	Medium	Medium	Medium
Predictive (Good)	Use periodic measurements to detect evidence that equipment is deteriorating and to avoid failing.	High	**Low**	Long	High	**Low**

The reactive maintenance approach results in low efficiency, and very high operation energy, and low maintenance expenses, but on the other hand high long life cycle costs. It also reduces the life expectancy of the equipment. On the other hand, the proactive maintenance approaches increase the efficiency of the devices resulting in lower operational energy and longer life expectancy of the devices and although the maintenance costs will be higher but the life cycle costs will be reduced.

3.1.2 Lighting

The building lighting appliances use 15% of the total building energy usage. Many approaches have been suggested by the researches to reduce the energy used by the lighting systems in buildings some which include the use of more efficient lighting systems, activity based lighting design and use of smart sensor for working areas. (Haq MAU, 2014).

One of the popular approaches in these days are the LED lighting systems that are very effective in reduction in the lighting energy use (Khan, 2011). However, researches show that there is a lack of knowledge in this area among building managers and users that need to be addressed for this approach to spread faster. Accordingly building administrators have to be informed more systematically about these approaches in order to adopt the building operations accordingly.

Another method in achieving energy efficiency in lighting equipment is the lighting control systems. While applying this method, there are some points to consider. Like the behavior of the users, the physical characteristics of the room, the amount of natural light penetration in the room and the activity in the specific area (Haq MAU, 2014). Furthermore, using the daylight sensors and implementation of daylighting efficient devices and lighting according to activity can reduce the energy for lighting needs up to 75% (Hinnells, 2008).

3.1.3 Building Envelope

The characteristics of the building envelope that are the fenestration, roof, walls, and foundation, along with the heating and cooling systems operation, are considered to have the biggest impact on the building energy use (Manioglu, et al, 2006). The building envelope is the main determinant in building indoor space conditions therefore, improving the insulation in building envelope, reduces heat gain and loss is and consequently the performance of the building is improved (Peng, 2014). Accordingly, a study done by Chua in 2010 and Chou show that the energy for cooling purposes in buildings is directly related to the insulation performance of the building envelope. The improvement in the material of the envelope is mentioned in many studies, for instance, the vacuum insulation material protects the building from heat loss and gain with an air tight layer. This type of panel has five times more efficiency than the usual insulation material (Roberts, 2008). The insulations can start as early as the construction phase, for instance the use of insulated concrete for the building structure will reduce the heat conductivity (Yun, 2013). The finishing material on building facade like the paint and plaster can be improved to increase the efficiency. Roberts in his study suggested the use of Nano technology painting material to improve the thermal performance of the building. These kind of paint materials have less heat conductivity features in comparison with regular paints (Roberts, 2008). The buildings that are exposed to wider temperature shifts during daytime and night time show better performance with exterior reflective coatings, while in areas with smaller range buildings with interior insulation layers work better (Haung et al, 2013).

In recent years, the use of double skin façade has been very popular among buildings. These façade systems help reduce the heat loss and gain also help improve the ventilation and humidity levels and at the same time help enhance the acoustical characteristics of a building. (Manz et al, 2008) ;(Zhou et al 2010). Some approaches suggest using Photovoltaic panels integrated with double skin façade systems in south facade of the building (Zogou, 2011). Shading elements, triple glazed windows, photo chromatic windows, ventilation glazing are among other elements that improve the building envelope efficiency.

3.1.4 Fenestration

The windows are among the most important heat loss points in building, to an extent which in a standard residential unit, 10-20% of the energy is lost through the windows (Roos, et al. 1994). The physical characteristics of the building fenestration is similarly a crucial factor in energy efficiency of the buildings regardless of the climatic factors. The ratio of window to the wall, the placement, orientation and the space depth are among these characteristics (Susorova, 2013). There is a significant potential in reduction of energy use in buildings in hot climates by applying changes in fenestration properties, but the same cannot be suggested for cold climates. Accordingly, many studies have focused on this subject to improve and enhance the fenestration in buildings. Some examples can be double glazing windows, triple glazing windows aero gels and etc (Roberts, 2008).

3.1.5 Shading

Shading devices and element are among the main passive approaches in order to reduce the cooling energy loads in buildings. The solar radiation can be controlled by implementing shading elements on certain part of the buildings. This approach can have positive feedback when applied to void areas of buildings that have the most level of transition of solar radiation inside the building. Shading devices and elements similar to other energy saving approaches and elements can be beneficial if they are used correctly and in the right time of the year, but they can be counter- productive if applied incorrectly. The it is necessary to have control on the shading devices in other to achieve thermal and visual comfort throughout the year. If applied correctly these passive strategies reduce the heat gain by the building and therefore less energy is consumed by mechanical equipment to cool the building. The main drawback of the shading elements is reduction of daylight in the spaces (Pacheco et al, 2012).

3.1.6 Orientation

Building orientation can be considered the most important factor effective on buildings solar passive design, which has to be considered from the initial phases of building design. The building azimuth and accordingly the orientation is the determinant of the solar radiation amount received by façade (Pacheco et al, 2012). The ideal building orientation have positive effects and benefits on buildings as follows:

- It can be considered as a low-cost approach in initial stages of building design towards building efficiency.
- It leads to reduced energy consumption in buildings.
- It can be a simple approach to avoid complex passive approaches.
- It increases the efficiency of other complex approaches.
- It increases the amount of natural lighting in more spaces of buildings therefore reducing the energy demand for artificial lighting.
- It can improve the performance of solar energy collectors.

It is usually agreed that the optimal orientation for rectangular buildings in order to have heat gains in winter and also control the radiation in summer is towards south. Generally, the largest façade should be facing to south direction. In another study in hot and humid regions it was concluded that the main glazed façade of the buildings should face south and if not possible south east to get the maximum energy efficiency (Shaviv,1981).(Table2).

Table 2: Energy consumption in relation with orientation. Source: Shaviv 1981

	Energy consumption at three orientations (kWh/year)					
	South	%	East	%	West	%
Heating	186	0	231	24	219	18
Cooling	281	0	286	2	369	31
Total	467	0	517	11	588	26
*T*max (°C)	26.4		26.6		27.0	

Figures bellow (Figure 12, Figure 13) show the building performances related to orientation in different shapes and angles. It shows that best orientation for rectangular buildings is the longest façade to face south side. But in square shaped buildings 45 degrees' rotation achieves the best performance. (Aksoy e al, 2006)

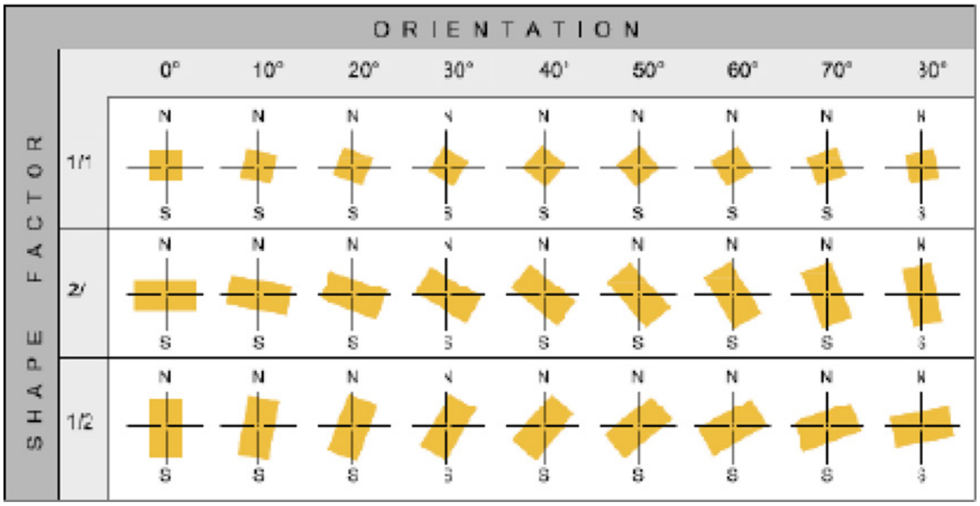


Figure 12: Shape factor and orientation (Aksoy e al, 2006)

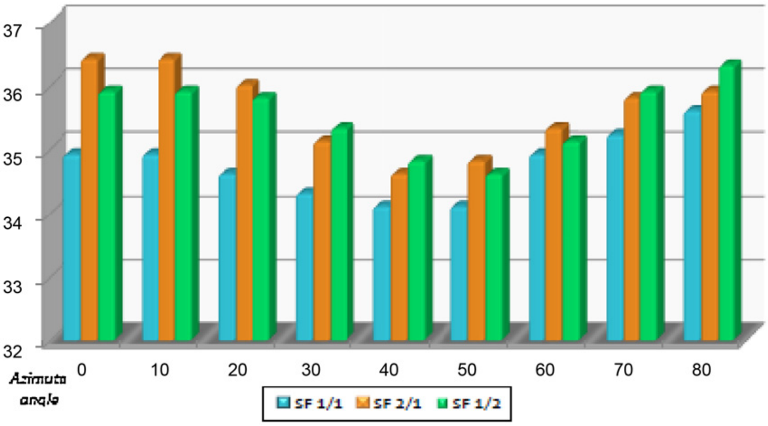


Figure 13: Annual energy saving according to orientation and shapes in previous figure (Aksoy e al, 2006).

Although most of the references on passive techniques and building orientation suggest the buildings should be facing to south, there are increasing agreements in different studies that the most optimal angle for a building to perform at maximum is 20-30 degrees from south side (Little fair, 2001).

The table below also shows different energy savings obtained from different orientation angles, it also shows that the best angle for overall energy saving is 30 degrees (Passive solar hand book, Vol 1).

Table 3: Energy saving according to orientation degree of a rectangular structure (passive solar hand book, Vol 1).

Energy saving ($/year)

Installation	Change in orientation (in reference to the south)		
	30°	45°	60°
Heating	29	26	36
Cooling	58	15	0
Heating, ventilation, and air conditioning (HVAC)	53	38	23
Total	140	79	59

3.1.7 Micro Generation Using Renewable Energy Sources

Renewable energy systems are very beneficial methods to increase the performance and efficiency of buildings. Integrated photovoltaic and thermal panel are popular choices in many buildings to both produce hot water along with electricity. They can be added to buildings as retrofits (Ibrahim et al, 2014).

Geothermal heat pumps or ground source heat pumps are one these systems that are both for hot and cold seasons and climates. A hybrid geothermal system can considerably reduce the heat generation of building (Sarbu, 2014) ;(Yang, 2010).

For the maximum reduction Co2 emissions and energy saving the best approaches are hybrid approaches that benefit from a combination of natural energy sources, but if the cost of such systems are the priority in decision making then the hybrid systems are the last and the solar heating equipment are the first choices the choice in renewable technologies mainly rely on these factors: reliability, installation costs and availabilities, maintenance, the ease of operation, environmental protection, technologies and the costs (Rezaie, et al, 2011). According to this study the it can be said that:

- For hot water supply the solar thermal panel are the lowest cost approaches.
- For electricity, the PV panels are most suitable.
- The geothermal energy and are very efficient and environmental friendly but the installation costs and also the regular maintenance requirements are the main challenges.
- The hybrid approaches are considered to be the most effective and better strategies in order to: reduce Co2 emission patterns and higher efficiency.

3.2 Occupant Behavior Concerning Energy Consumption in Buildings.

A considerable extent of building energy consumptions is caused by the building occupants interaction with the building and related behaviors. To tackle the urgent need for reduction of energy use in buildings globally, technological innovations and physical enhancements in buildings are very necessary but these innovations are insufficient by their own. Buildings are dynamic organisms and they have occupants that show complex and unpredictable behaviors. Accordingly, it is of utmost importance that the technological enhancements alongside with behavioral dimensions in energy consumption must be considered together to help achieve a low energy building profile (Gunay et al, 2013) ;(Blight et al, 2013). Recent studies have shown that the complete understanding of building systems alongside with the complex behavior of the occupants is very essential factor to fill the gap in the building energy efficiency sector (Bordass, 2004). Scientists in the field of social science have been studying the behavior of occupants in fields of user behavior, the user attitude, the consumption patterns of the occupants and etc. for decades (Sovacool, 2015).

Numerical studies and simulations on the occupant behaviors show that the users with waste full styles use double the energy of the other users in office buildings, this is where the users with attempts to save energy used half the amount in comparison to the standard user (Lin et al, 2013),similarly, studies have unveiled that the energy consumption in residential units is largely dependent on the occupants behaviors which is not related to a specific geography and is considered a global phenomenon. A research from Denmark shows that the energy consumption differs almost three times due to the occupant behavior differences compared to apartments in same building block with similar characteristic (Andersen 2009). Another research similar to this in Germany have shown an alteration with the factor of two in the residential sector (Calì, 2016). Furthermore, considerable amount of energy and even in some cases like offices more energy is consumed during none occupation hours than the occupation times. This is caused by the occupant's behavior, like, not turning the lightings off and not unplugging the equipment, and this is amplified with the bad building design like lack of sufficient control systems (Masoso et al, 2010). Although the ineffective engineering for the HVAC system and malfunction of the building systems and also shortcomings in the building façade account for poor performance in buildings, the occupant behavior is considered to be one of the main causes of the energy consumption gap in buildings. Studies similar to this matter in china has showed that the electricity consumption in different units of the same block vary up to ten times due both engineering and physical faults and also occupant using manners (Zhou, 2014).

This is also an important aspect in highly technological and well-engineered buildings. Buildings with high energy standards, low carbon emissions, net zero energy buildings and passive designs, which have the potential to use minimal energy and satisfy the comfort needs of the occupants, however, this is only if the buildings are operated exactly the way they were meant to be operated. Researches have shown that the knowledge and education of the building users in how to use the systems and operate the building to achieve the peak performance is highly crucial. Also, the occupant's anticipation and perception of comfort in the living environment is very important in this issue (Day et al, 2015). Turner and Frankel underlined this fact by saying "as technical performance standards ratchet tighter, behavioral factors gain relative importance”. Their study shows that the results from stimulations and prediction are not reliable (Turner et al, 2015). The differences between the buildings energy consumptions in simulations with real life results showed that every user acted and behaved differently while using the dwellings and which this is resulted from differences in understanding and functioning the building systems and itself.

Researches on occupant behavior are going on to show its importance on energy related issues, and which it is a fundamental part that affects the global energy consumption, that can fill the gap of the predictions done in simulations and numerical calculations and real life consumption of buildings, and that it is as important as the technological advancements (Hong et al, 2017). Hence it is very important to understand the occupant behavior in order to move towards energy efficient building with high-pitched performance and minimal energy consumption in both residential and commercial sector. Therefore it is important to recognize the energy using elements and settings for comfort to involve the users to interact with these systems (HVAC, set points) the building elements (windows, shading elements, etc), and the building appliances (plugs, lighting, etc.),(Masoso et al, 2010);(Chang, 2013).

3.2.1 Occupant Behavior and Characteristics

The occupant’s behavior is very crucial in the consumed energy. The main energy in buildings is used by the occupant not the building. The users are proactive behavers in the environment in order to suit the space according to their comfort desires (Janda, 2011). Therefore, the occupants consume energy while using the HVAC systems, appliances, lighting systems and hot water systems.

Occupant behaviors that affect energy buildings use can be separated in two categories. First is the adaptive actions and second are non-adaptive actions.

Adaptive

Humphrey’s principle states that ‘‘if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort’’ (Nicole et al, 2002). Accordingly, occupants and users of the buildings either take actions to change the environmental conditions to their preference and comfort requirements (e.g.: adjustments in openings, adjustments in blinds and shading elements, changing the settings in heating and cooling equipment’s, changing the lighting conditions) or make changes in their own conditions in order to adapt to environment (e.g.: Changing the clothing layers, or changing activity level).

Non-adaptive

The non-adaptive activities are the management of the plug load either in residential units or office buildings also reporting to the building manager relating the discomfort issues, if the building is being operated by managers and building operators which can result in reduction of energy consumption. The plug load can also be under the category of adaptive actions if they are used for heating or cooling equipment that can alter the building energy consumption. This kind of electricity plug energy usage is related to the comfort levels and preferences of the users and are completely entailed to the overall energy intake of a building. Occupants can also choose to take no action in case of the lack of appropriate systems (Deuble et al. 2012).

Occupant with their adaptive action in the indoor environment effect the building performance, specifically the environmental air quality and the energy consumption of the building over time. (Michael, 1998) Environmental conditions cause the users to make changes in the buildings elements and systems which then affects and alters the energy consumption pattern. Accordingly, the changes with the intention of the adaption by the users causes a perturbation in the indoor conditions. For instance, in winter season if a user opened the window to provide the desired conditions of comfort (either caused by over heating or un pleasant air quality) or even due to a habitual behavior (like opening windows when waking up or entering a space), both of these actions cause a change in the environment conditions and also the energy transition, this leads to the increase in energy consumption in order to replace the lost heat due to energy flow (Hong et al, 2017).

The influence of the occupant behavior on the building efficiency can be measured by two methods: A) by comparing the building performance of similar buildings with different occupant behaviors and B) using the building performance simulator with dissimilar occupant behavior data. Both of these approaches to get data either by direct investigation of behavioral influences or by computer simulations, are among advanced data quantification techniques (Hong et al, 2017). The data collection on the building occupant behavior is new subject in the building energy efficiency subject. The observation and measurement of occupant movement and presence, the interaction with windows and shades and blinds, implementing controlling systems for HVAC, lighting appliances and electrical plugs, are all getting more in the assessment of energy in buildings. For instance, researches have investigated an observed these systems to identify the relationship between the monitored elements like the closed or open windows, the position of shades, the features of the climatic conditions and indoor conditions like temperatures and humidity, the users and occupants behavioral pattern and the energy consumption rate. The data related to the behavior that affect the energy use can be collected with physical and none physical ways.

3.2.2 Behavioral Intervention

Understanding the real patterns of occupant behavior and the potential it offers to the efficiency in energy consumption is achievable by a multidisciplinary research both in physical and psychological research (Sovacool et al, 2015) ;(Steg, 2008). Despite the emerging concepts and emphasis on the correlation between occupant and the built environment, researches and building operators in most of the cases consider the technological approaches and overlook the approaches that include occupant behavior subjects (Sovacool et al, 2015). Therefore, tough full and conceptualized behavior, human interaction and impact on building and decision making processes have to be considered in building designs and behavioral modeling (Wagner et al, 2007).

It is to be said that the process of recognizing the behaviors and decision making process is difficult because of the complex nature of human behavior due to different characteristics of the users like cultural and habitual variances. For instance, due to different metabolic factors and biological differences and certain environmental factors it is difficult to predict a user’s comfort preferences (Holopainen et al, 2014). Thermal comfort can even be effected by social and psychological factors for instance the values, the beliefs, habits and social status that can also be a determinant for occupant behavior (Sovacool, 2009).

Occupants with behaviors towards energy efficiency have shown to be an economic and effective approach to reduce energy usage up to 20% in buildings related to the type of behavior mediation. Researches in different and various fields have defined 3 main areas to have behavioral energy saving approaches and actions: 1) Employing technical solutions which will enhance the building to us less energy using very efficient appliances. 2) Sociological strategies that encourage that emphasizes on behavioral changes that engage with energy usage. 3) Fostering socio-technical approaches which support the occupant behavior with the use of smart monitoring systems and demand control technologies (Hong et al,2017).

Technical Strategies

This strategy requires high amount of investment at first steps to change the old equipment with new and more efficient ones. In this approach the results are immediate, for instance by installing LED lighting appliances the electricity usage drops up to 60% due to their very high efficiency. The use of energy labeling in the past decade have had good influence on costumers to adopt to more energy efficient equipment (Guo et al, 2010).

The Sociological Approach (non-technical)

In this way of persuading energy efficiency, the sociological factors are involving. The use of successful campaign and emphasizing of peer comparison to improve and promote energy usage reduction is residential units is shown to be achievable (Cuddy et al, 2010).

Socio-Technical Strategies

This approach involves small amounts of investment to equip the buildings with support and the user's involvement (D'oca et al, 2014) These small investments are mainly to install the smart controlling systems and minimal technical infrastructure, and also some expenses to support the behavioral interventions i.e.: the monetary rewards. Very advanced building operation systems that include Human-in-loop smart control systems and HVAC set point systems have proven to reduce the energy on office buildings by 15-20 % (Baker et al, 2016). Also, another study confirms that these technologies can account between 16-20% of energy saving in residential sector in US (Frankel et al, 2013).

Considering the applicable strategies to change the occupant behavior toward a more energy efficient behavior, researches have divided these approaches from the last three decades into two general groups of **antecedent** and **consequence** strategies.

Antecedent approaches are strategies that include education and defining goals and also providing the facts and also resources and presenting examples of appropriate behaviors. **Consequence** strategies are the methods that have daily weekly or monthly feedback which also include the financial rewards systems. It is concluded by the researchers that providing the information alone is not sufficient to derive users to behave properly. Therefore, feedback and reward approach was a more successful strategy in energy reduction approaches (Hong et al, 2017). But the downside is that the effect of reward systems only worked until their discontinuation (Steg et al, 2009). So, they have to be continuous procedure or be replaced with something in similar approach (Sweeny et al, 2013) Identified economic and environmental factors as user's motivations toward more energy efficient behavior. Economic factors were recognized as the main motivation for behavioral changes and after that was the environmental concerns.

The determinants of the occupancy pattern are mainly the personal lifestyle, the preferences, the understanding of comfort, mindsets, the individual background and the physical characteristics of the building (Andersen et al., 2009; Schweiker and Shukuya, 2009). In a Danish study on behavior, the control of heating, mechanical ventilation and air-conditioning (HVAC) systems, and the indoor environment, Andersen et al. (2009) found that ventilation and heating behavior is influenced by, amongst other things, perception, gender, and ownership. A research in Japan (Schweiker and Shukuya, 2009) specify that the elements like experience, mindset, culture and origin determine the way the HVAC systems are operated rather that external influencing factors.

3.3 Thermal Comfort

3.3.1 Formation of Thermal Standards

One of the drawbacks of modern world is the extensive use and approval of employing mechanical power for achieving desired temperatures in buildings for their occupants. This fact has caused to considerable energy use in building sector, so much that one third of all fossil fuels are used in buildings. (Solomon. 2007). Hence, standards and limitations in thermal comfort act as control system to determine how buildings are to be cooled or heated (ISO 7730). In the means of finding a logical model that can identify people's preferences on environments thermal quality, there have been a lot of explorations and investigations done by researches in the physiological and thermal responses of people in several different situations. One straight forward definition for thermal comfort can be ‘‘that condition of mind which expresses satisfaction with the thermal environment" (ANSI/ASHRAE 55-2004).

Numerous scientific fields such as mechanical engineering, building structure and building physics, psychology and physiology are required in thermal comfort research field. There are three main motives for understanding the significance of thermal comfort (Nicol JF, 1993):

- Sense of satisfaction in people
- Balance and reduction in the energy usage

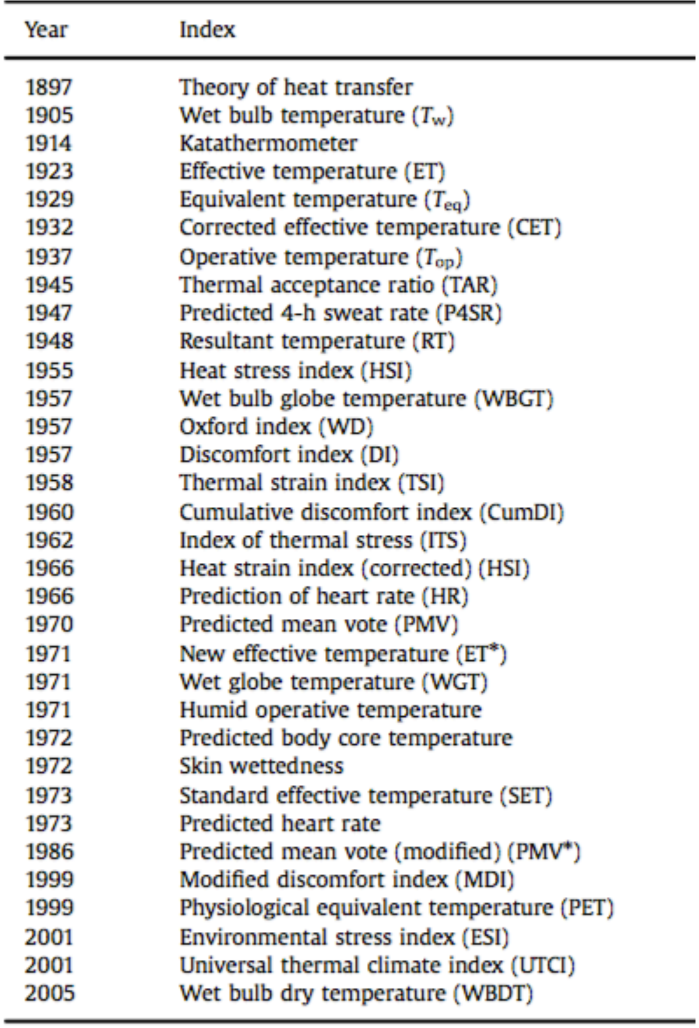
- To have the tools required to acquire standards

Additionally, six objectives were proposed by Raw and Osland for achieving information on thermal comfort (Raw and Osland, 1994):

- People to have control on environmental conditions
- The enhancement of air quality
- To reduce energy consumption
- Reduce the negative impacts on environment by reduction in CO_2 emission
- Enhancing the efficiency of the occupants
- Providing evidence in order to change regulations and standards

Thermal comfort is different according to the type of the space: outdoor spaces, semi open spaces and enclosed spaces, and is achieved through sets of parameters that work together both environmentally and in human body. The focus in this study is around the enclosed spaces. In 1774 the first concept in this field started by a British physician. Subsequently, scientists developed various guides related to this subject and today there are different standards for thermal comfort used in building sector. Determining the array of comfort conditions referred to as thermal comfort is a complex task which is closely related to personal and environmental factors. Thermal comfort in indoor spaces is mostly based around two separate models: steady state models and adaptive models. Steady state models are mainly based around Fanger's PMV and PPD calculation models and the adaptive models are the result of information and contradictions while studying the thermal comfort in real field studies. Table 4 shows a full list of the studies.

Table 4: List of solid state studies (Taleghani et al, 2013).



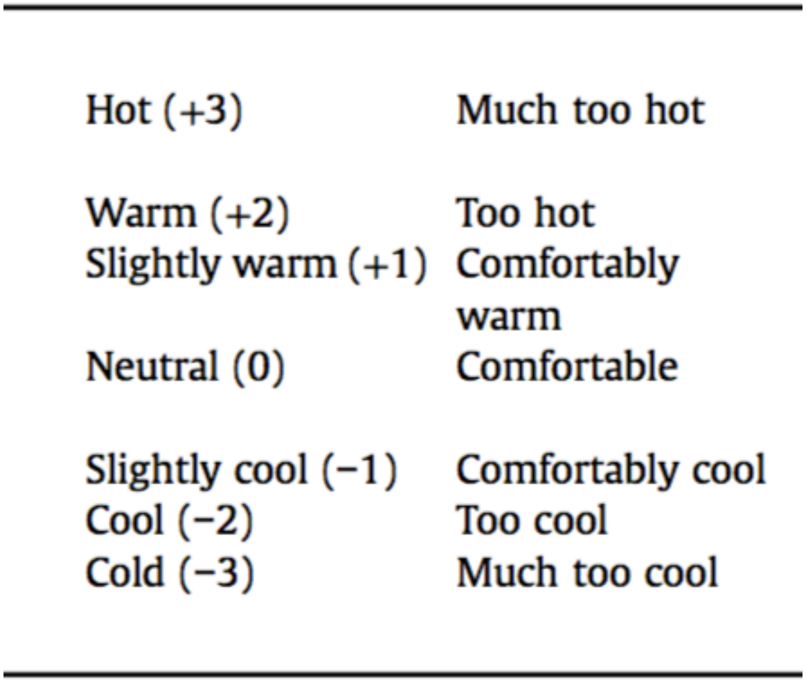
Year	Index
1897	Theory of heat transfer
1905	Wet bulb temperature (T_w)
1914	Katathermometer
1923	Effective temperature (ET)
1929	Equivalent temperature (T_{eq})
1932	Corrected effective temperature (CET)
1937	Operative temperature (T_{op})
1945	Thermal acceptance ratio (TAR)
1947	Predicted 4-h sweat rate (P4SR)
1948	Resultant temperature (RT)
1955	Heat stress index (HSI)
1957	Wet bulb globe temperature (WBGT)
1957	Oxford index (WD)
1957	Discomfort index (DI)
1958	Thermal strain index (TSI)
1960	Cumulative discomfort index (CumDI)
1962	Index of thermal stress (ITS)
1966	Heat strain index (corrected) (HSI)
1966	Prediction of heart rate (HR)
1970	Predicted mean vote (PMV)
1971	New effective temperature (ET*)
1971	Wet globe temperature (WGT)
1971	Humid operative temperature
1972	Predicted body core temperature
1972	Skin wettedness
1973	Standard effective temperature (SET)
1973	Predicted heart rate
1986	Predicted mean vote (modified) (PMV*)
1999	Modified discomfort index (MDI)
1999	Physiological equivalent temperature (PET)
2001	Environmental stress index (ESI)
2001	Universal thermal climate index (UTCI)
2005	Wet bulb dry temperature (WBDT)

Steady State Studies: These studies were applied in order to establish the solid-state thermal comfort data. These researches were carried out in special chambers that can replicate different climatic factors (Figure 11). In this method, the variables as clothing and metabolic rate are set by the task and are unchangeable. The reason is to stimulate the desired condition, and control unwanted elements that can affect the results (Heidari, 2000).

Figure 14: Climate Chamber to conducting experiments and gathering information. source: http://chatterbox.typepad.com/portlandarchitecture/2014/05/gz-brown-and-the-climate-chamber-.html

Climate chamber approach focuses on heat interchange course in human body. The classic approaches to thermal comfort models were based on the steady-state models established in 1970 by Fanger (Table 1 shows a full list of the studies). Fanger stated that the thermal comfort sense is directly associated with the skin temperature and the sweating rate which is a limited range. To achieve this model, he used results from a climate chamber that the skin temperature and sweating were observed from the users who voted the condition they were in as satisfying. (Peeters et al, 2009). He introduced theories about heat exchange in human bodies. He mentioned that human bodies try to have thermal balance. The PMV and PPD method was presented by Fanger to determine the comfort and discomfort of the occupants in a preset of environmental and physical variables. In this system, the thermal responses of users are quantified by asking their comfort vote for one of the rates from -3 signifying very cold to +3 specifying very hot as shown in Table 5, the equations Fanger proposed determine PMV of the occupants. The data driven from these votes enabled Fanger to develop equation that predict the responses of the occupants to a set of environmental and physical factors (clothing and metabolic rate) affecting comfort. The predicted percentage of dissatisfied (PPD) determines the number of users unhappy with the conditions. The users who rated outside -1 and +1 are considered dissatisfied with the conditions. It was with this studies and empirical studies that Fanger introduced the relation between PMV and PPD as shown in Figure 15 below. In this figure for the PMV of 0 which is predicted to be neutral shows 5 % of predicted percentage of dissatisfaction(PPD). What this shows is that it is almost unmanageable to satisfy everyone at the same time that are experiencing the same climatic factors. Consequently, with his method the ideal thermal comfort can be accomplished through the correct combination of clothing, environmental condition and metabolic rate. Standards like ASHREA 55 and ISO 7730 have used Fanger’s equations and principals in their models.

Table 5: Comfort scales in Fanger PMV equations (Peeters, 2009).



Hot (+3)	Much too hot
Warm (+2)	Too hot
Slightly warm (+1)	Comfortably warm
Neutral (0)	Comfortable
Slightly cool (−1)	Comfortably cool
Cool (−2)	Too cool
Cold (−3)	Much too cool

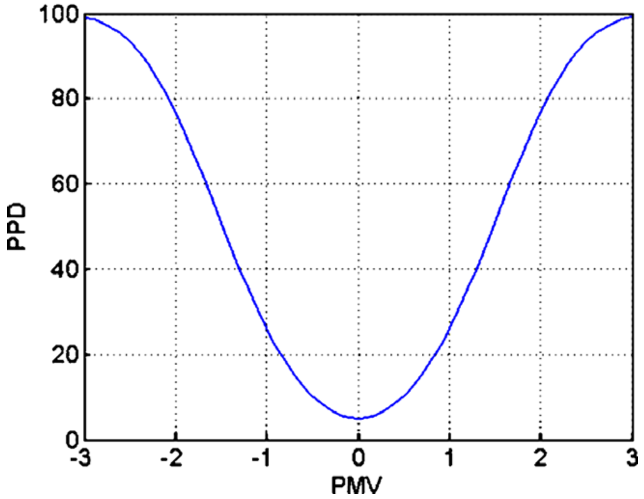


Figure 15: Predicted percentage of dissatisfied (PPD) as a function of predicted mean vote (PMV). (Peeters, 2009)

Fanger noted six factors that affect the thermal comfort rates. These elements set the basis for standards like ASHREA 55. There are six major characteristics that determine and influence the thermal comfort sensation: metabolic rate, clothing insulation, relative humidity, air velocity or air speed, air temperature and mean radiant temperature.

1) Metabolic Rate: It is the unit of energy flow rate in humans that is a result of chemical activities in the body that results in work and heat production. (ASHREA 55 ,2010). Every individual has a different metabolic rate according to their body and activity type and also the surrounding conditions. The unit to describe this is met units. According to this unit 1 met is equal to 58 watts per m^2, this is equal to energy produced by an average individual in resting and seating position per surface area of that individual. There are different ranges of metabolic rates for activities from 0.7(40 W/m^2) met for sleeping to 2.0-3.4(155-200 W/m^2) for house cleaning up to 7.8-8.6(420-505 W/m^2) for

wrestling.

2) Clothing: This refers to the insulation provided to the individual by the clothing layers. The importance is due to the effect it has on the great gain al loss of the body that can cause comfort or discomfort according to the environment conditions. Relative humidity and air velocity can effect the amount of insulation a clothing piece provides and can reduce its effects. The clothing insulation is measured with 'clo'. For instance, 1clo is equal to insulation of trousers, shirt and a jacket. The ASHREA standard provides a list of clothing 'clo' units to take into consideration while determining thermal comfort. According to ASHREA if the occupant has the freedom to adjust their clothing then an average clothing 'clo' can be determined in order to achieve comfort.
3) Relative Humidity: It can be described as the ratio between the water vapor in the air with the highest amount of vapor that the air can hold in it. Temperature and pressure is directly related to the amount of vapor water can hold in it. High humidity levels cause discomfort in since the evaporation of body sweet is reduced due to high density of vapor in the air and accordingly the heat loss of the body is reduced. Low humidity levels lower than 20-30% are also discomforting because they cause discomfort in mucous tissues. The suggested humidity level is between 30 to 60 percent in condition building.
4) Air Velocity: ASHREA 55 define the air velocity the average air movement that is exposed to body in a uniform manner.
5) Air Temperature: It is described as the average temperature of the space that the individual occupies. It is measured with a dry bulb thermometer; accordingly, it also is called as dry bulb temperature. According to ASHREA

55 three different parts of ankle waist and head are considered in this since they are position differently while seating or standing.

6) Mean Radiant Temperature: The heat transmitted from surfaces as radiation is defined as radiant temperature. This is closely related with the materials characteristics that determine the emissivity of them.

On the other hand, the comfort zone that is defined by the ASHRAE 55 standard is prepared according to the data driven from office buildings and the direct application of this standard to residential buildings is questionable. In office buildings, the user's activities and their amount of control over the environment is very limited while in the accommodation settings the range for the control and activities is much larger. (Hwang et al., 2009; Karjalainen, 2009).

Studies on Adaptive Models: The studies that are carries out to explore the thermal comfort in real conditions. In these researches the clothing insulations and also the metabolic rates of the users are recorded. The primary aim is to find out what the subjective responses of the users are best described with the combination of environmental variables. The fundamental factor that effect all the study is that the users have the ability to change the environmental factor so that they get to their desired comfort zone (Nicol JF, 1993). Fanger's equation were being used more in practice and accordingly it had a few criticisms about it:

1) clothing had an important role in resistance.
2) The user's activity and also their metabolic rate.
3) The unpredictable and changing nature of thermal condition.
4) The personal preferences and psychologies of users that can change the comfort levels for individuals. For instance, the ability of adapting or the user

expectation.

Hence, some researchers like Humphrey and Nicol tested the results achieved by steady state research in real world (Nicol JF, 1993). What they mentioned is that the thermal comfort temperature range is larger in real life experiments than what the models suggest, specially in naturally ventilated buildings. They showed the inconsistency between the field studies and the solid-state studies results. Humphrey by putting into consideration a series of different researches done in several years stated that the use of ISO7730 has caused a miss assessment of thermal comfort, since it did not consider the human adaption capacity for in thermal comfort. Similar result by investigating ASHREA standard surveys can be found (Taleghani et al, 2013). deDear and Brager have divided the studies and the result into two part: the naturally ventilate buildings and the mechanically ventilated buildings. They revealed the predicted models are much more close in the mechanically conditioned buildings, but in naturally conditioned buildings the predictions did not match accurately.

The adaptive theory is based on the notion that if changes in environment parameters causes a discomfort, the users can react to it in a way to get back to their comfort zone. (Humphreys MA, 1997). The field study approach how ever has come into formation of adaptive thermal comfort standards as American ASHREA 55 2013, EN5251 European standard and also Dutch ATG guideline. All these models and standards are used in a largescale in both practice and research inside their field (Taleghani, et al, 2013).

The two approaches of thermal comfort studies which are the chamber studies and the field studies as they were reviewed here are not two completely separate method of approaching thermal comfort, but as Parsons pointed, there is no "chamber versus field" situation in the research arguments, and these two approaches complement each other in order achieve a more comprehensive thermal comfort guidelines (Parsons, 2002).

3.3.2 Most Recent Developments in Standards

The international standard ASHREA 55 2013 is applied universally and accepted worldwide for indoor spaces comfort conditions. ASHREA 55 standard combines indoor thermal elements as air temperature, humidity, radiation, velocity with personal factors of clothing and metabolism in order to predict thermal conditions acceptable by majority of users as comfortable. ASHREA 55 before employing adaptive principals was very similar to ISO 7730. ASHREA assigned deDear and Brager in 1990s to run a specific research to gather information from a variety of field studies from many countries around the world (Figure 16) (Taleghani et al, 2013).

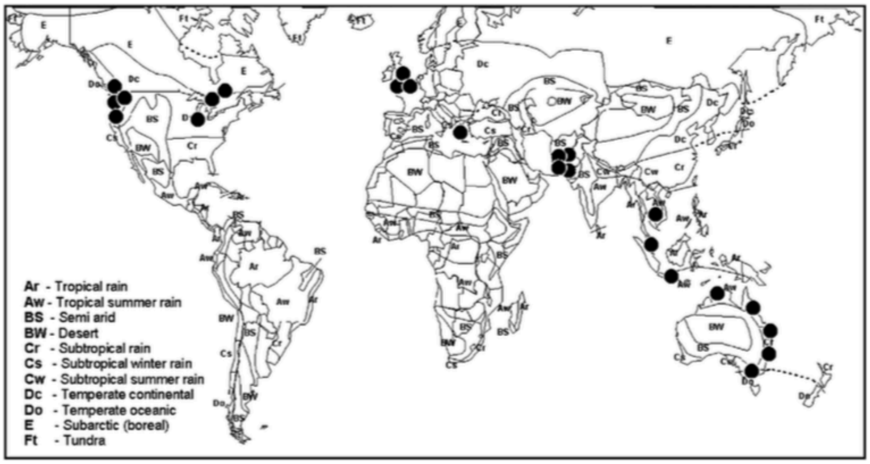


Figure 16: reagons that the ASHREA data are obtained for the standard.(deDear et al, 2002)

The study showed in naturally ventilated buildings the thermal comfort responses of the occupants is very related to the outdoor temperatures and is different from responses which come from mechanically ventilated buildings. The reason is the differences in thermal experiences and the clothing differentiations, the degree of control and different in user's expectations.

They were at first designed to be applied in mechanically conditioned spaces and their results were derived from thermal chambers by analyzing human body heat exchanges. Then a number of case studies on adaptive behaviors of the occupants have challenged the result of these standards when applied to the real world, and they have shown that the comfort is largely altered by the outdoor thermal conditions, user expectations and also cultural values. (Auliciems, 1981; Humphreys, 1978; Humphreys and Nicol, 2002). The current ASHREA 55 standard have been changed considering the results from these empirical studies that emphasize the importance of outdoor temperature in the comfort zone of the users in naturally ventilated buildings. The hypothesis of the adaptive approach says that the users have a certain amount of control over the environmental factors that are effective on their thermal comfort sensation (Brager and de Dear, 1998). Therefore, it is expected that the adaptive approaches would meet the human expectation of comfort in residential buildings where their active participation is an important factor. The participations are either personal behavioral adaptions or modifying environmental elements in order to achieve comfort. There are different approaches toward adaption that are related to each other and are influenced by one another.

Psychological adaption: Refers to the expectation of the indoor climate and the user experiences (Humphreys, 2007).

Physiological adaption: There are two separate subjects relating to this, one is the genetic adoption that is to genetically adopt the species for harsher climates, the other one is to change the bodies thermoregulation by constant exposure to thermal and environmental influencers (Brager, 1998).

Behavioral adoption and adjustment: That is all the action one can take to modify the heat loss or gain of the body in other to achieve the state of comfort and thermal balance. (Brager, 2002) These adjustments can either be personal, or cultural and habitual, and environmental (Fiala, 2001).

Thermal Comfort in Residential Buildings

The studies done previously on residential building show differences between the standards and the users responses. These differences are lower neutralities, the over estimation of the PMV and greater adaption than the predictions of the models (Becker and Paciuk 2009; Han et al. 2007; Wang, 2006; Ye et al., 2006; Peeters et al, 2009). There have been researches on thermal comfort and different studies for more than a century but these researches are rarely focused on residential buildings and the main extent of these studies are based on office buildings. Without considering that the A/C units have become one of the main electricity consumers in residential buildings, there have never been a serious research done over the air-condition usage pattern, the adaptive actions, and thermal comfort sensitivity in residential setting (Kim et al, 2016). One of the reasons for this is the difficulties in collecting data from the private houses. According to a study done in the University of Sydney in Australia in period of two years on residential buildings, they have achieved a comfort zone for the temperate cities of Sydney and Wollongong that both cities are among temperate regions, show 80% similarities with ASHREA 55 standard. This result as shown in

Figure 17 show lower temperature for minimum accepted temperatures and also lower results for maximum accepted and considered comfortable temperature. They calculated the temperature with the formulas bellow.

Upper 80% acceptability limit (°C) = 0.26 × $T_{pma(out)}$ + 21.25 (7)

Lower 80% acceptability limit (°C) = 0.26 × $T_{pma(out)}$ + 12.25 (8)

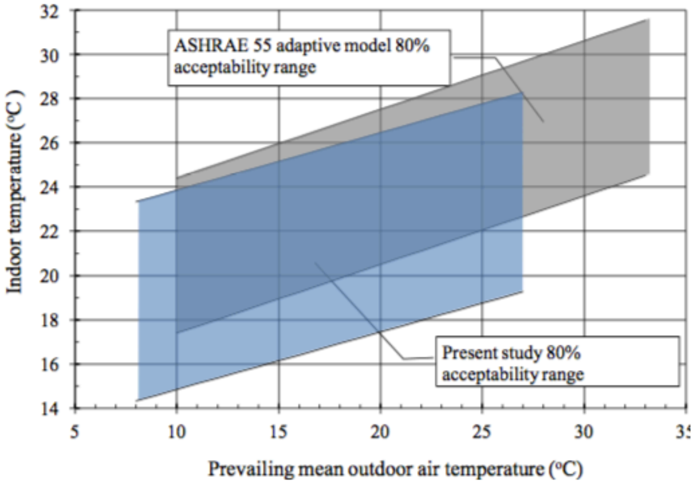


Figure 17: Comfort zone achieved for the residential sector (Kim et al, 2016)

Considering the data shown in Figure 18 from the same study suggests that outdoor temperatures between 22 and 28 are found to be the range that people use of mechanical energy for heating and cooling is below 20%. This figure shows that at around 25°C the use of natural ventilation is at its most and the mechanical energy use is at its minimum use. Accordingly, it seems acceptable to consider 20°C as the favorable outdoor temperature (Kim et al, 2016). This data can be used in systematical heating and cooling management in dormitories of Cyprus due to similar climatic characteristics of in both cases.

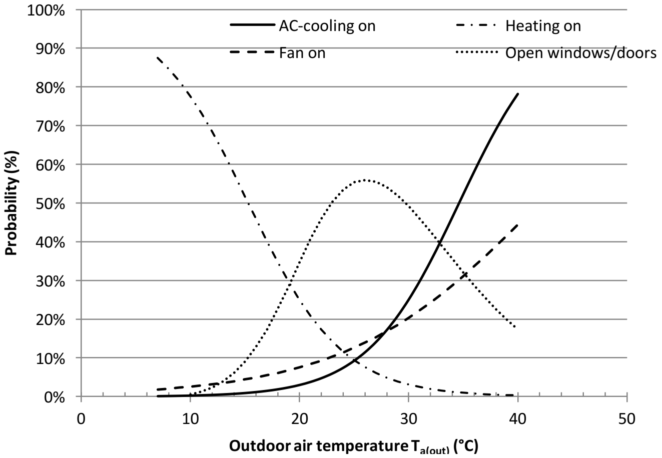


Figure 18: The expected percentage of adaptive strategies operational as a effect of outdoor air temperature (Kim et al, 2016)

3.3.3 Effects of Gender and Age on Thermal Perception and Comfort:

The thermal sensation among genders seems to be different. The studies have shown that women show more dissatisfaction in identical environmental conditions than men. (Karjalainen, 2012). There are some morphological differences among women and men, which can be explained as more surface area in woman and body segments than men, a smaller body size in comparison to men in average, also smaller body muscle, and more surface to mass relation. Additionally, the clothing insulation patterns have been observed by researches to be different. The differences are shown in different way one of them being different neutral temperature preferences that mainly is proved that women prefer warmer ranges than men, females also have shown to be more sensitive to changes in conditions, and that the dissatisfaction among women is greater. Also, some researches have shown that the comfort zone for women is a more limited range. (Mishra and Ramgopal, 2013) Females tend to prefer slightly warmer spaces than the male users (Indraganti and Rao, 2010). Due the lower acceptance of temperature among females they have more need in individual optimization and adaptive actions and controls.

Some other researches show differences in neutral temperature between young and old age groups. these differences in thermal sensations might be due to the differences in body fitness levels, morphological differences and weakening factors that come with aging (Mishra and Ramgopal, 2013). Older people tend to prefer warmer temperatures than the young generation and their thermal sensation in slightly lower, therefore the older building users are less tolerant to the changes in the conditions (Intraganti and Rao, 2010).

Chapter 4

FIELD STUDY

4.1 Cyprus

The island of Cyprus is the third biggest in the Mediterranean region, and it is very dependent to the energy imports mainly fossil fuels as oil and gas. The Eastern Mediterranean university is in Famagusta city that is one of the eastern cities in the island (Figure 19).

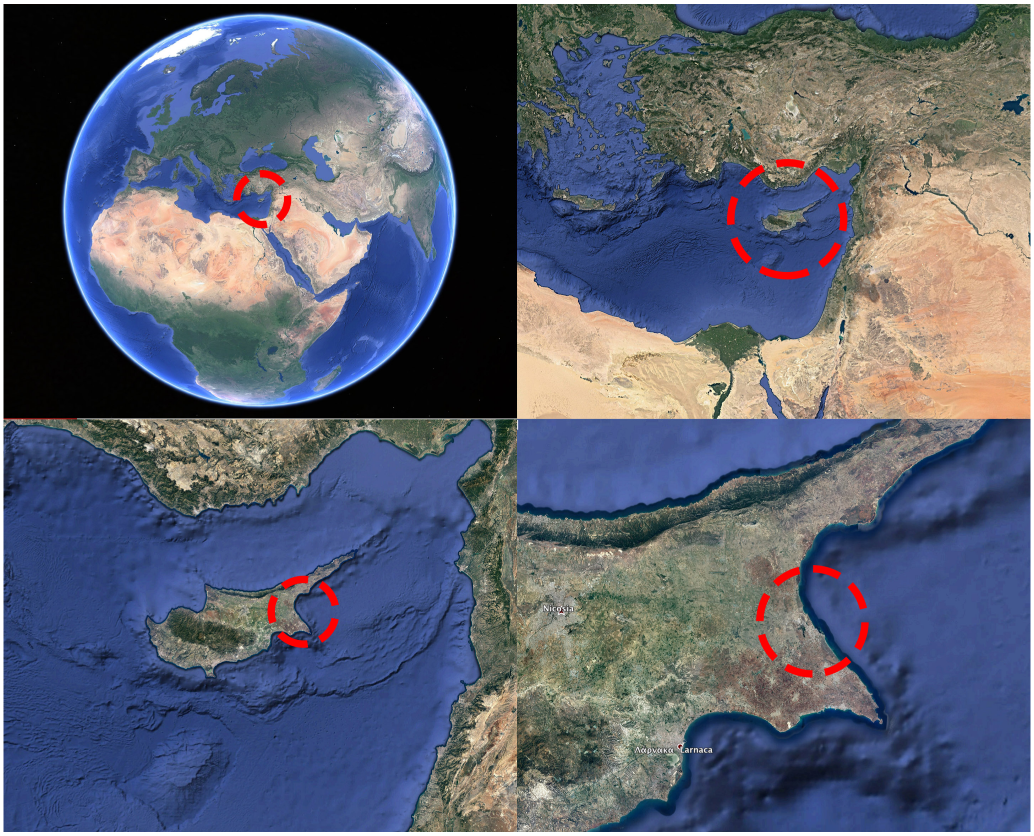


Figure 19: Cyprus and Famagusta map. Source: Google Earth Maps

KIBTEK (Cyprus Turkish Electric Authority) along with a private Turkish company AKSA produce and distribute the North Cyprus electric energy requirements from fossil fuels (Yenen et al, 2013). KIBTEK operates a 60MW power plant that is generate by steam and six 17.5MW diesel powered generator for peak time requirements. The AKSA on the other hand provide 92MW to the grid. There is also a 1.27 MW solar power plant that uses PV panels to produce electricity (Yenen et al, 2013). 20% of total imports in Northern Cyprus belongs to the import of petroleum for energy needs and all of the fossil fuels are imported to the island (Katirciogly, 2014).

Cyprus Climate

Cyprus is known to have very hot summers and mild winter in the whole Mediterranean region. The climate in Cyprus in considered to be subtropical in most of the island and semi-arid in the north-east part which is the Karpaz district. Winter and spring are the main rainy seasons in the island and summers are generally dry and hot. The snow fall in the island is only limited to highland which in this case is the Toroddos mountains. The annual average temperature is around 24°C maximum and a minimum of around 14C. As illustrated in the figures (Figure 20 and 21) bellow the warm season in Cyprus lasts around 8 month from April to November with average maximum temperature of 33 degrees. The relative humidity varies from 50% to 69% with its peak in February.

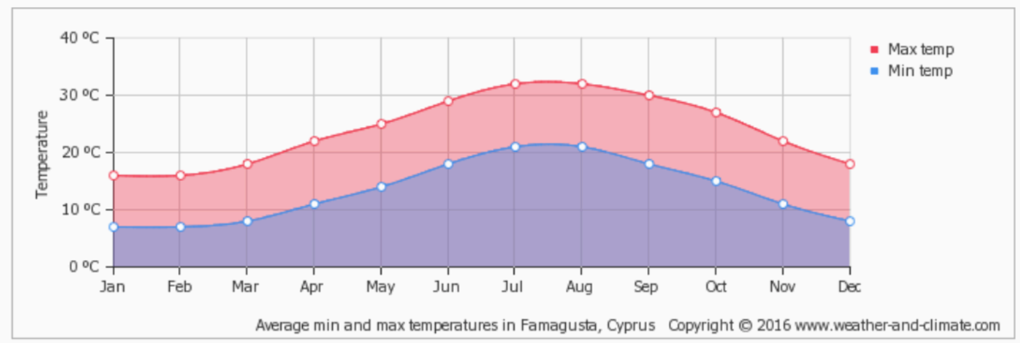


Figure 20: Average minimum maximum temperature in Famagusta (www.weateher-and-climate.com).

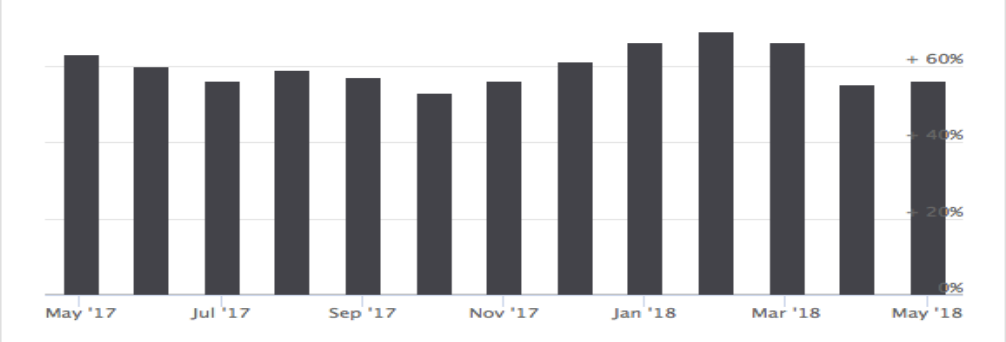


Figure 21: average humidity in Famagusta (www.weateher-and-climate.com).

4.2 Universities and Education in Cyprus

From the 1990's the educational demand has increased in Northern Cyprus, students from Turkey and all over the world mainly Middle East and Africa are traveling to Cyprus more and more every year. The main universities in Northern Cyprus are namely The Eastern Mediterranean University (EMU), the Near East University(NEU), The Lefke European university, Girne American University(GAU), the Cyprus International University(CIU), Middle East Technical University Northern Cyprus Campus(METU), The Istanbul Technic University(ITU) the Northern Cyprus campus and the University of Mediterranean Karpasia (UMK). Among these EMU is the largest and the oldest educational institute, starting its activities since 1979 (SPO, 2012). The population of the international students have been increasing continuously. The reason can be the internationally recognized universities and also accredited universities that positively contributes to the educational image of the island. Accordingly, the expansion in the universities infrastructures and also the accommodation and facilities for this ever-increasing student population cannot be unnoticed, and also this can and may be compared with international equivalents. This puts the high education in the Northern Cyprus position among the most important sectors that bring foreign currency and value to the country. This development consequently has resulted in increasing demand from his sector for energy. (Katircioğlu, 2014). The high education institutes use around 4% of the total energy end use in the island.

Energy Consumers in University Campuses

Main energy consumers in university campuses are divided into: electricity use in buildings, fossil fuels for the means of heating equipment (hot water supply) and fossil fuels for transportation means. The electricity with 60% of total energy use in the biggest category it's followed by 30% in the category of fossil fuels for heating purposes and 10% for transportation. As a matter of fact, the main energy sources in universities are electricity and fossil fuels (Katircioğlu, 2014).

Dormitories in universities are among the most important building units in the campuses. They accommodate considerable portion the students of the universities all around the year and have an important share of the total energy use. Dormitories accommodate a specific demography. This demography is comprised of young students mainly ranging from 18 to 24. Their living styles and behavior are influenced by their age and unpredictability. This study focuses on this type of building and demographic to find the weak points and try to improve them in the means of energy consumption.

4.3 Eastern Mediterranean University

Eastern Mediterranean University is located at the city of Famagusta in Turkish Republic of Northern Cyprus (Figure 22). It has been established in 1979 and since then it has attracted student from Turkey and all over the region. EMU plays a vital role in Famagusta economic, social and everyday life. In other words, it can be claimed that the Famagusta city that is known today is almost build around the university, and it grows in line with the university. Today there are around 20,000 students from 106 countries around the world in this university. And providing the accommodation for all these students. It is to say that the total population of the city is around 40,000, accordingly the student population is almost half the total population of Famagusta. This alone highlights the role of dormitories and student accommodation units in the city and EMU total energy consumption.

Figure 22: Eastern Mediterranean University campus. Source: Google Earth maps

4.3.1 EMU Dormitories

Eastern Mediterranean University has total of seventeen dormitories operating in the campus and more are already under construction. These buildings account for a considerable portion of the built structure in the university. The dormitories in the EMU campus are located at the Northern part of the campus. The space heating and cooling in almost all of the dormitories except a few is done by the use of split A/C units that operate most of the occupation period according to observations. The majority of these dormitories are constructed more than a decade ago. The main energy used for space heating and cooling is electricity (other than the emergency electricity generators that us fossil fuels) and for water cooling the main resource is gas, but there are some cases that use electric water heaters.

4.3.2 Dormitories Selected for the Study

Two dormitories are selected among 17 total dormitories of the university for this study are Kamacıoğlu dormitory and Prime Living dormitory (Figure 23). Kamacıoğlu dormitory is operating since 2005, it can accommodate up to 500 students at maximum capacity.

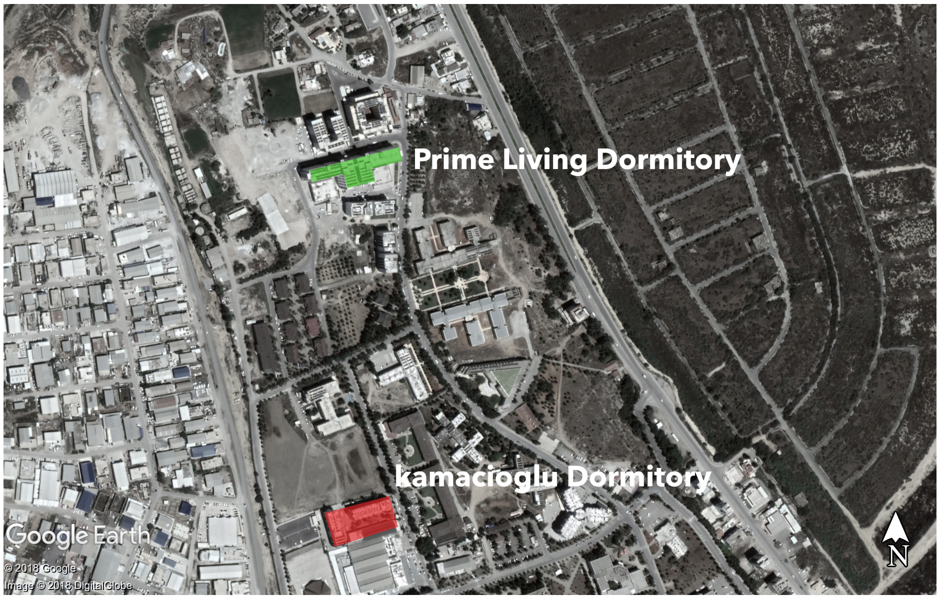


Figure 23: Satellite view of the dormitories selected for the study in EMU. (Google Earth maps)

The other is Prime Living dormitory is in operation since 2015. The Prime Living dormitory is selected because it is one of the latest student accommodation units built in the EMU campus and also it is popular and in high demand among the students. On the other hand, the Kamacıoğlu was selected among the other buildings because it is also one of the high demand dormitories and it is similar to many other dormitories existing in the campus that are build more than a decade ago. The two buildings have different characteristics that will be observed and put into discussion.

4.4 Data Analysis.

4.4.1 Observation and Interviews

The dormitories were observed to investigate the physical characteristics of the buildings as of mechanical heating and cooling systems and their maintenance conditions, the lighting facilities and types, the smart control systems if existing and similar issues bellow each dormitory observation result are presented and compared.

Kamacıoğlu Dormitory:

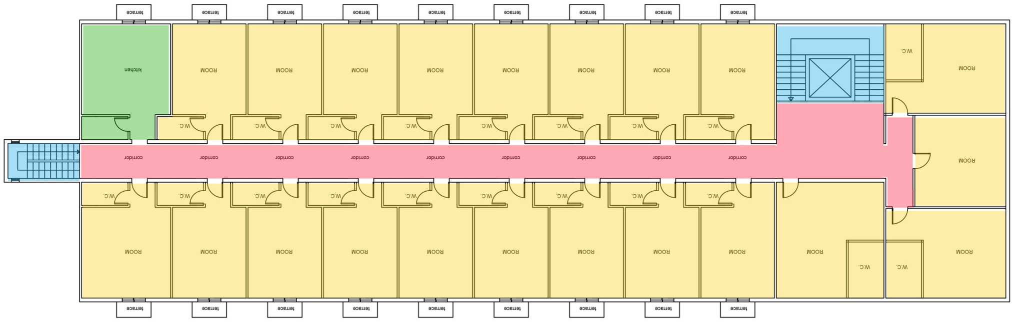
This dormitory is operating since 2005. The dormitory is consisting of 274 rooms which each one can accommodate two students. The complex is consisting of two separate six stories building blocks. The observations done in the dormitory can be divided into the following categories: 1) The building structure, envelope and orientation. 2) fenestrations. 3) HVAC systems. 4) Lighting. 5) Hot water supply. 6) Local energy generation, micro energy generation

1) The building structure, envelope and orientation: The building blocks are six stories reinforced concrete frame structures. The building envelope in conventional construction methods that includes brick and is covered with plaster and white paint wash with grey ant balconies and roof line. There are no layers for heat insulation and

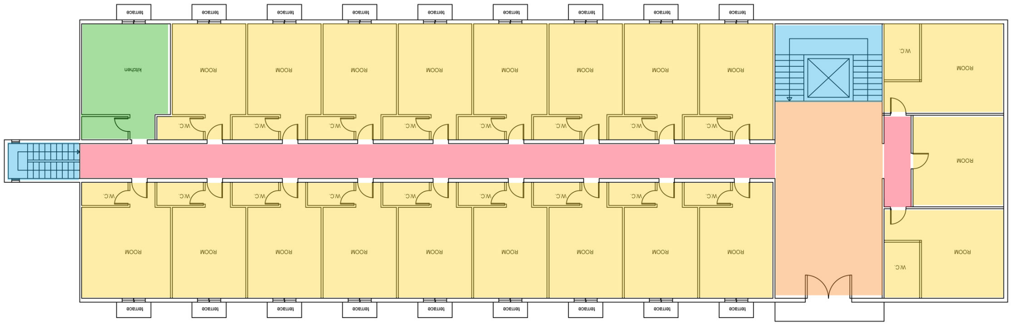
similar applications. The white paint in the facades as mentioned previously reduces the building heat gain rates in hot seasons (Figure 24). Also, as seen in the picture there are no shading elements considered in this facility, only the slight shading by the balconies may be considered only in the block A due to south orientation.

Figure 24: Kamacıoğlu dormitory Facade (Photo taken by author).

This dormitory is consisting of two blocks A and B. The typical plan layouts are slightly different in them. Each floor in block A is consist of 17 standard rooms and 4 larger suit rooms. Block b has 21 standard rooms with one suit in each floor. Each floor in both blocks includes one cooking area (Figure 25 and 26).



Typical Floor Plan

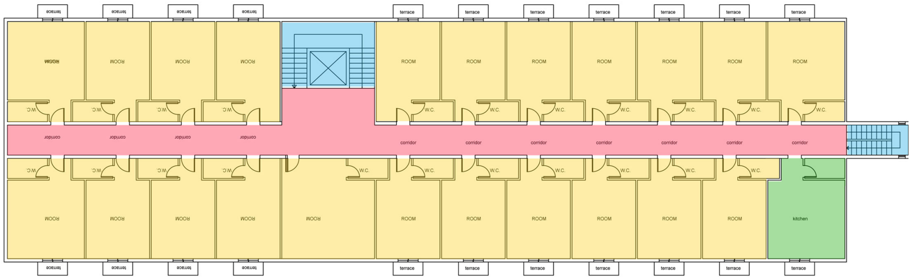


Ground Floor Plant

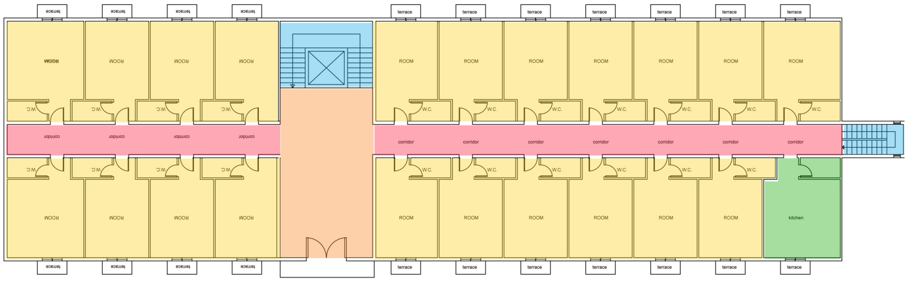
🟨 ROOMS
🟩 KITCHEN
🟦 VERTICAL CIRCULATION
🟥 HORIZONTAL CIRCULATION
🟧 LOBBY

Figure 25: Ground floor and typical floor plan of block A Kamacıoğlu dormitory

There are no study rooms or common areas considered in either of the building blocks. The plan layouts show dense organization of rooms placed along a long corridor with almost no natural light or ventilation in it. This suggest that the economical factor has been the main focus while the design. The students in this dormitory are not separated by gender and they are randomly placed in the rooms.



Typical Floor Plan



Ground Floor Plant

🟨 ROOMS
🟩 KITCHEN
🟦 VERTICAL CIRCULATION
🟥 HORIZONTAL CIRCULATION
🟧 LOBBY

Figure 26: Ground floor and typical floor plan of block B Kamacıoğlu dormitory

The orientation of the building blocks as show below are north and south in block A and east and west in block B (Figure 27). Accordingly, the block A south façade can benefit from heat gains in cold season and slightly in block B east façade is the first half of the day. The orientation of the Block A according to the researches is at the optimal orientation. While the Block B is not following the appropriate orientation to achieve maximum efficiency.

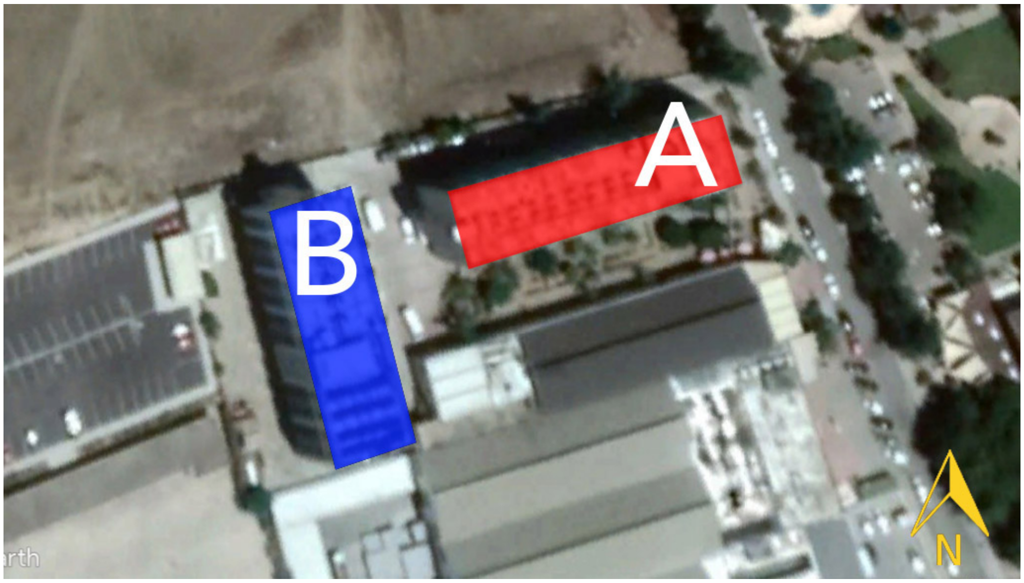


Figure 27: Kamacıoğlu Building orientation top view. (Google Earth maps).

2) Fenestrations: The windows for the rooms regardless of the building direction are 220.150cm double glazed with aluminum frame sliding windows (Figure 28). The windows provide the rooms with good amount of day time illumination during the day. There are no shading elements applied to the windows apart from the overhang of the balcony. The air tightness of the windows is sufficient and help reduce the heat transfer between the room and the outdoor environment, unless the maintenance of the windows is neglected. In some cases, that were observed in this dormitory this kind of neglecting were noticeable that reduce the air tightness of the rooms and flow of energy between the room and outdoor is increased.

Figure 28: Door and window types in Kamacıoğlu dormitory. (Photo taken by author).

The doors of the rooms that open to the corridors are 80.220 centimeters and are wooden material. The seals of the doors in sides are alright but the bottom are not sealed properly that causes the transition of air between the room and corridors (Figure 29).

Figure 29: Air gap in the Kamacıoğlu dormitory room doors. source : Author

3) Heating Facilities: Kamacıoğlu dormitory approach for space heating is the split air-conditioning condensing units. All the 274 of the rooms are equipped with separate units that are used for space heating in winter season, they are also used in summer season for the cooling purposes. Many of this units are operating since 2005 and only the completely broken devices are replaced. The observations have shown that the maintenance on these devices is neglected. The units don't get serviced until they are in none functioning condition according to the management of the dormitory. The investigations show the badly maintained units in most of the rooms, which lead the way to devices inefficiency in providing desired temperatures of the users and using extra energy to deliver the required performance. The maintenance approach according to the classification mentioned before is placed among the reactive approach.

4) Lighting: The lighting in dormitory block are for illumination of the lobby, corridors and rooms. There are also lighting for the open areas in the dormitory but the study will focus on the interior lighting equipment. The lobbies have been recently equipped with LED light bulbs which are turned on in the dark hours of the day. The corridors are illuminated with incandescent light bulbs. The lights are operated by motion sensors. The main issues in corridors according to observation are the low amount of illumination in of the light bulbs and the very short setting on the motion sensors which make the visual comfort distorted for the users. The rooms of the dormitory varied in the lighting type in use. The observation showed that traditional incandescent lamps from 60 watts to 200 watts, CFL light bulbs and also LEDs are being used in the rooms. From 40 visited rooms 8 were CFL, 4 LED and 28 incandescent light bulbs. (figure 30).

Figure 30: most of the lights are regular incandescent lamps. (Photo taken by author).

The bathrooms in the dormitory had CFLs installed originally, but later due to lack of replacement they have changed it to regular incandescent light bulbs mainly 40 watts.

5)Hot water supply: The hot water in Kamacıoğlu dormitory is provided by a set of solar energy heaters, a heat pump unit and the end a central gas combustion unit, and then delivered to room (Figure 31). The hot water is available all day long for disposal. The water energy waste from the heating point to the rooms according to the interviews is around 10 degrees.

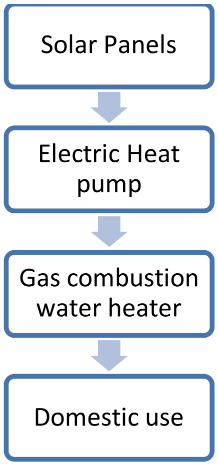


Figure 31: The hot water supply system sequence in Kamacıoğlu Dormitory

6) Local energy generation: Kamacıoğlu dormitory have solar water heating equipment fitted in the roof tops, they are used for hot water supply in hot season as seen in figure above.

Prime Living Dormitory:

1) This dormitory is eight stories reinforced concrete frame structure. The walls are brick and are equipped with water and heat insulation layers and are covered with white plaster (Figure 32).

Figure 32: Prime Living dormitory (Photo taken by author).

This dormitory is consisting of two blocks each block is 8 stories with 28 standard double rooms, one single room and two one plus one suit rooms for each floor in each block. There is one kitchen for each floor for cooking purposes. The common areas in this dormitory is the Lobby for both blocks and the study room is only at ground floor as shown in the plans that is very insufficient for the whole building. The plan organization of this dormitory similar to Kamacıoğlu is very dense with room placed along long corridors with minimum natural lighting and ventilation. The two blocks are divided by gender meaning that female and male are placed separately in each block, this can lead to different thermal requirements in each block (Figure 33).

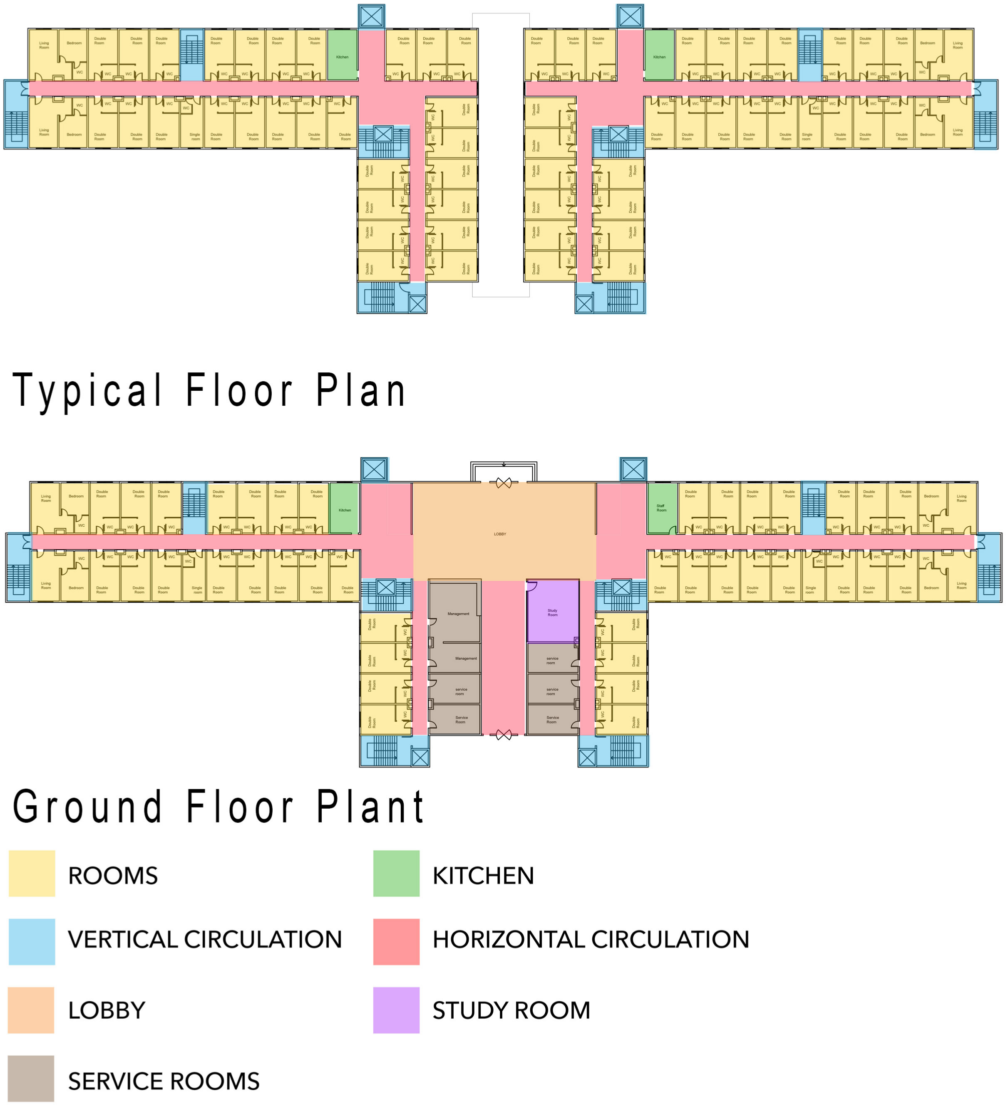


Figure 33: Ground floor and typical floor plan of Prime Living Dormitory

The orientation of the building longest facade block is south in some parts and east and west in another part as shown below. It is slightly angled toward the south and the room oriented toward south benefit from heat gains in cold season that is the main focus of the study (Figure 34). The rooms located at the part where two blocks meet are very close to each other that both causes lack of direct sunlight, and also loss of privacy.

Figure 34: Prime living dormitory building orientation (Google Earth maps).

In terms of shading elements there are no shading elements considered in the design and these dormitory is a somehow isolated structure and the surrounding building does not have and shading effect on it.

2) Fenestrations: the windows in this complex are double glazed aluminum frame windows in same sizes and dimensions regardless of the building orientation. There are also no shading elements applied to the openings of the building. The doors are wooden material and they are sealed properly in most cases (Figure 35). The windows are equipped with sensors that switched if the users open the windows and turn the heating or cooling equipment off in order to prevent more energy escape from the rooms to outdoor environment.

Figure 35: Prime dormitory doors and windows (Photo taken by author).

3) Heating Facilities: This dormitory takes different approaches in heating cooling and ventilation purposes in this dormitory. The dormitory uses multiple methods each for specific time range and purpose. The space heating in this dormitory is done by floor heating systems that uses hot water flow. The rooms are equipped with control systems which users can reduce or increase according to their needs. The space cooling needs in this dormitory is supported by a central cooling system (Fan coils) mounted in the roof this building that consumes electricity to cool the rooms in hot season. The central cooling system is serviced to insure maximum efficiency according to manager and since it is singular unit the maintenance and the observation over the functionality can be done easier in comparison to separate systems.

4)Lighting: According to the observations and interviews, all of the lighting appliances in the whole building are LEDs. The lightings in corridors common area are all equipped with smart motion sensors. The LED lightings in rooms are fixed to the ceiling and are not changeable with other alternatives (Figure 36).

Figure 36: The LED lighting fixtures in Prime dormitory, (Photo taken by author).

5) Hot Water Supply: As mentioned before the hot water is supplied by different methods: geothermal energy, solar energy and electricity. The heated waters are kept to be used in rooms and heating systems (Figure 37).

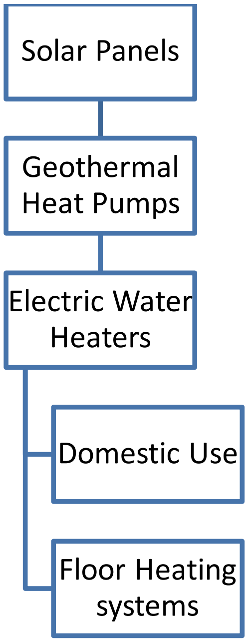


Figure 37: The hot water supply system sequence in Prime Living Dormitory

6) Local Energy Generation: The different approach that this dormitory takes benefit of is the geothermal heat absorbers equipped in this dormitory that gain heat from hot

water reservoirs deep underground. This heat is then absorbed by special mechanical equipment and used for different purposes, as providing the hot water for space heating equipment and also hot water uses of the occupants. To support these systems there are sets of solar water heating panel installed that heat the water and added to the circulation. All of this operation are controlled by software that can control, open and close the water circulation between these systems in order to gain the maximum performance. If the gained heat from these systems are insufficient the extra amount is provided using electricity.

Observation Outcomes:

The observations and interviews has assisted the study in order to reveal the weak points and positive points in the dormitories efficiency and energy consumption. These points are similar and also different among the dormitories; the following is a summary of these observations and interviews.

Both dormitories are similar in structure and fenestration properties and construction methods, but there is a difference in the building envelope of the two buildings and that is the exterior heat insulation that prevent the heat exchange between the interior and exterior in Prime dormitory. This leads to considerable improvement in the buildings thermal performance. The air tightness of the fixtures in both dormitories were observed, in the Kamacıoğlu dormitory the door opening to corridors are not completely air tight and lead to heat exchange between the rooms and corridors. The building orientation in both dormitories have some issues, in Kamacıoğlu one of the building blocks is in the worst efficient orientation and in Prime Living dormitory, a very close proximity between two parts of the block lead to lack of natural light and heat gains in cold season.

One of the main differences in both dormitories is the separation of genders in different blocks. This fact can help in better management the thermal requirements of each block since the preferences and thermal sensations are different among genders.

One of the major differences in both dormitories are HVAC systems. Kamacıoğlu uses split A/C units in each room that even according to the managers of the dormitories are not the proper choice for the building. On the other hand, the Prime dormitory uses central HVAC units (Fan coil) that uses cold water circulation for cooling in summer, and the heating is done by floor heating systems that according to managers are operated by water degrees around 33 degrees celsius. This water is heated using geothermal heat pumps and solar heating equipment.

The lightings in the dormitories were different from each other as well, Kamacıoğlu did not have a unified lighting approach and mostly the appliances were incandescent low efficient light bulbs. On the other hand, the Prime dormitory operates entirely on LED light that are fixed and unchanged able, which this leads to great savings in the lighting energy of the buildings.

The hot water supplies in both dormitories is partially done by solar energy and partially by other equipment. In prime dormitory, the geothermal energy is used to along with solar energy to heat the water, and if required electricity water heater also fill the gaps. In Kamacıoğlu the extra heating requirements are done by heat pumps (electricity) and gas combines. The heated water in Prime dormitory is also used to heat the rooms by floor heating equipment and helps reduce the extra electricity consumption by the building.

the observations showed different decision making and the effects of these approaches over the overall performance of the buildings. Also, it has shown the importance of professional and correct management in the building operation and maintenance of equipment that lead to higher building efficiency and therefore much lower energy consumption rates.

Interviews:

A set of questions were asked from the dormitories management to clarify subjects relating performance of buildings and also the occupants, the results are presented below:

Difference between academic year and summer in occupation of buildings:

The Kamacioglu management mentioned that the dormitory in academic year was completely occupied but in the summer the percentage of students remaining is less than 20%.

The Prime living dormitory management also responded that the number of students in the summer is around 20% compared to academic year.

The peak energy usage time:

Kamacioglu mentioned that the peak energy season for them is the end of first semester of academic year.

Similarly, prime living dormitory peak energy use was in January and February months.

Building energy efficiency approaches:

The Kamacıoğlu dormitory mentioned that there has not been any serious attempt to achieved energy saving other that the LED light bulbs that due to their in appropriate lighting characteristics they were all changed by the student themselves. Also, they had installed electricity control systems but due to competition among dormitories the decision has been made to give the students free energy with no limits.

On the other hand, the Prime Living dormitory mentioned that they have installed LEDs in entire building, they are using smart sensors in windows and also motion sensors. The electricity is limited for the students to 1500 Kilo watts. They also mentioned that the decisions upon the selection of heating and cooling units have been in a way to achieve efficiency in energy usage.

The misbehaviors observed from the users:

Kamacioglu management mentioned that the users keep the rooms electricity consuming units like HVAC and lighting operating while away. The rooms are equipped with card systems to activate the electricity by almost in 80% of them the student have placed a permanent card to keep the power available at all times. They also mentioned that the users open windows while the heating equipment are still operating.

Prime living dormitory management also mentioned similar problems in the room electricity cards and operation of the rooms. They mentioned that since the window are equipped with sensors the heating equipment turn off when they windows are opened.

Approaches towards renewable energy use:

Kamacıoğlu dormitory mentioned their use of solar radiation in hot water supply in limited times. They also mentioned the probable future plans to invest in PV panels to produce electricity.

Prime living dormitory mentioned the solar hot water supply along with the use of geothermal heat pumps for hot and cold water supply.

Maintenance of the building equipment specially HVAC units:

Kamacioglu dormitory management said that the maintenance of the Split A/C units are not done regularly due to high cost of maintenance and lack of professional staff. they mentioned that they prefer to change the whole machine after the breakdown.

The Prime living dormitory management mentioned that all the systems are maintained and repaired regularly in order to achieve maximum efficiency.

4.4.2 Questionnaire Survey

To gather information about the occupant's characteristics (Age, Gender, Status) and their behavioral action in the dormitories a set of questionnaires were prepared and distributed randomly in both dormitories among 20% of the sample population. The questionnaire is comprised of 20 questions that first four of these questions are asking the respondents about their gender, age, nationality and status. Following them there are questions asking them about their occupation pattern and the HVAC units using patterns in question 5 to question 10. Then there are questions about the direct sunlight penetration to their room and its time and duration. There are a set of questions designed to understand the occupant's intentions towards opening window for the ventilation purpose and their and if they consider the issue of heat loss and gain while doing so and the operation of the HVAC units while opening the windows. Similar questions are also asked about the use of lighting equipment to measure their actions. The respondents are also required to answer question about their awareness about environmental crisis and energy saving and also intentional actions in terms of saving energy. Finally, two question were designed to gather information about the clothing pattern and insulation of the users while they are in their rooms. The questionnaire can be found in Appendix A. The result from these questionnaires in both dormitories are presented and compared bellow:

Questionnaire Results:

The results from the first part of the questionnaire show that the dominating age for the occupants is between 18 to 24 followed by 25 to 30 years of age. In the study population sample the 18 to 24 age range were considerably larger in the Prime dormitory respondents in comparison to Kamacıoğlu dormitory as they are illustrated in the figures below (Figure 38,39). The young majority of the dormitory occupants makes dormitories slightly different from other accommodation buildings. Younger generations tend to show unpredictable habits and not mature behaviors more than the older users. This special user types make Dormitory building typology to focus on and requires approaches more focused based on the young generation.

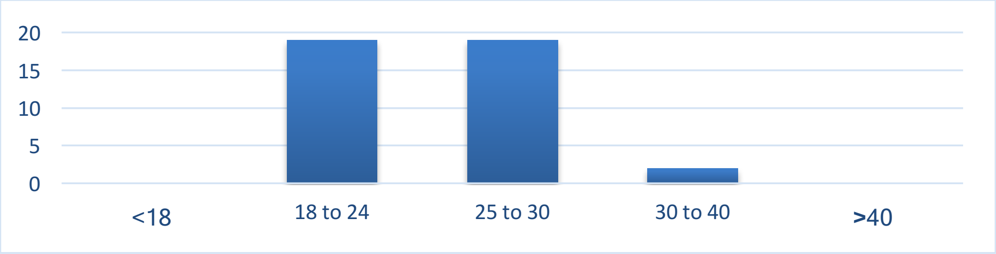


Figure 38: Kamacıoğlu dormitory age range. source: author

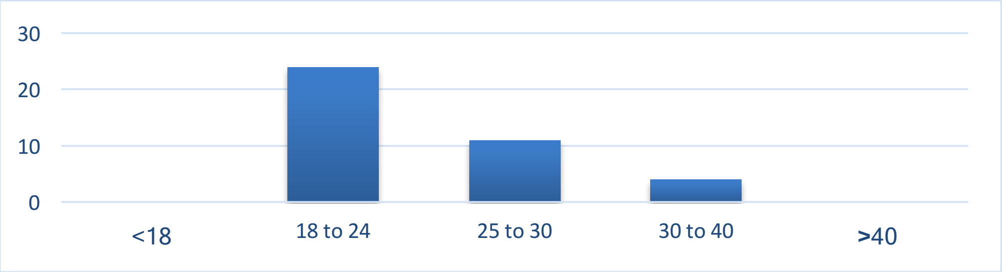


Figure 39: Prime dormitory age range. source: author

Regarding the Gender in the dormitories the result show very close percentages in both dormitories, but in prime dormitory female students are slightly more in comparison to Kamacıoğlu dormitory as show in the charts in Figures 40 and 41.

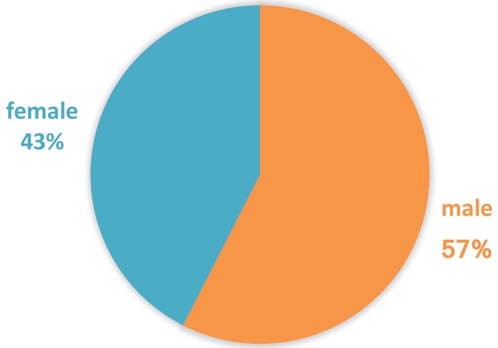


Figure 40: Gender in Kamacioglu dormitory respondents.

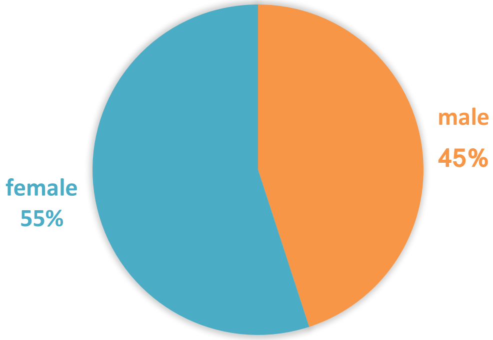


Figure 41: Gender in Prime dormitory respondents

According to the questionnaire respondents most of the students around 75% are studying in undergraduate level followed by postgraduate students as shown in the charts in Figures below.

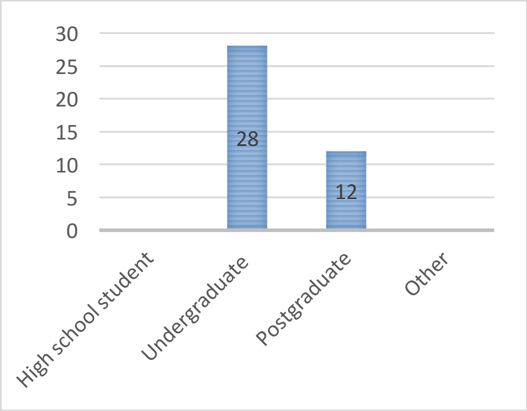


Figure 42: Kamacıoğlu student status. Source: author

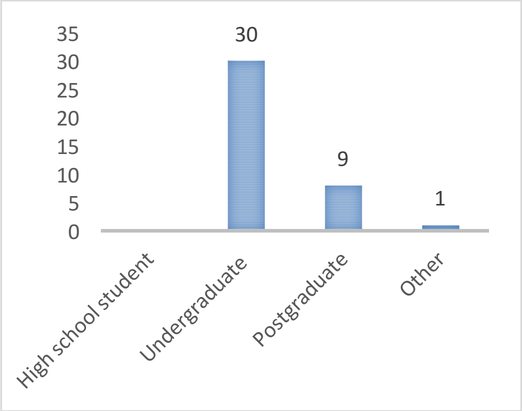


Figure 43: Prime dormitory student status. Source: author

The data driven from the result of the questionnaire show the occupancy pattern of the respondents from each dormitory as illustrated in Figures 39 and 40. Almost all the respondents have mentioned their presence at night time and afternoon and evening are the least occupied hours in the dormitories according to the survey. Half the respondents from the dormitories mentioned that they are at their rooms in the mornings around a quarter of the respondents from each dormitory mentioned their existence in their room in afternoon, and following that around 15 respondents from each dormitory mentioned their presences in the evenings generally. The figures below show the results in more detail.

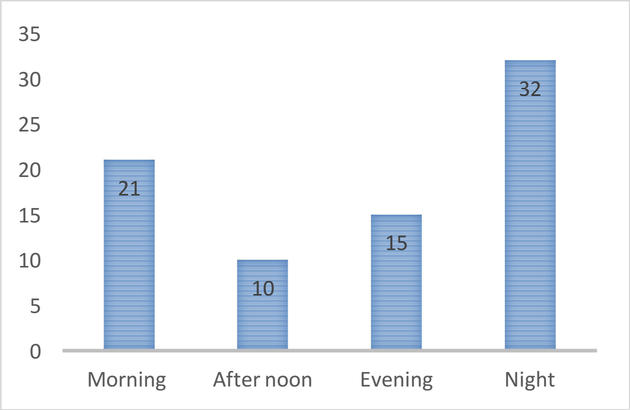


Figure 44: the occupation time rages of Kamacıoğlu dormitory respondents. Source: author

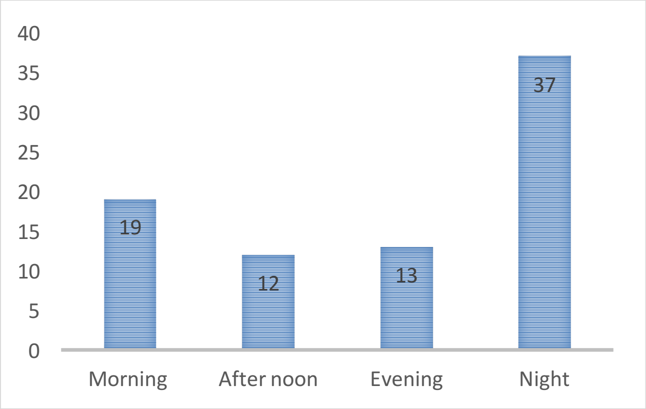


Figure 45: the occupation time rages of Prime dormitory respondents. Source: author

The result suggests that the slightly more energy usage in the dormitories is in the mornings and the night time since the majority of the students are present in the room at that times. But there are other factors to be considered, researches have shown as reviewed in this study that comfort temperatures while sleeping are slightly lower or in one of most occupied hours of the rooms which are morning the orientation of room that get sunlight should require less active heating to get the desired temperature.

The further survey results show that the respondents frequency in operating the air conditioning units. Almost 90% of the respondents from both dormitories answered to this question as ‘always’ and ‘usually’. This finding emphasizes on the major role of the HVAC units in energy consumption of buildings as it was reviewed in the literature review which point to the fact that main energy in the buildings are used to space heating and space cooling. The data as shown in Figures 46 and 47 show the results.

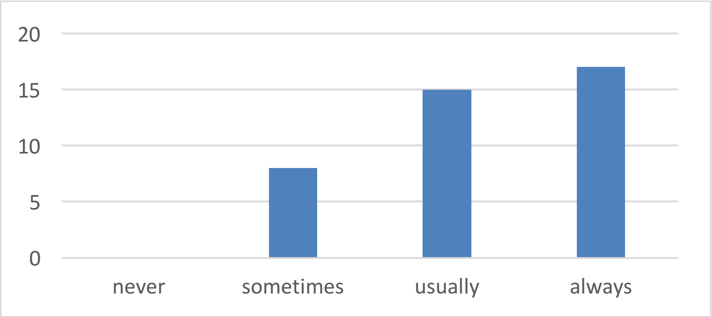


Figure 46: A/C usage pattern in Kamacıoğlu dormitory. Source: Author

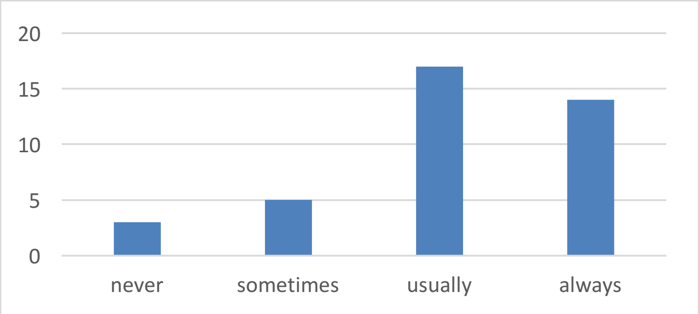


Figure 47: A/C usage pattern in Prime dormitory. Source: Author

Further the respondents were asked to mark the period of the day they most likely use the A/C unit of the room, the figures driven from the results clearly show the equal distribution of the usage time between the determined ranges. Only the night time is slightly mentioned more than the other choices (Figure 48,49). This finding emphasizes on the importance of night time A/C usage of occupant in the rooms. Some researches in the field of thermal comfort has found that the thermal comfort temperature while sleeping is lower than regular times.

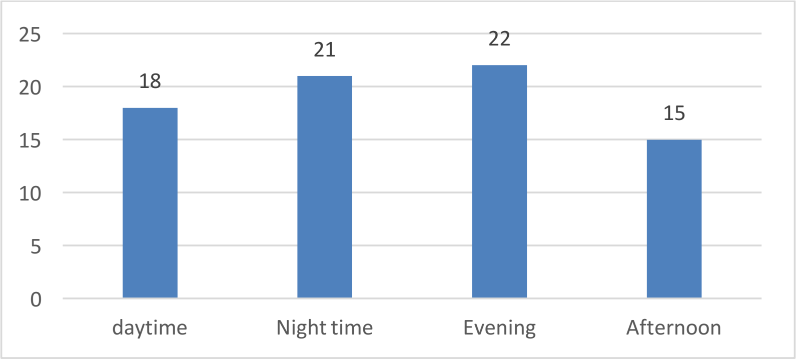


Figure 48: A/C usage time in Kamacıoğlu Dormitory. Source: Author

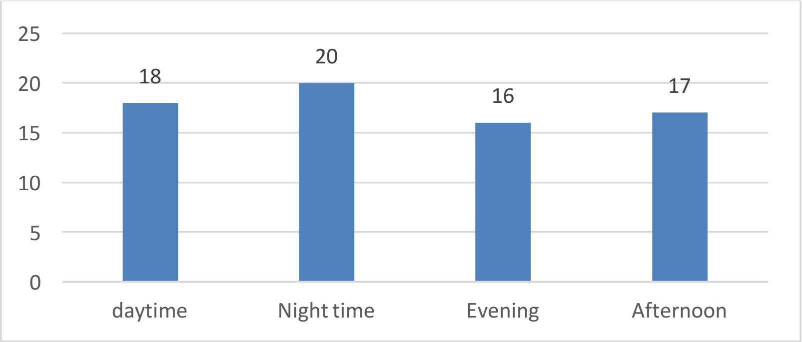


Figure 49: A/C usage time in Prime dormitory. Source: Author

The favorable temperature asked from the users are 21-23 and 24-26. The figures. The result show the higher popularity of the 24-26-degree range for favorable temperature in the dormitory users (Figure 50,51).

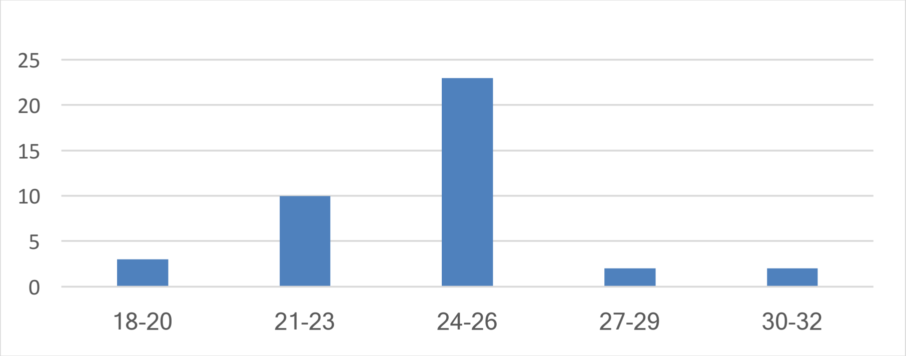


Figure 50: Favorable temperature as mentioned by Kamacıoğlu dormitory respondents. source: Author

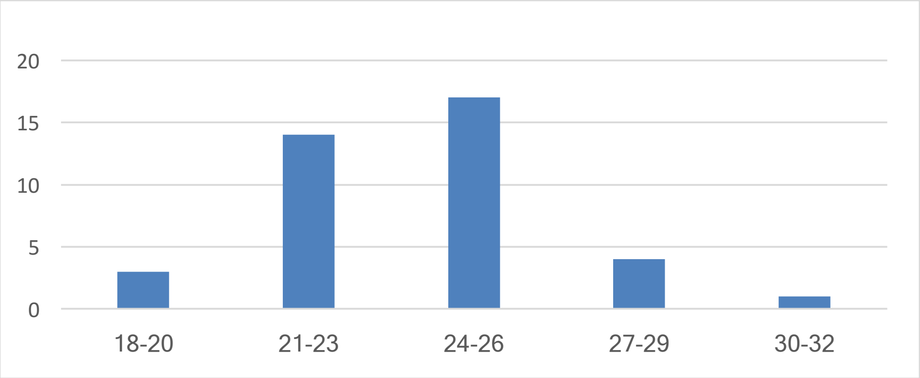


Figure 51: Favorable temperature as mentioned by Prime Living dormitory respondents. source: Author

Following this question the respondents were asked to mark their setting on the A/C units for winter and summer seasons. The results in Figures 52 and 53 show that the settings are almost at the maximum capacity both in winter and summer season. The temperature set by the users in A/C unit for summer season is 18-20 that is almost the maximum capacity for space cooling devices. The same is almost true for winter season setting that is set by the users to the upper capacity limits of the units. This can also be related to the low maintenance of devices to provide the desired temperatures. The favorable temperature as shown in figure bellow is different than the settings on devices.

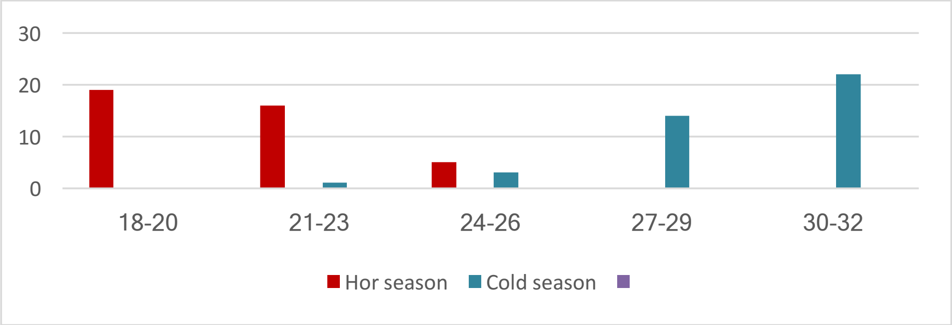


Figure 52: A/C unit settings in Kamacıoğlu dormitory in hot and cold season. Source: Author

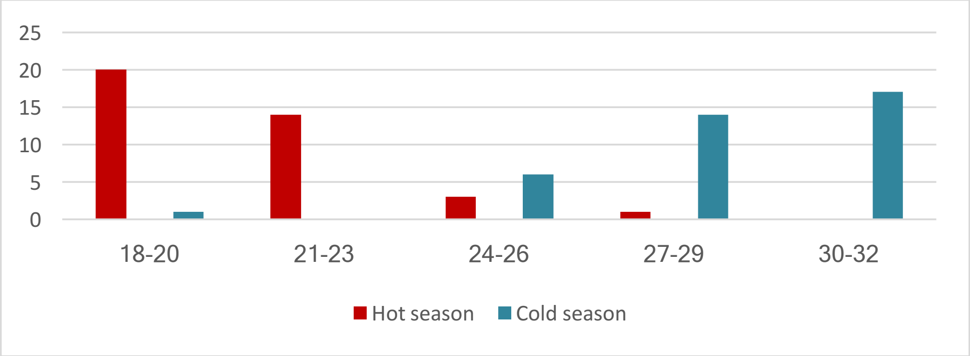


Figure 53: A/C unit settings in Prime Living dormitory in hot and cold season. Source: Author

Another question that asked the direct sunlight penetration the users rooms found out that about half the users had sunlight in their rooms which among them the majority mentioned they have sun light in the morning time, and around 30% said they have sunlight in afternoon and evenings this is evident in both dormitories.(Figure 54-57) The existence of direct sunlight can improve the thermal conditions along with helping the lighting conditions in rooms which can result to reduction in energy use by artificial lighting and mechanical appliances in this periods. The facts about this finding and information of how to react to save energy can be delivered to students by campaigns and educational programs.

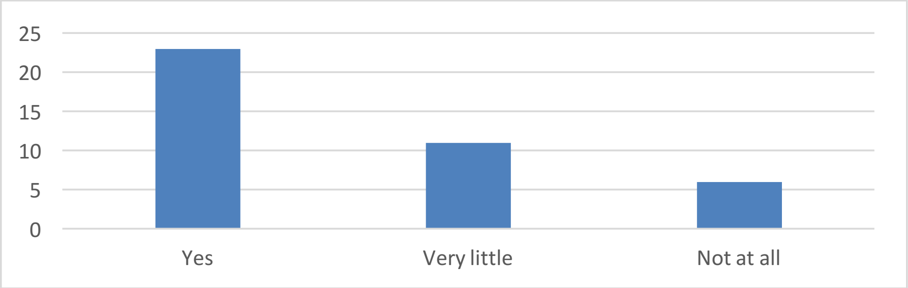


Figure 54: the presence of sunlight as mentioned by the Kamacıoğlu students. Source: Author

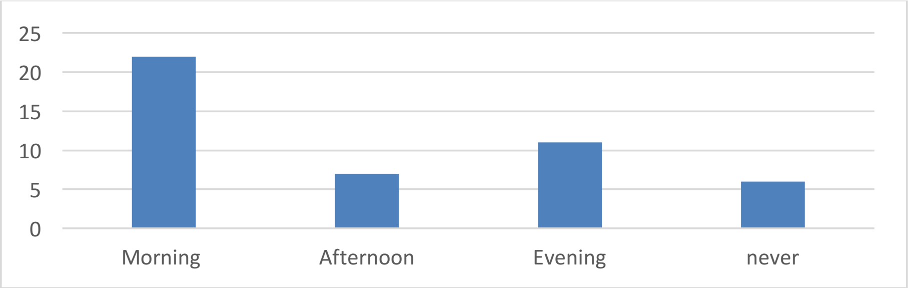


Figure 55: direct sunlight existence time range in Prime Living respondents rooms. Source: author

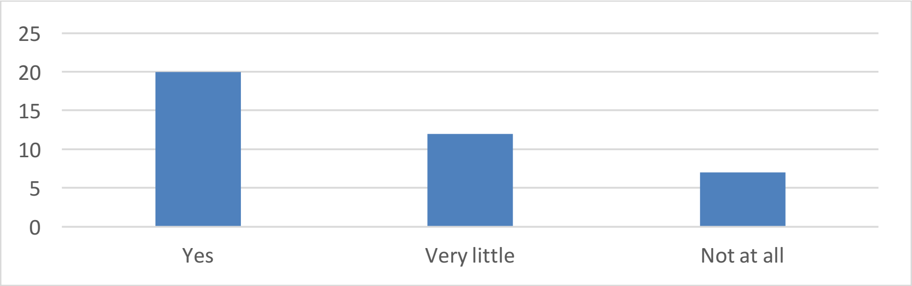


Figure 56: the presence of sunlight as mentioned by the Kamacıoğlu Dormitory students. Source: Author

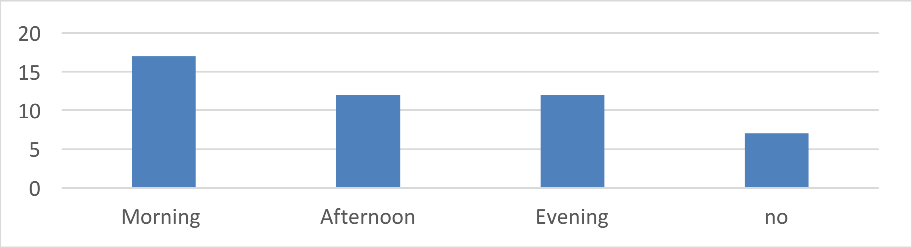


Figure 57: direct sunlight existence time range in Prime Living Dormitory. respondent's rooms. Source: author

Moreover, the respondents were asked to answer if they opened the window of their room in order to ventilate and condition the room. the answers as shown in Figures 58 and 59 below show that most of the users usually or always open the windows in their room. Only a small portion of the users said that they never open the windows in their room. This is mainly to ventilate the polluted air of the rooms to replace it with fresh air. The lack of sufficient ventilation in the rooms can be one of the reason. Another reason can be the habit and culture of opening windows in existing rooms.

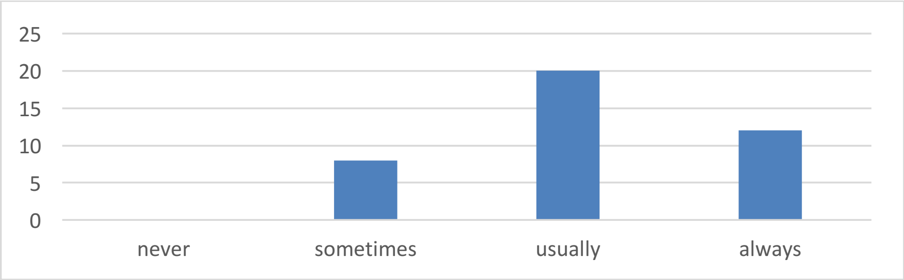


Figure 58: Kamacıoğlu Dormitory users window opening pattern. Source: Author

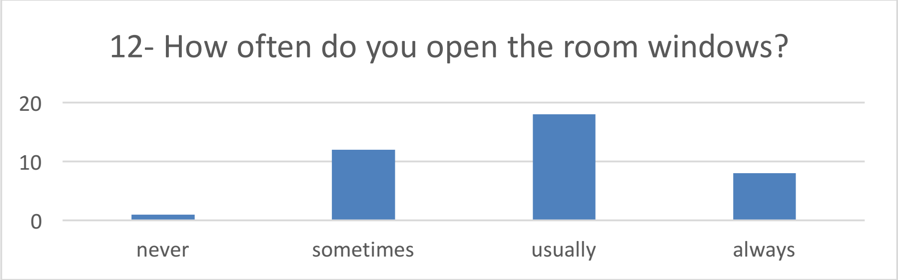


Figure 59: Prime Dormitory users window opening pattern. Source: Author

Subsequently the users were asked if they open the windows while the mechanical cooling or heating systems are operating in. This question was asked to determine the behavioral patterns and miss behaviors. Around half of the responders in Kamacıoğlu said that sometimes the A/C unit are operating while the windows are open. In Prime dormitory, the responses where different. Near 40% mention that usually the systems are off and 20%, mentioned that always it is off. The considerable point here is that the Prime dormitory uses smart sensors that turns the mechanical system off if the window is open. So, either the user turns the system off or not it is automatically turned off (Figures 60,61). It to be emphasize that considerable number of students open the windows while the systems are operating and while the rooms are cooled or heated by the mechanical systems. This is major behavioral issue since it causes the heat transfer between the inside and outside as the systems are operating specially in buildings without smart sensor.

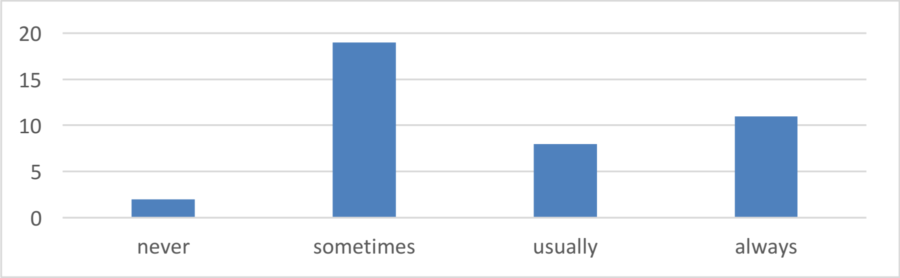


Figure 60: the misbehavior pattern of opening windows while air conditioning units are active. Source: Author

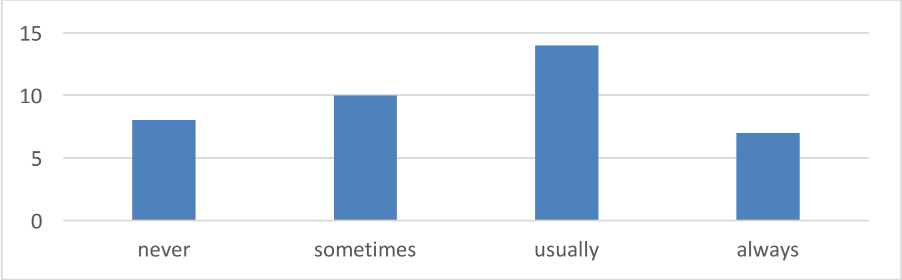


Figure 61: the misbehavior pattern of opening windows while air conditioning units are active. Source: Author

Another question targeted to the users asked them if the A/C units were off while they were away from their rooms. Around 30% of the respondents from both dormitories mentioned that the system was some time off and another 30% mentioned that usually they are off. The results clarified the considerable number of users who does not consider the energy wasted during this period (Figures 62,63).

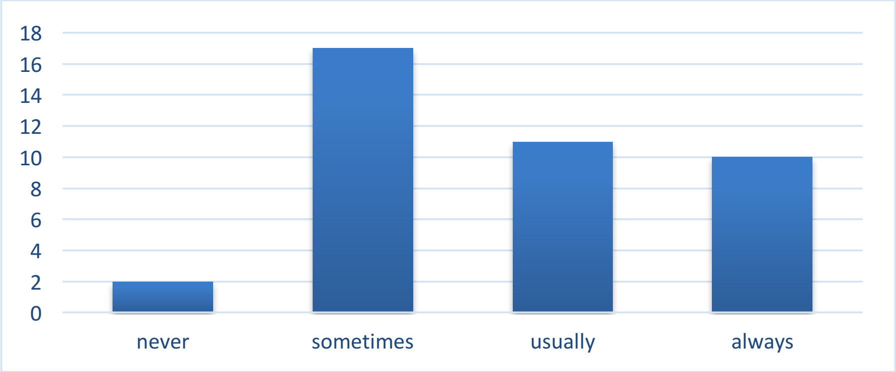


Figure 62: the pattern of A/C unit operation in un occupied times in Kamacıoğlu dormitory. source: Author

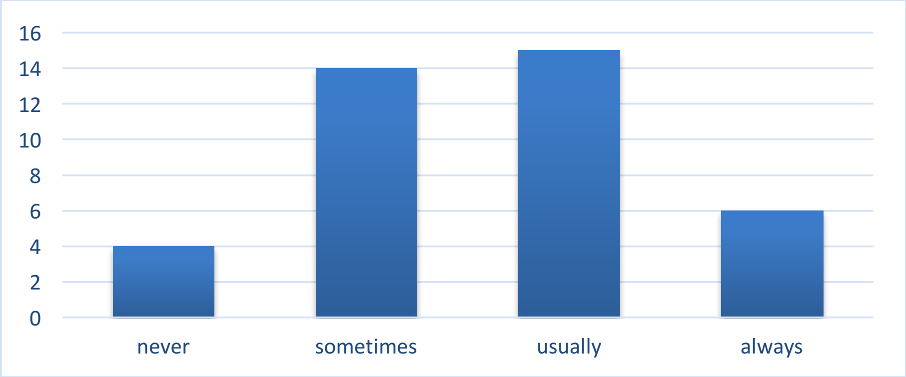


Figure 63: The patterns of A/C unit operation in un occupied times in Prime dormitory. source: Author

Further the lighting use of the occupants were asked by a few questions. They revealed that the more than two third of respondents from both dormitories never turn the lights off in the day time, and following that the result show that considerable quantity of users does not turn the lights off while away (Figures64-67). Around 40% of the users mentioned that they sometimes turn the light off while away. This is among the main bad behaviors of the occupants that can be seen among a considerable portion of the survey respondents.

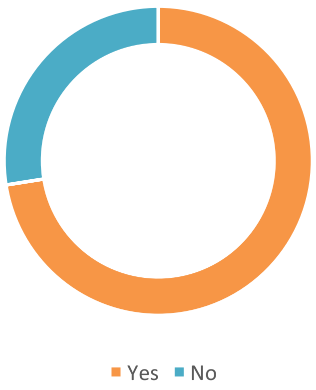


Figure 64: The Lighting appliances usage during daytime among Kamacıoğlu dormitory respondents. Source: Author

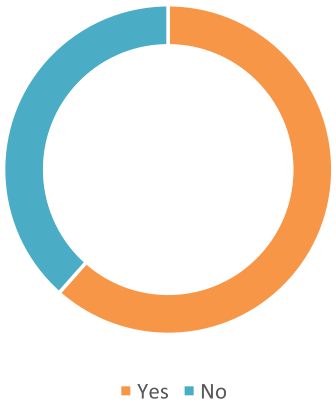


Figure 65: The Lighting appliances usage during daytime among Prime Living dormitory respondents. Source: Author

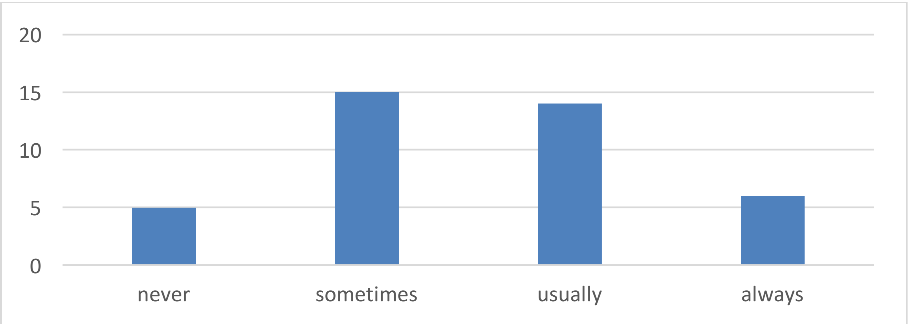


Figure 66: the pattern of lighting fixture operation in un occupied times in Kamacıoğlu dormitory. source: Author

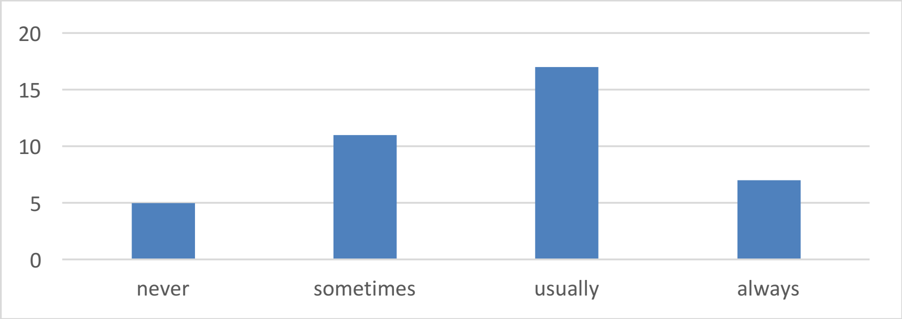


Figure 67: the pattern of lighting fixture operation in un occupied times in Prime Living dormitory. source: Author

The survey asked the users about their approaches towards adapting themselves or the environment in order to reach comfort conditions. The answers are presented in the charts available in figures below and it shows some users only rely on the mechanical systems that is around 50% in Kamacıoğlu and 25% in Prime Living dormitory mentioned the clothing to be the first attempt. This is where the 50% of the users in both dormitories mentioned that they adopt both approaches to achieve thermal comfort in their rooms (Figures 68,69). This shows the diversity of approaches applied by students in order to provide comfort and the ability of approaching either of the approaches. There are considerable number of student that only rely on mechanical system. This is relatable to the clo level of the student which revealed very low clothing insulations in many cases, therefore mechanical equipment has to fill the remaining thermal gap to provide de desired thermal conditions of these occupants.

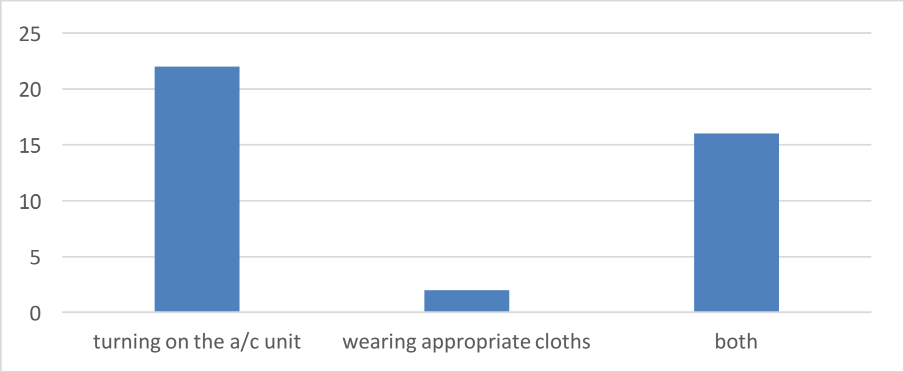


Figure 68: Kamacıoğlu dormitory student responses to approaches towards reaching comfort in cold season. Source: Author

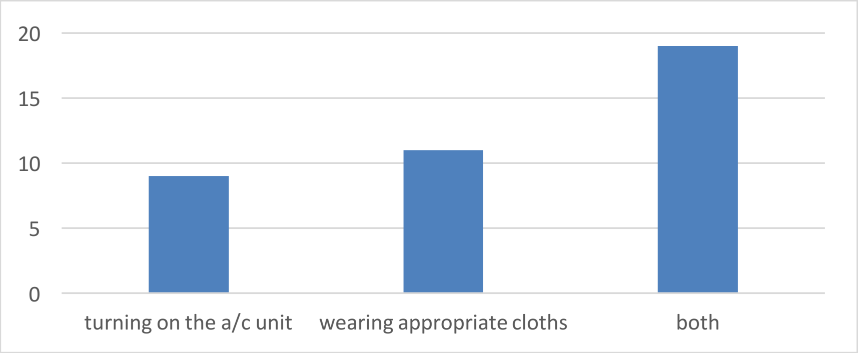


Figure 69: Prime Living dormitory student responses to approaches towards reaching comfort in cold season. Source: Author

The survey respondents were asked if they were aware of the global energy crisis and the impacts on the environment, and around 75% of total respondents mentioned their awareness of the cause and majority of the users mentioned that they take actions occasionally or sometimes toward energy saving (Figures 70-73). This can be an indication towards intentions and care of the respondents toward this serious matter but the level of awareness and to what extent the users are aware about the required action are different among the students. This issue can be improved with informing the users of what actions they can take to more frequently be involved in the energy saving path.

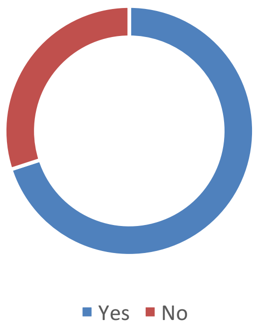


Figure 70: Kamacıoğlu dormitory respondent’s awareness on environmental crisis. Source: Author

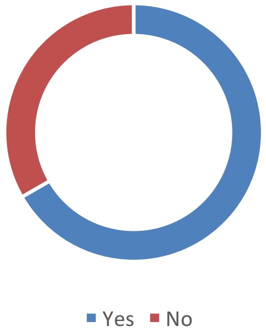


Figure 71: Prime dormitory respondent’s awareness on environmental crisis. Source: Author

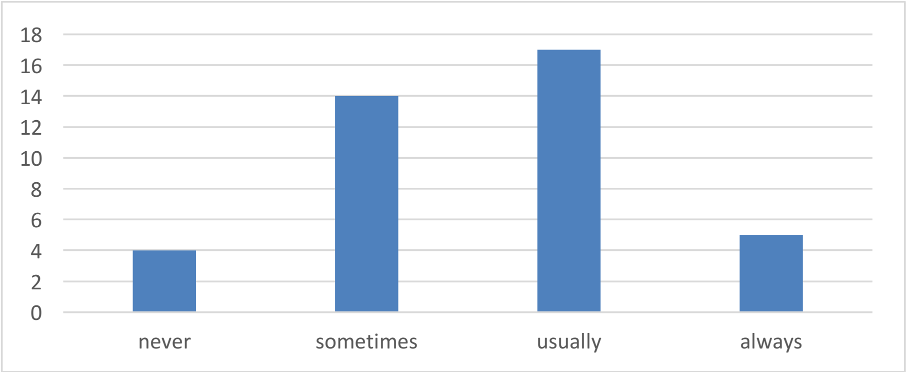


Figure 72: Students attitude towards energy saving the frequency of the actions. Kamacıoğlu respondents. Source: Author

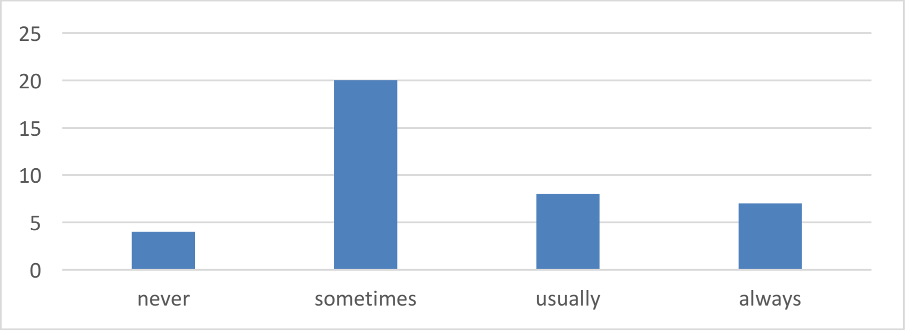


Figure 73: Students attitude towards energy saving the frequency of the actions. Prime Living dormitory respondents. Source: Author

Lastly the respondents were asked to specify their clothing at their room in the cold season. The data acquired from this section is shown below which will be uses to specify the comfort range for the individuals participated in the survey. As shown in the charts bellow the range of the clothing insulation (clo) spans from 0.14 to up to 1.27. this is where the 0.5 clo is to be the average for summer and 1 clo for winter.

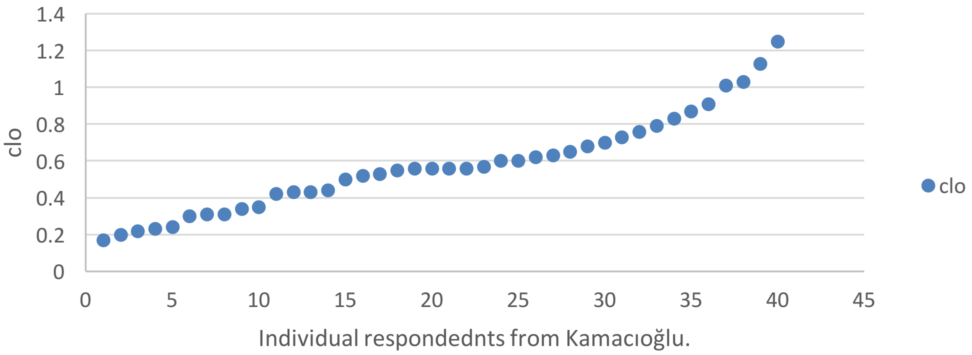


Figure 74: Clothing Insulation levels among Kamacıoğlu Dormitory users, Source: Author

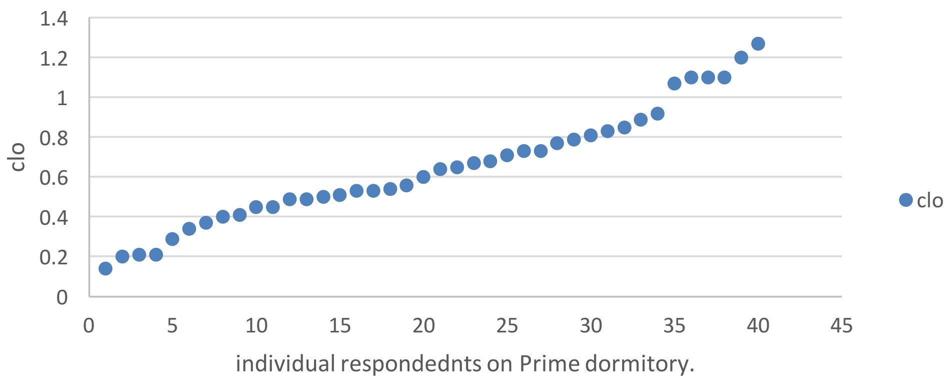


Figure 75: Clothing Insulation levels among Prime Dormitory users, Source: Author

As shown in the figures above the clothing insulation range in the cold season is very wide that consequently results to largely different air temperatures to achieve comfort. According to calculations in PMV method in a typical winter day the comfort temperature for the lowest clo recorded is 26.6-30.5 in which the comfort temperature for a person with 1.2 cloth insulation is around 19-24. This will clearly result to more mechanical energy usage to heat the space to be suitable for lower clothing insulation individuals. This is where the Adaptive principal is very useful. As mentioned before, the occupant either can adapt themselves or the environment in other to be in thermal comfort conditions. the figure bellow is suggested by ASHREA 55 2013 as comfort zone in adaptive principal.

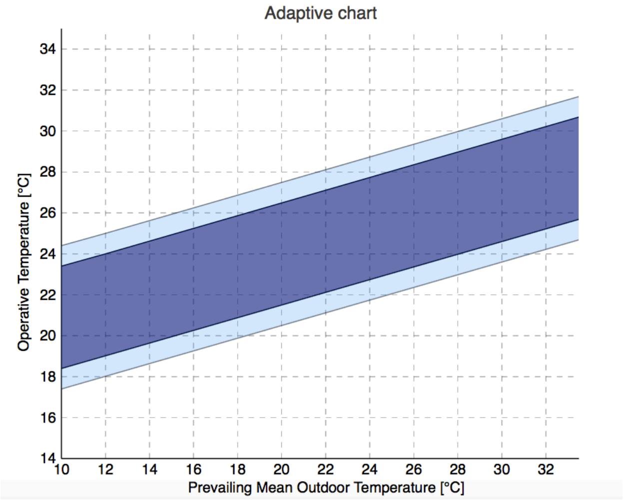


Figure 76: ASHREA 55 Adaptive Approach Comfort temperature zone Source: ASHREA 55 2013

Questionnaire outcome:

The result of the survey done in both dormitories have provided the study with information which assist in finding and improving some of the important issues in dormitories energy consumption.

- The young individuals are occupants of these facilities and female and male population are almost equal. As reviewed before the younger users tend to prefer lower temperatures than old users and this fact influences the thermal requirements of the dormitory building that has to be considered in the building management procedures.
- The occupancy is more in nighttime followed by mornings. This might indicate the peak energy uses of the rooms specially for HVAC systems.
- Majority of the occupants use the A/C units in high regularity and in many cases during the whole occupation time. This again emphasizes on the importance of the HVAC system energy efficiency alongside with it being the leading energy using equipment in buildings

- The most dominant time range in which the users use HVAC are mornings and nights.
- The favorable temperatures among a vast majority of the occupants are in mid-range of the available choices in the survey which was 24-26 degrees Celsius, but on the other hand the settings on the A/C units are in maximum capacity in hot and cold season.
- Considerable portion of the users have sunlight in their rooms mainly in morning but also in other times of the day. Therefore, the need for artificial lighting and also heating the rooms with mechanical equipment should be reduced because of the sun light heat and light.
- Apart from a small group the rest of the respondents open their windows in most of the times in order to ventilate the air in the room or as a habitual action or to smoke cigarettes and simmer stuff. This action as discussed before lead to energy waste and heat transition between inside and outside.
- The survey found that a considerable number of individuals in different patterns from very little to high tend to open the windows without considering if the mechanical system is turned off or is operating. Consequently, all the energy consumed by the conditioning units is wasted through the air movement between inside and outside. As mentioned before the HVAC systems are the biggest energy consumers in buildings and trough this action a big portion of the energy use in building is wasted.
- Similarly, the findings showed that the running of the HVAC units and lighting fixtures of the rooms while the rooms are un occupied in substantial number of respondents. This again shows a bad behavior that causes a purposeless energy use and huge waste.

- Users take different approaches towards reaching their desired comfort levels. Some use only mechanical equipment some adjust clothing and some benefit from both. The best approach would be benefitting from both which with education and guidance might be achievable.
- The clothing insulation of the individuals as presented in the charts were very unpredictable from a range of 0.14 to 1.27, this in consistency in clothing insulation leads to a very irregular pattern in HVAC energy use due to different temperature preferences in rooms. It is of vital importance to acquire the users with information and compatible approached towards selecting proper clothing that will provide them the appropriate amount of insulation while reducing the thermal requirements for comfort and consequently reducing the energy used to heat the rooms.

Chapter 5

CONCLUSION

5.1 Conclusion

As mentioned earlier in the thesis the global climatic crisis and the global warming issue is a serious threat to the environment, ecosystem and human societies. Majority of this crisis is considered by the international organizations to be due to using nonrenewable energy resources as fossil fuels which are mainly coal, oil product and natural gas. Consuming this energy resources result in emission of greenhouse gasses(GHG) mainly $CO_{2.}$ The excess emission of the GHG in the atmosphere is the main cause for the global warming crisis and climate change.

The global energy use is due to different energy consuming sectors as transportation, services, manufacturing, construction, mining and building sector. A considerable amount of this energy is consumed by the building sector. Building sector itself is divided into different segments as Service sector, Commercial sector, Office buildings, Industrial buildings and residential and accommodation sector. The residential and accommodation sector on its own is responsible for around 20% of the total energy end uses in developed countries and 30% in developing countries. As reviewed in the study the majority of the energy in residential sector is consumed for the space heating purposes, followed by Electric appliances and the Hot water supply systems. The evidences show that 92 % of the buildings cost are related to the building operation during the building life cycle, therefore it is of vital importance to improve the efficiency in the way buildings are operated, it can be said that applying energy efficiency actions is considered to be the main base for reducing energy usage and the negative footprints on the environment and also attaining cost effectiveness in the building sector.

As this research has covered, there have been numerous studies and movements towards achieving lower energy consumption rates and energy efficiency. Thermal comfort can be described as standards and approaches to reduce excess energy use to condition the living spaces and at the same time assure the comfort of the building users. The studies have shown that to achieve thermal comfort a series of elements have to work with each other as humidity, air speed, air temperature, human metabolism and clothing insulation. Also, very importantly the adaptive approach pointed that the users of the buildings have the capacity to adapt themselves (Clothing insulation) or to adapt the environment (Changing the effective factors) in order to get to desired comfort state.

Further in building efficiency the improvements in the physical characteristics of the building including the building envelope(Finishing material as paint, external and internal insulations, double skin facades, shading elements, etc.), orientation and shading elements, facilitating appropriate and more efficient appliances for the building, using smart energy management technologies to assist the energy reduction in buildings and changing into more efficient lighting systems like LED appliances have been emphasized in this thesis. additionally, the use of renewable energies and micro generation like geothermal energy, sunlight and similar renewable sources could be considered to reduce the use of fossil fuel. Although best results are driven from hybrid renewable energy systems.

Another approach that is as important as technical issues and strategies in energy reduction is the occupant behavior. The extent of energy consumed in buildings is closely related to the behavior of the building users. In order to overcome the issues in building energy efficiency, the technological and physical improvements in buildings has to be considered along with the behavioral patterns and occupant role in the building energy use. Occupant behaviors can be separated into two groups of adaptive and non-adaptive. Adaptive changes as Humphrey mentioned are either behaviors that occupant do to restore their comfort if it has been distorted, or, adopting themselves or the environment to fit their desires. Non- adaptive measure as evident from the name is related to behaviors that have to be changed in order reduce energy consumption such as reducing the unnecessary plug loads and manage the unoccupied times energy waste. The understanding of the building occupant behavior and implementing strategies to cope with those behaviors and characteristics and also behavioral intervention approaches are necessary.

Further in this thesis two cases Kamacıoğlu dormitory and Prime Living dormitory were investigated and analyzed. The two dormitories have considerable differences with each other. The differences were both in operational dimensions and physical dimensions. Also, according to the interviews the main occupancy pattern is in cold season therefore the focus has to be on the building heating purposes. One of the other differences that affects the building performance is the separation of genders to different blocks in Prime Living dormitory, since the thermal sensation is considered to be different among the genders.

The result of the observations and interviews can be summarized in tables bellow as advantages and disadvantages of each dormitory:

Table 6: Kamacıoğlu Dormitory Pros and Cons in terms of energy efficiency.
Source: Author

Advantages	Description	Consequences
Using Solar Radiation heating panels	The dormitory uses Solar radiation heating panel to support the hot water supply systems.	Reduction in energy requirements for hot water supply.
Double glazing windows.	All the windows in the dormitory are double glazing with aluminum frame and white paint.	Reduces solar heat gains by the buildings and also heat losses from the building in cold season
Disadvantages	Description	Consequences
The split A/C units	The dormitory is equipped with split units in each room that are usually lowly maintained or very old.	These systems are considered to be highly energy consuming and if not maintained properly will lead to extreme inefficiency. This lead to increase in energy use.
Inefficient lighting	The lighting fixtures are mainly Incandescent and there is no policy on the lighting equipment.	These lighting systems are not efficient at all and lead to over consumption of energy and also heat loads in hot season.
Poor Maintenance	The maintenance especially in HVAC units are not done until they are not functioning	This lack of maintenance leads to inefficiency in the dormitory equipment and therefor increase the peak energy use and significant energy losses.
Lack of Insulation layers in building envelope	There is no insulation layer in the building envelope	Leads to heat losses and gains throw trough building walls and structure.
Lack of electricity control systems	The electricity is provided with no limits to the users	Lead to un controlled and miss use of the electrical energy and energy loss.
Orientation	The B block of the building is oriented in such way that lead to least energy save.	The benefit from correct orientation is not achieved completely.
Air movement from room doors	The doors are not properly sealed	Leads to energy loss trough air movement from rooms to corridors.
Lack of shading elements	There no shading element implemented in building	The benefits from Shading elements are missing.

Table 7: Prime Living Dormitory Pros and Cons in terms of energy efficiency.
Source: Author

Advantages	Description	Consequences
The external insulation layer	The building is covered by thermal insulation layers from outside	Leads to reduction in heat loss and heat gain of the building and reduces the energy requirements to provide comfort temperature.
Double glazing windows	The windows are aluminum double glazing windows with tint glass.	This lead to reduced solar radiation gains and also energy loss trough windows.
Window sensors	The windows are equipped with sensors that cut off the heating and cooling systems when the windows are opened	This system leads to reduced energy losses due to heat loss or gain through window opening.
HVAC system	The heating is done by floor heating that hot water is mainly provided by Solar panels and Geothermal heat sources, the cooling is done by a central cooling system that the water is cooled by the support of cold water reservoirs underground and partly by electrical equipment.	The Floor heating requires less temperatures to temperate the room and the hot water is supplied by renewable sources, therefore results in considerable energy saving. Central cooling is proven to be more efficient approach and the cooling is assisted with geothermal sources, and leads to lower energy use
Regular Maintenance	The maintenance of the HVAC equipment and also Energy harvester system are done regularly and proactively.	The regular maintenance of the units result in maximum efficiency of them and result in considerable energy savings.
Efficient lighting	The whole dormitory is equipped with LED lights	These lighting systems lead to significant energy saving
Hybrid renewable energy system	The dormitory is equipped with Geothermal heat pumps and Solar radiation panels for hot water supply for all uses. (heating and domestic use, and cooling in summer)	The hybrid systems have proven to be the most significant and efficient in this sector and lead greater energy savings.
Electricity usage limits	The dormitory provides each room with specific amount of electricity for each academic year	Limits the energy waste trough miss uses and reduces energy consumption.
Disadvantages	**Description**	**Consequences**
Lack of shading elements.	There no shading element implemented in building	The benefits from Shading elements are missing.
High cost of geothermal equipment and maintenance	The Geothermal pump systems have to be maintained regularly and the initial costs are high	This may lead to lack justification in initial costs and total energy saving cost reductions.
Orientation	The orientation of a considerable portion of the building blocks in in least efficient direction.	The benefit from correct orientation is not achieved completely.

The analysis of the questionnaire results show that almost all of the building users are in young ages that require different thermal conditions that old users, therefore it is important for the building operators to make decisions accordingly. Further the majority of users operate the HVAC units at almost maximum capacity. This is partly related to the poor conditions of the mechanical systems and a/c units, and in prime dormitory as mentioned by the manager of the dormitory the circulation hot water of the central heating is slightly at lower temperature. the inefficiency of the mechanical devices has resulted in using more energy to get to desired conditions for the spaces in use by students.

The results from the questionnaire showed the lack of appropriate occupant behaviors in line with the logic and concept of energy efficiency. The result showed behavior like opening windows while the HVAC units are active, or leaving the energy consuming appliances in operating position while the rooms are unoccupied, or using artificial lighting in daylight, that lead to big energy wastes. Also, results showed very inconsistent clothing insulation among the users that leads to very different and in most cases, high temperatures of comfort which has to be provided by the mechanical equipment. Although the results show a considerable number of the students are claiming to be aware of the global issues in terms of environmental and climatic factor but the behavior are not in line with this awareness.

5.2 Suggestions

Physical and Technical Improvements:

The observations and also investigations considering the claims by Prime dormitory management, puts this dormitory in a somehow more successful case in energy performance among dormitories. Although more investigations and analysis on the prime dormitory approaches and the cost justification of the applied method would reveal that either the Building is an ideal example of an efficient dormitory or not. But certainly, the dormitory benefits from more strategies towards energy saving than Kamacıoğlu dormitory. Dormitories in EMU and the region by considering energy efficient approaches can improve the energy performance of their building that would be beneficial for the institute, the users and the environment. Some of these approaches can be described as follows:

HVAC systems:

- Correct choice of HVAC units by considering regional characteristics, building characteristics, and most importantly in the case of dormitories the focus should be more on the space heating efficiency due to the main occupancy patterns of the dormitories that are mainly in cold seasons.
- Regular maintenance of the existing HVAC systems to assure maximum performance and efficiency.
- Using Hybrid systems to reduce the energy loads in the HVAC systems.

Lighting:

- Utilize more efficient lighting system.
- Choose correct type of lighting in line with activity.
- Appling unified lighting systems.

Control system:

- Appling limits to user energy consumption.

Renewable energy sources:

- Benefiting from existing renewable energy sources
- Hybrid systems are proven to have the most efficiency.

Behavior interventions:

The behavior abnormalities and miss behaviors were observed in both dormitories. according to what said before, in even very highly enhanced buildings the wrong behavior of the occupant lead to inability of this buildings to deliver their maximum efficiency. Therefore, this study according to previous studies and efforts in this field suggest organizing regular campaigns to educate the students and specially the newcomers by providing them with the knowledge and information about:

- The current issues and global climatic and environmental crisis.
- Educating the users about misbehaviors
- Giving the user instructions about the correct and efficient behavior.
- Showing the results of their action in bigger pictures and global scales and also the effect of positive actions on future generations.
- Educating the users with correct combination of clothing in cold seasons.

These educational movements are absolutely necessary but as mentioned are not enough by their own. Research has shown that the effect of this kind of interventional approaches (Antecedent) that provides the users with information are not long lasting and users turn into their previous habit shortly. There for additionally approaches that include award systems (Consequence) should be considered along the educational campaigns. This study suggests that:

Institutions should consider approaches and strategies that include reward systems to encourage students to employ and continue energy saving behaviors. The monetary rewards can be in forms of partial refund of the annual tuition paid to the dormitory according to the energy using rates of the students. This kind of reward would encourage students to save energy which will in future be beneficial for the dormitories energy consumption and therefore economic factors and also benefit the students by reduction in their dormitories expenses and also attract students to join the dormitories because of this reward system, and in a more holistic perspective will affect the global crisis of climatic and environmental issues. The dormitories should also consider the effective factor of gender and age. Separation of the genders in different building blocks can help target the correct thermal requirements for each gender.

All the findings in this study with reviews of the current studies in this field and the facts and reality of the global energy and environmental crisis which at the end impact life on the planet earth, emphasize on the importance of implementing actions with least footprint of environment, in all sectors. The building sector as an important energy consumer has great potential to reduce total global energy consumption. This study by focusing on the student accommodation units in Eastern Mediterranean University showed the weak point and also the potentials and opportunities in these building sectors to achieve better performances and increase the efficiency rate, by different approaches and strategies. All the efforts that take place in order to increase efficiency of the buildings and improving the energy performances in them will lead to less total energy consumption and therefore lower impact on environment and reduced greenhouse gas emissions, also they will improve the building economic performance by reducing the total building life cycle cost and reduced energy expenses of buildings. These approaches need to be taken more seriously by the institutes owners and operators either by policies and legislations from higher authorities also by increasing the knowledge and awareness in both on owners and users.

5.3 Further studies

Further studies can be a more detailed analysis of the mentioned approaches in terms of their exact contribution to energy efficiency in dormitories on EMU. Deeper analysis and investigation on the roots and reasons behind occupant behavior in using the buildings. Studies to find the optimum approaches in energy reduction and efficiency considering environmental, climatic, social, economic and political conditions and factors in North Cyprus.

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URL, 1: http://www.kibtek.com

URL, 2: http://maps.google.com

APPENDIX

Appendix A: Questionnaire form

Questionnaire consent form

- This questionnaire is prepared to aid and be used in a related study by the department of Architecture in EMU on energy consumption patterns in student accommodation units. This research will investigate the physical factors of dormitories alongside with the behavioral factors of the users effective on the overall energy consumption of the dormitories. This questionnaire is design to assist this information. Accordingly, you are invited to take part in this research by filing this questionnaire with your truthful answers. It is to be noted that **no personal information** will be obtained from you, therefore please try to go through this questionnaire with reliable and accurate answers.
- The final result of this study can help reduce the energy usage and resource consumption in student accommodation units, consequently it will benefit the users and business owners.

- Voluntary nature of participation: Participating in this questionnaire is **completely voluntary**. You can refuse to answer or withdraw any time you wish so.

- Risks: There is no risk in participating in this research.

- The questionnaire will be excluded if you give any information which is deemed inconclusive or if you do not satisfactorily complete the questionnaire.

We would like to thank you in advance for your valuable time and contribution to this research

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I have read and understood the information regarding the research project and the study. I also understand the fact that participating in this questionnaire is totally voluntary and I can withdraw from answering it at any time. Therefor I give my consent to participate in this study

Participant signature:

Researcher signatu

Questionnaire

Answering Direction:

· Put a check (√) to your corresponding answer. Thank you in advance for your time and support.

1- Please indicate your *gender:*

☐ Male ☐ Female ☐ Other

2- Please indicate your age group below

☐ under 18 ☐ 18 to 24 ☐ 25 to 30 ☐30-40 ☐ over 40

3- Please indicate your nationality of origin:

………………………………………….

4- Please specify your status:

☐ High school student

☐ Undergraduate student

☐ Postgraduate student

☐ Other

5- Please specify the time range you are most likely at your room (multiple choices are possible):

☐Morning ☐afternoon ☐evening's ☐night

6- How often do you use the air conditioning *(AC unit)?*

☐Never ☐Sometimes ☐Usually ☐Always

7- Considering the using of AC unit, what time of the day do you turn it on? *(multiple choices are possible)*

☐Daytime ☐Nighttime ☐Evenings ☐Afternoon

8- What is your favorable room temperature from the range below?

☐18-20 ☐21-23 ☐24-26 ☐27-29 ☐30-32

Cooler ←←←←Neutral →→→→Warmer

9 - What temperature do you set your ac unit on during hot seasons?

☐18-20 ☐21-23 ☐24-26 ☐27-29 ☐30-32 ☐the settings are done by the institute.

Cooler ←←←←Neural →→→→Warmer

10 - What temperature do you set your ac unit on during cold seasons?

☐18-20 ☐21-23 ☐24-26 ☐27-29 ☐30-32 ☐the settings are done by the institute.

Cooler ←←←←Neutral →→→→Warmer

11- Do you get sunlight to your room?

☐Yes ☐very little ☐not at all

If Yes What times of the day you have direct sunlight in your room

(you can select multiple):

☐Mornings ☐Afternoon ☐Evening

12- How often do you open the room windows?

☐Never ☐Sometimes ☐Usually ☐Always

13- Do you turn the A/C unit off while the windows are open?

☐Never ☐Sometimes ☐Usually ☐Always

14- Do you keep the lights ON during daylight?

☐Yes ☐No

15- Is the AC unit turned off while you are not at your room?

☐Never ☐Sometimes ☐Usually ☐Always

16- Are the room lights turned off while you are away?

☐Never ☐Sometimes ☐Usually ☐Always

17- Are you aware of the environmental problems and global warming issues?

☐Yes ☐No

18- Do you ever consider the matter of energy use and try to make some saving?

☐Never ☐Sometimes ☐Usually ☐Always

19- In the cold season in order to get warm which of the following to do take into consideration. (you can choose multiple answers)

☐Turning on the heating unit in the room.

☐Wearing appropriate clothes.

☐Both

20- Please mark the items you use as clothing in the cold season during you accommodation in your room.

Head	*None*	*Hat*	*Scarf*			
Upper body layer 1	*T-shirt*	*Shirt*	*Long sleeve thin*	*Long sleeve tick*	*Scoop neck long sleeve*	*Long sleeve sweat shirt*
Upper body layer2	*Sleeveless vest thin*	*Sleeveless vest thick*	*Long sleeve vest thin*	*Long sleeve vest thick*	*Pajamas thin*	*Pajamas thick*
Lower body	*Short shorts*	*Walking shorts*	*Straight trousers thin*	*Straight trousers thick*	*Sweat pants*	*Overalls*
Feet	*Ankle socks*	*Long socks*	*Stockings*	*Sandals*	*Shoes*	*slippers*