A STUDY OF ENERGY AND DAY LIGHTING PERFORMANCES FOR RESIDENTAL BUILDING DESGIN UNDER HOT CLIMATES IN KSA

BY

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بسم الله الرحمن الرحيم

DEDICATED TO MY FATHER, MOTHER, SISTERS AND BROTHER

ACKNOWLEDGMENT

All praise and thanks are due to my Lord, ALLAH SUBHAN WA TAALA, for giving me the health, knowledge and patience to complete this work.

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Table of Contents

Table of figures

List of Tables

Abstract

Name: Ali Mohammed Al-Dossary
Title: A STUDY OF ENERGY AND DAY LIGHTING PERFORMANCES FOR RESIDENTAL BUILDING DESGIN UNDER HOT CLIMATES IN KSA
Department: Architectural engineer
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In recent years, annual global energy consumption has been rapidly increasing which resulted in problems of energy-related environmental issues such as global warming. In Saudi Arabia, the demand for buildings including commercial and residential sectors has increased because of the escalating growth in population and 80% of the total electric energy consumption in the Kingdom has been consumed by building sectors. Among buildings, residential building sector is heavily dependent on mechanical cooling and has consumed over half of the energy consumption.

The efficacious implementation of a daylighting and energy saving system in early stages of designing residential buildings , as well as the designing of larger sized windows can have a major effect by allowing more daylight into an area within the building, which leads to the demand for shading to minimize excessive loss of heat or gain and balance heating and cooling of the building which results in less energy consumption.

The main objective of this research is to study the energy consumption and daylighting performance of residential buildings located in the eastern provenance in KSA, specifically: Dammam, Al-Khobar and Al-Ahsa city, through interviews and surveys distributed to residents living in said cities, A base case was extracted according to the results. The energy simulation program eQuest and the daylight analyzing program AutoCAD were used to create an improved design of the interview and survey results. The results showed a reduction of Annual energy consumption from 79,290 kWh to 76,176 kWh, the cooling load reduced 2.5% in total.

A set of designing tools in the form of tables and graphs were created to aid in energy efficient window, shading and glazing designs through the implementation of daylighting as a main factor.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

DHAHRAN, SAUDI ARABIA

الخلاصة

الإسم : علي محمد علي ال عمار الدوسري
عنوان : دراسة أداء الطاقة والإضاءة الطبيعية لتصميم المباني السكنية في ظل المناخات الساخنة في المملكة العربية السعودية
التخصص : الهندسة المعمارية
تاريخ التخرج : 2019 مايو

في السنوات الأخيرة ، ازداد الاستهلاك السنوي للطاقة بشكل سريع مما أدى إلى مشاكل متعلقة بالقضايا الطاقة البيئية مثل الاحتباس الحراري. في المملكة العربية السعودية ، ازداد الطلب على المباني بما في ذلك القطاعات التجارية والسكنية بسبب النمو المتصاعد في عدد السكان واستهلكت تلك المباني ما يقارب 80 ٪ من إجمالي استهلاك الطاقة الكهربائية في المملكة. بين المباني ، يعتمد قطاع المباني السكنية اعتمادًا كبيرًا على التبريد الميكانيكي ويستهلك أكثر من نصف استهلاك الطاقة.

يمكن للتطبيق الفعال لنظام ضوء النهار وتوفير الطاقة في المراحل المبكرة من تصميم المباني السكنية ، وكذلك تصميم النوافذ الكبيرة الحجم أن يكون له تأثير كبير من خلال السماح بمزيد من ضوء النهار في العديد من المناطق داخل المبنى، مما يؤدي إلى الطلب على التظليل لتقليل الخسارة المفرطة للحرارة أو الكسب والتوازن في تسخين وتبريد المبنى مما يؤدي إلى تقليل استهلاك الطاقة.

الهدف الرئيسي من هذا البحث هو دراسة استهلاك الطاقة وأداء ضوء النهار للمباني السكنية الواقعة في المنطقة الشرقية بالمملكة العربية السعودية ، وتحديداً: الدمام والخبر ومدينة الأحساء ، من خلال المقابلات والدراسات الاستقصائية الموزعة على المقيمين في المدن المذكورة، ومن ثم استخراج النموذج الدراسة الأمثل قاعدة وفقا للنتائج. لأنشاء تصميم محسن تم استخدام برنامج محاكاة الطاقة eQuest وبرنامج المحاكاة لتحليل الضوء AutoCAD

لنتائج المقابلة والاستقصاء. أظهرت النتائج انخفاضًا في استهلاك الطاقة السنوي من 79،290 كيلو وات في الساعة إلى 76،176 كيلو وات في الساعة ، وتقليل حمل التبريد بنسبة 2.5٪ في المجموع.

تم إنشاء مجموعة من أدوات التصميم في شكل جداول ورسوم بيانية للمساعدة في تصميم نافذة، التظليل وانعكاس النافذة بطريقة فعالة من خلال تطبيق ضوء النهار كعامل رئيسي.

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CHAPTER 1

INTRODUCTION

1.1 Background:

The topic "Daylighting and energy performance" is considered to be fairly recent, as in the year 1906 a society by the name "illumination engineering society" was created and its purpose was to study lighting implementations, but the term "illumination engineer" was first acknowledged in the year 1944 by Benjamin Thompson in the book "On the Management of Light in Illumination" since back in 40's "Daylighting and energy performance" was called "illumination engineering", the idea was however is to study the effects made by lamps or natural light within a space or area (John Walsh, 1951).

By the year 1966 the highest concern when it came to daylighting and energy performance in buildings is the estimation of its performance, as formerly the procedures done to study daylighting and energy performance was leaning more to a graphical nature, for Example: Waldarm's diagrams (Hopkinson, Petherbridge & Longmore, 1966), from that point, the topic grew some attention and researchers started to create experimental tools that can calculate the daylighting and energy performance, thus many indicators have been created such as the Daylight Factor (DF) which is still used to this day, and recently by the beginning of the 2000 another indicator was made which is Daylight Autonomy (DA), as well as many efforts were used to discover the influence of daylighting on the buildings thermal performance and electrical waste.

As well as energy as a conservative building method, in a sense is considered relatively a new topic, as it was first defined as a code year 2007 by the Indian bureau of energy efficiency and it was called: Energy Conservation Building Code, the code itself consisted in principal to encourage efficient buildings when it came to energy matter, it required acquiescence procedures.

An example of a building that used Daylight and energy saving methods is the headquarters of Ministry of External Affairs Jawaharlal Nehru Bhawan in new Delhi which is a building that is perfectly in unison with nature, making it the first Energy Conservative Building Code that is governmental and gained the green building certification with LEED, the reason why is that it concentrated on making an energy conservative/friendly building in the designing phase, by implanting the following tools to achieve said goal:

a. Roof insulation.
b. Double Glazing.
c. Courtyard planning.
d. Using energy affective technologies and methods.

Figure (1) A picture of the headquarters of Ministry of External Affairs
Jawaharlal Nehru Bhawan in new Delhi

which resulted in the following:

1. Indian Standards of lighting was achieved.
2. Lighting ability concentration was accomplished which is lower than 0.8 W/Sq.Ft.
3. Lighting Power Density was reduced due to the use of daylighting methods such as windows and sensors.
4. manual methods of lighting were reduced due to the dependency on daylighting sensors in case of clients.

Figure (2) A picture of the headquarters of Ministry of External Affairs
Jawaharlal Nehru Bhawan in new Delhi at night

1.2. Study area:

Kingdom of Saudi Arabia is considered the second biggest Arabian country in the world with a Gross Domestic Product (GDP) of 683.8 billion USD in the year 2017, Fig (3). and a growing population of 33,413,660 of Saudi/non-Saudi residents by the year 2018, Fig (4). results in high consumption of energy within the country.

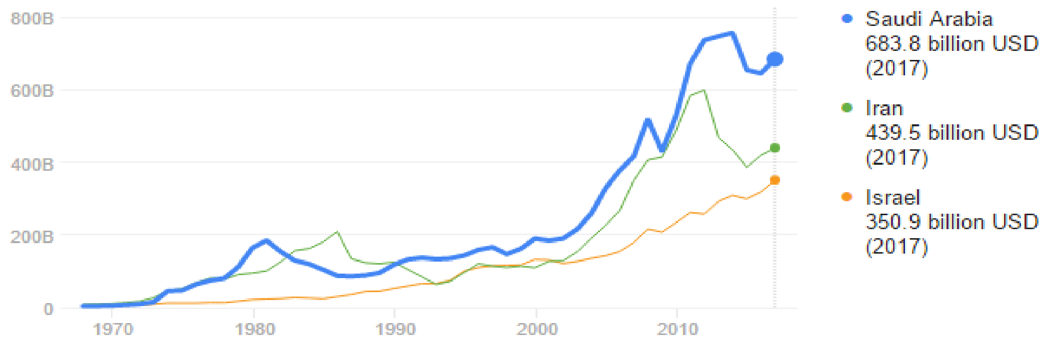


Figure (3) Gross Domestic Product (GDP) of KSA, 2017

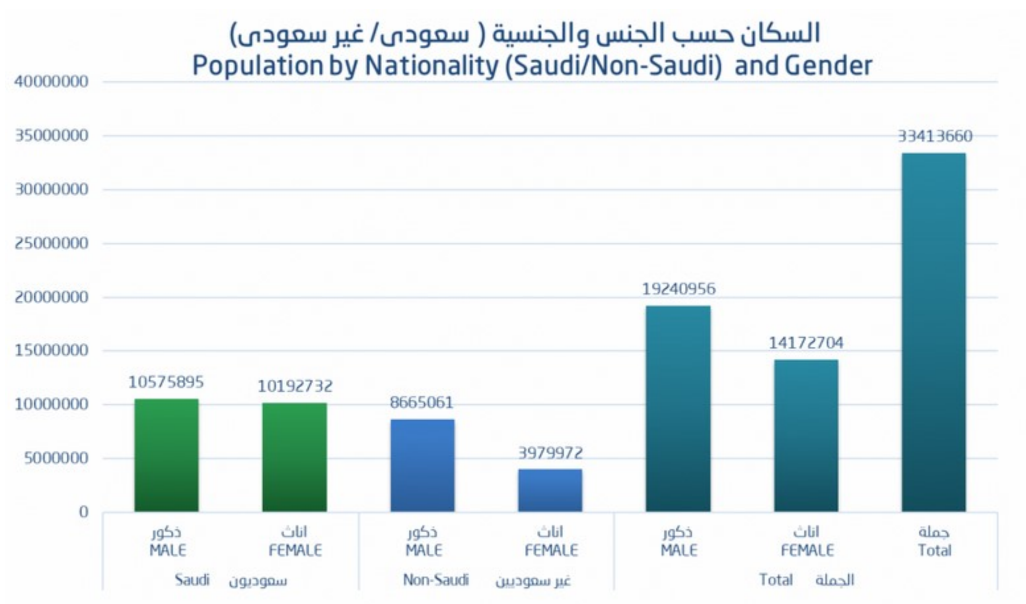


Figure (4) the number of population in KSA, 2018

According to the Saudi Arabian General Authority for Statics, A study was conducted from 4/14/2017 to 5/18/2017 on the Saudi Arabian population in order to collect information about the building features that the Saudi Arabian families live in and to extract indicators that is related to the building features and affect it, the research showed that the total of occupied buildings (regardless of housing unit type) by Saudi Arabian families reached 3504690 in 2017 compared to 2016 when it was 3417788, and the percentage of the average Saudi family size have reached 5.97 % compared to the year 2016 which was 6.24%.

The research was conducted in the Eastern Provenience in Kingdom Saudi Arabia, the reason why because it is considered the third high rated administrative area (after Riyadh and Makkah) when it comes to the distribution of housing units, Fig (5).

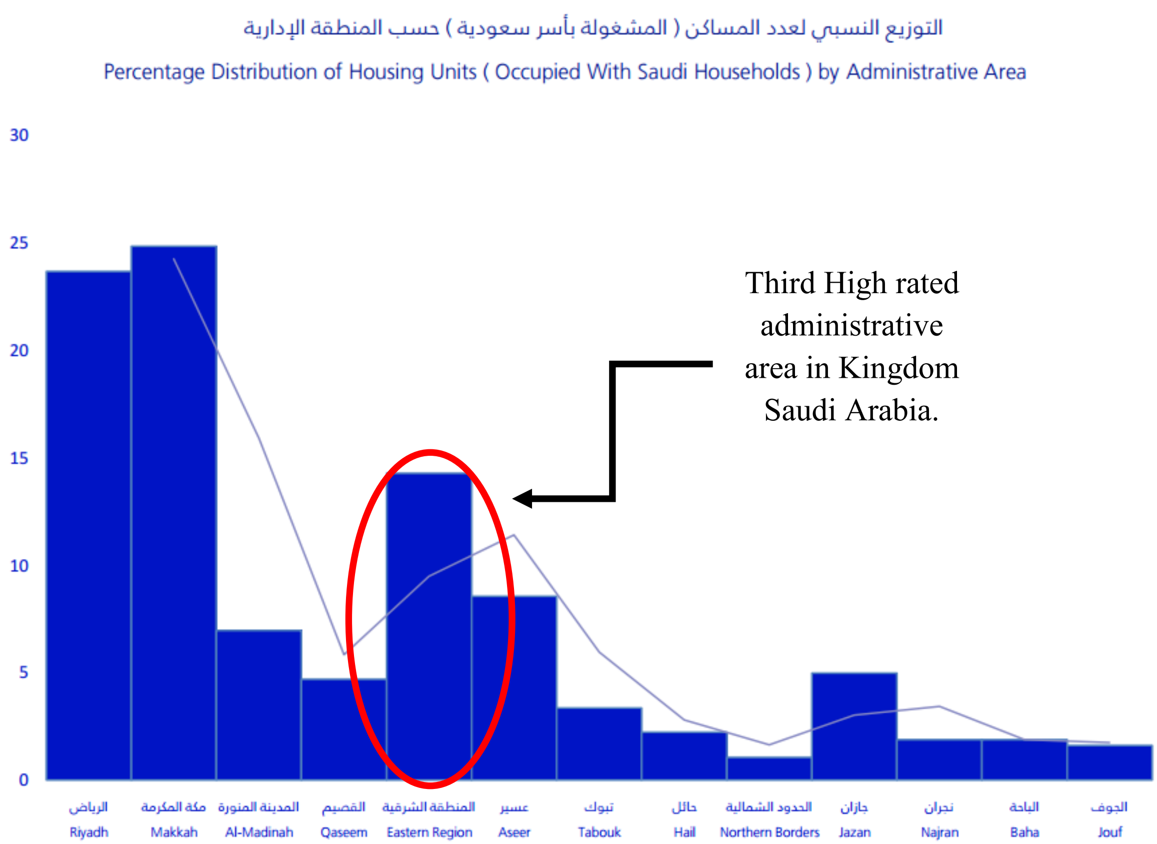


Figure (5) Rating percentage of the high rated administrative areas with Distributed Houses 2017

The previous chart proves as well that the Eastern Provenance is evolving compared to the other areas and from the time it first was established, and according to the Saudi Arabian General Authority for Statics the Housing units distribution (based on housing unit type) have changed in the last two years in the Eastern Provenience (wither to a higher percent than the previous year or less in the new year), Fig (6) .However, the focus of the research was on three cities in the Eastern Provenance, which are:

1. Dammam city.
2. Al-Ahsa city.
3. AL-Khobar city.

To investigate and find the best testing unit that represent the residential buildings that exist in the three cities, the chosen cities were picked due to the following elements:

1. Each of the three cities evolved throughout the history of Kingdom of Saudi Arabia with each evolving a little differently than the other which gives them a historical value.
2. The three cities are the most congested in the Eastern Provenance because of their high percentage of residential buildings.

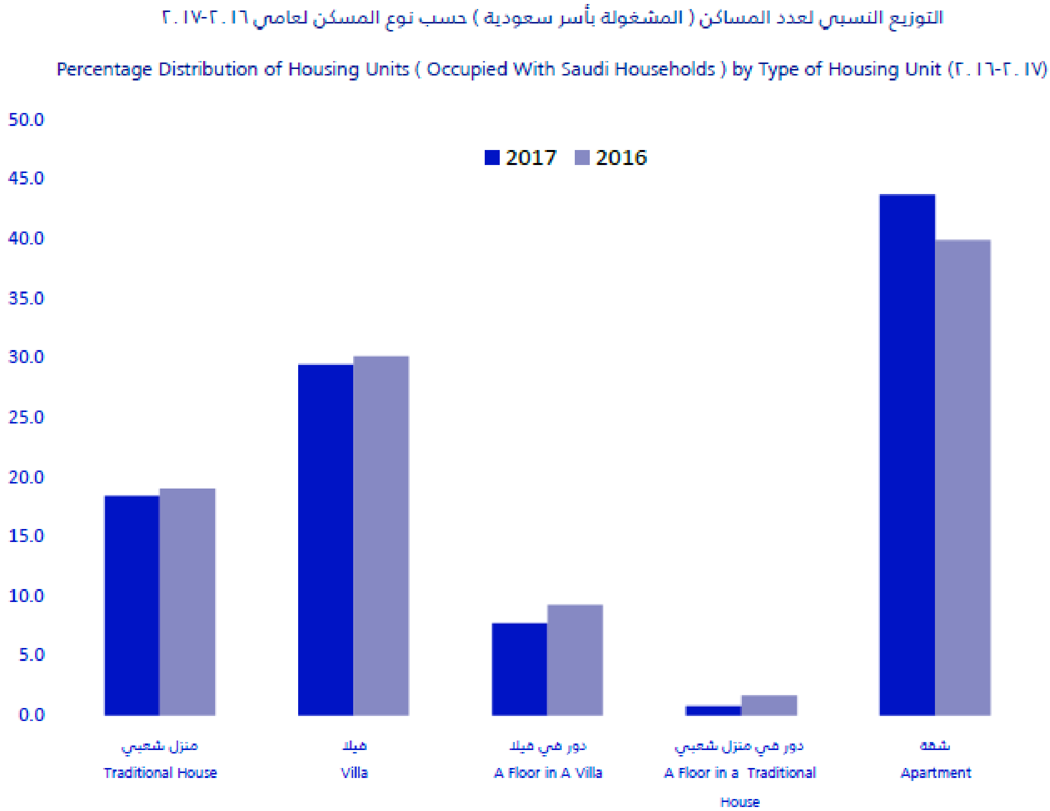


Figure (6) Housing units distribution based on type

the research covered the topic of energy and lighting by performing it on residential buildings, Energy and lighting topic holds a high value in Kingdom of Saudi Arabia, since the country haven't paid much attention to it in the late 90's but with the recent growth in population and economy the country started to take a different approach to start and try to think of methods in order to save energy and lighting expenses that is wasted by the Saudi citizen, the research that was conducted by the Saudi Arabian General Authority for Statics in 2017 revealed that in the Eastern Providence families that lives in villa's are divided into two groups based on their electric source:

1. Public Network group, Table (1).
2. Private Network group, Table (1).

The results of the Saudi families electric uses are arranged as the following:

Villa's in the Eastern Provenance	
Number of Saudi families that belong to the network group	Type of network
162900	Public network
543	Private network

Table (1) Results of the division of electrical sources

The following results suggest that a huge amount of energy is used by families who lives in villa's and use public electrical source which proofs that a massive amount of pressure is applied on the public electrical source by 99.8% compared to the private electrical source with only 0.19%, Fig (7).

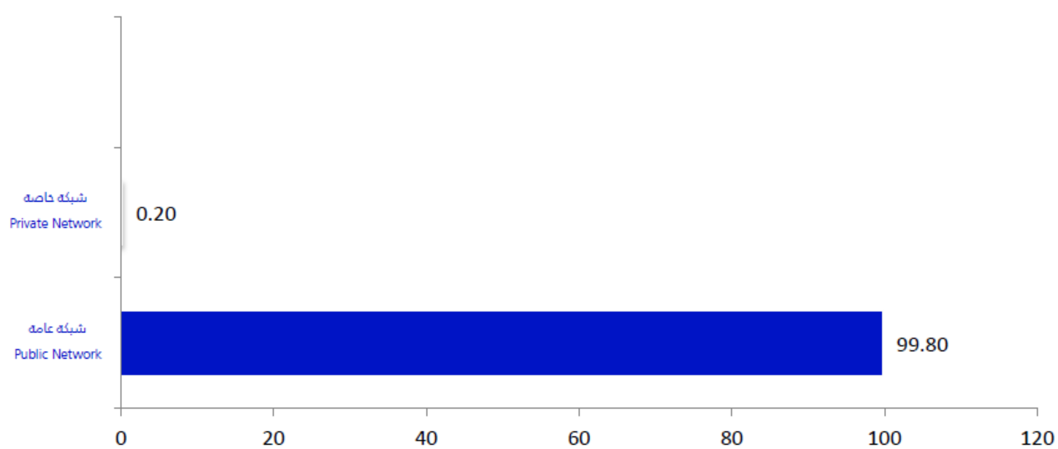


Figure (7) A comparison graph between private electrical source and public electrical source

1.2.1. Reasons behind the high consumption of energy by the Saudi building:

In order to find a solution for the energy consumption and lack of daylighting in Saudi Arabian families, the daily habits that the Saudi families perform without knowing its disadvantages' or the reasons that surround them that might affect as well were listed, which are the following:

1. The lack of a Thermal Insulator being installed within the wall's of the villa.
2. Most Saudi families leave the living room lights on throw out the duration of the normal day.
3. Saudi families usually clean the AC filter once every 2 months, while they are supposed to clean it once every week.
4. Most Saudi families will opt to buy and install lower priced devices to save up money, but the truth is that these lower priced devices consume more energy in the long run than the higher priced devices.
5. Saudi families usually close the curtains of their homes throughout the day and open it in the night due to the high temperatures of the sun most of the year.

Implementing daylighting and energy saving methods can benefit occupants and improve their heath as the following:

1. better sleep: The amount of exposure to daylight can actually affect the normal human sleeping patterns, because the normal body haves a biological clock and the exposure to daylight first thing in the morning can restart it and keep the energy balance in check and notifies the nervous system to shift to its working phase.

2. more productivity: Humans become more active when exposed to high amounts of daylight or better lighting environments, as it minimizes eye strain and decreases fatigue.
3. Prevents (S.A.D) syndrome: High exposures of daylight can help in preventing (S.A.D) or Seasonal Affective Disorder which is directly relate to availability or lack of light in winter, to avoid or cure from it is to design windows that allow high amounts of light to enter the rooms of offices and homes.

Kingdom of Saudi Arabia is sunny most of the year thus providing light, specifically in the three cities that were picked for the research as the three of them have a somewhat similar weather it is good to try and take advantage of that, Fig (8) , Fig (9), Fig (10).

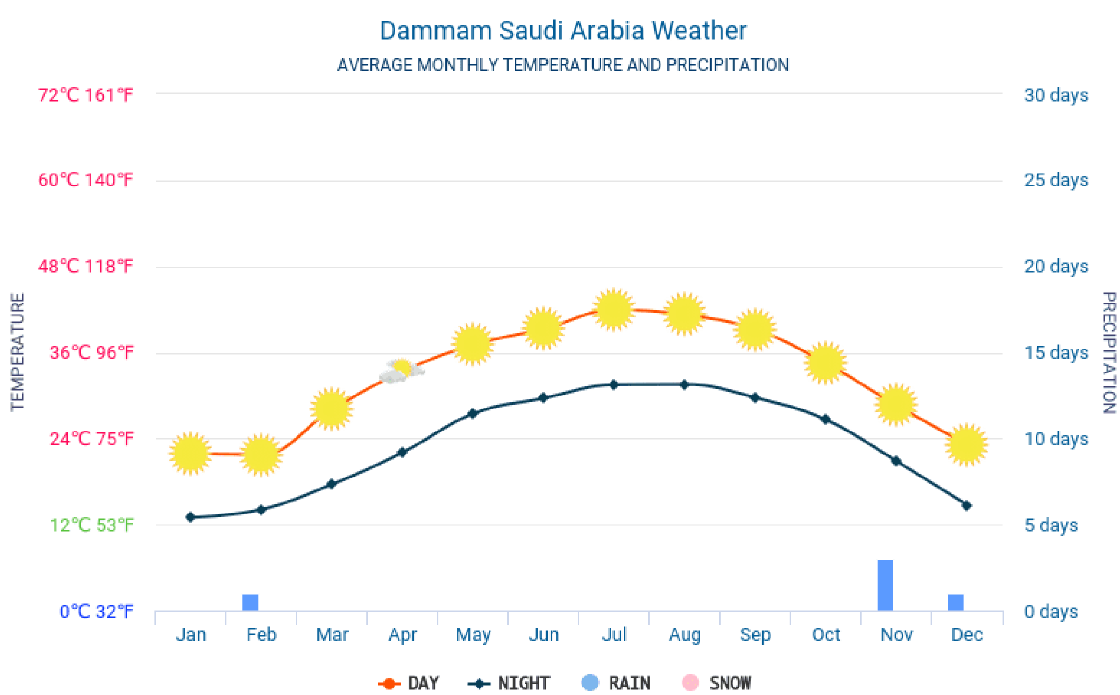


Figure (8) Weather in Dammam city, KSA

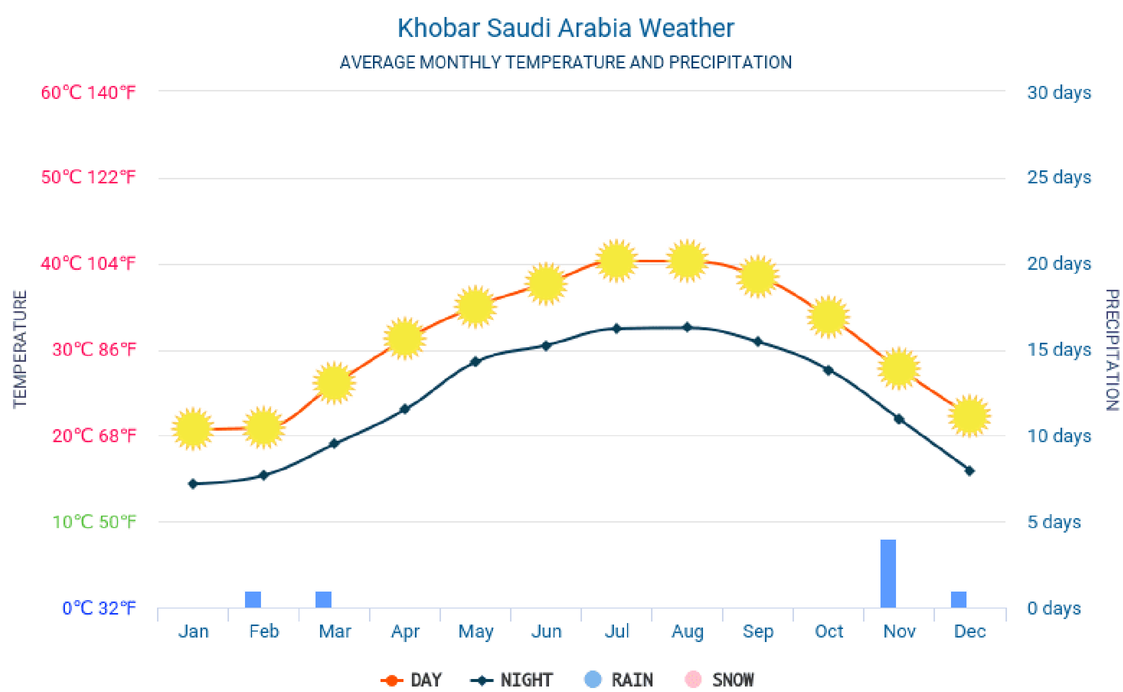


Figure (9) Weather in Al-Khobar city, KSA

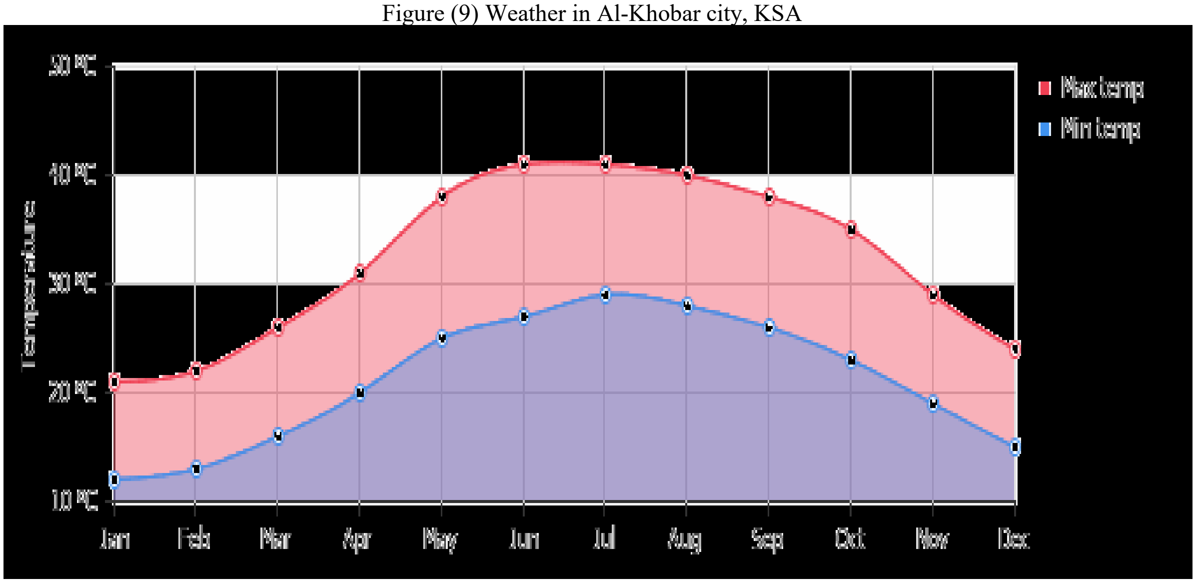


Figure (10) Weather in Al-Ahsa city, KSA

And the fact is Kingdom of Saudi Arabia have ranked the 18th country of Electric Energy Generation (it includes the consumption and loses of energy) by 204,200 GWh/yr which proves the country's need for more energy saving methods, the reason why is because most of residential buildings use huge amounts of energy and lighting, the type of residential buildings that was chosen was villas and the reason why is because most Saudi Arabian families will opt to get one taking in consideration it gives them a higher level of privacy by owning an area to themselves, haves a longer life span than apartments and more cost efficient when it comes to maintenance as a villa will only need a yearly maintenance but an apartment will need a monthly maintenance.

1.3. Statement of the Research Problem

Villa's are the second highest housing unit in Kingdom of Saudi Arabia, with the total number of 1031647 villas occupied by Saudi Arabian families, which means a total of 24.99% from the total housing units occupied by Saudi families in the year 2017, resulting in the high consumption of electric energy of the general network that is being used by the Villa occupants by 643448 which can result to a shorter life span for the building itself and health issues for the resident. Therefore, this thesis will study the consumption methods done by the occupants in order to implement an affective daylighting method that can save electricity and reduce energy consumption.

1.4. Significance of the Research

The findings of the study will provide reference and guidance for the subsequent standard for residential building design for an acceptable indoor environmental quality and energy efficient under a hot climate in KSA.

1.5 Research Objective:

The main objectives of the research are to:

1. Assess luminous environment of residential buildings in KSA under a hot climate by adding sufficient amounts of daylight.
2. Evaluate energy and daylighting performance of design variables considering daylight comfort level and energy saving.
3. Establish an energy efficient daylighting residential building design guidelines under a hot climate in KSA.

1.6 Scope and Limitations:

The thesis has faced the following limitations:

- The measures that will be used in this study will concentrate on residential buildings under hot climates in KSA in the designing stage.
- The testing unit will be based according to the results acquired from the survey and interview results under the name of the conventional characteristics of villa located in KSA.
- while simulating the building, it will only be measured according to the results or data we have collected.
- Some significant modifications might be applied to the study sample to aid in achieving results that will save energy.

1.7 Research Methodology

1. A comprehensive of literature review to figure out the relationship between daylight percentage and energy saving by daylighting systems and design variables.
2. A field occupant survey answered by residents in residential buildings in KSA to quantify daylighting comfort and interviews with specialists to identify the ideal parameters and designs that represent the ideal villa.
3. Assess daylighting and energy performance with design variables by using a couple of simulations to optimize daylighting system balancing both daylighting comfort and energy efficiency.
4. review the results and create a set of recommendations based on it.

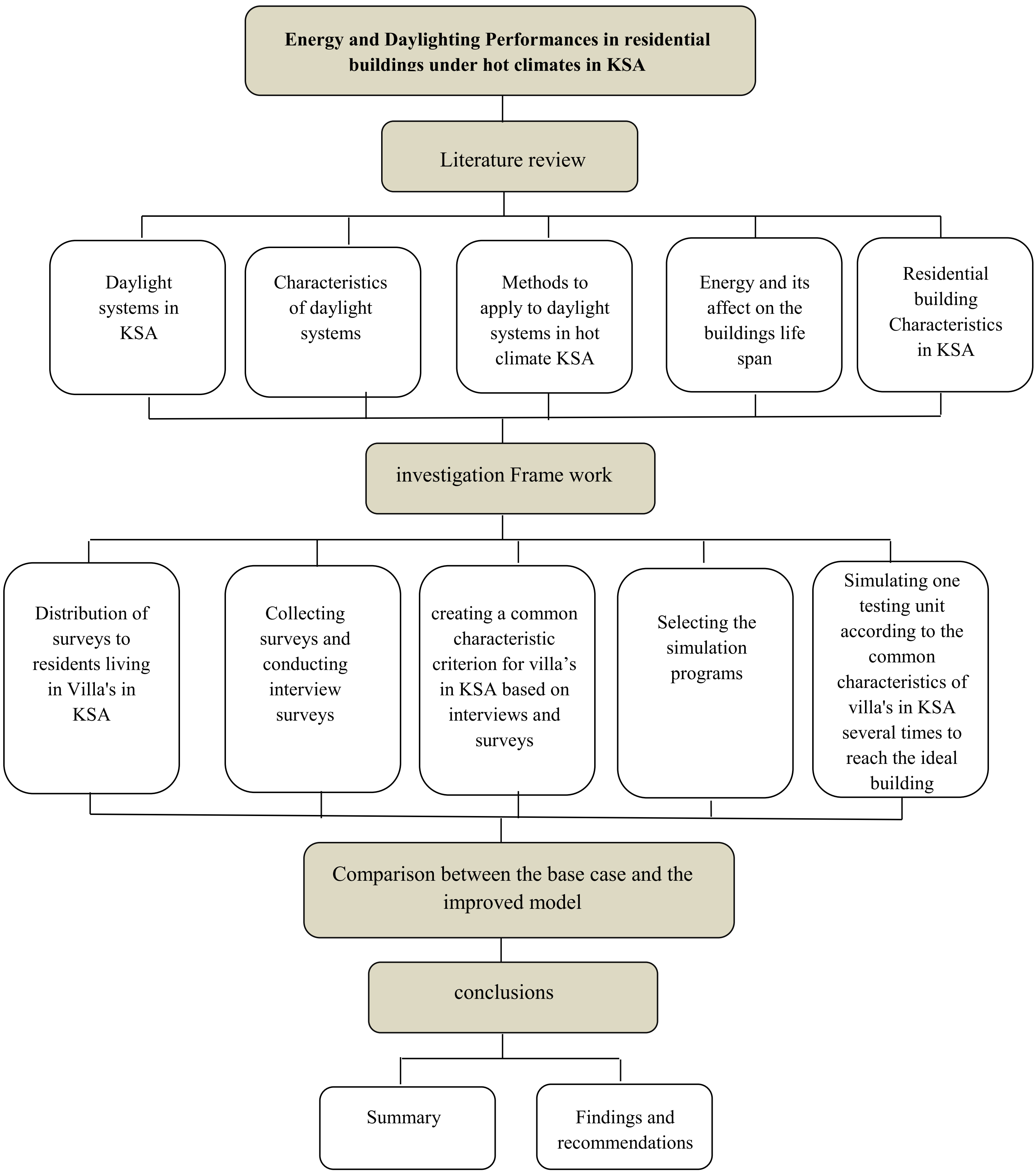


Figure (11) A map of the research methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Theoretical background:

2.1.1 Daylighting availability and sources:

A foreseeable manner of an amount and orientation of obtainable daylight is made by the usual and daily movements the sun does with esteem to a specific geographic area on earth. An addendum to the foreseeable manner, different results are produced due to the changing weather, air contamination and temperature. Around 40% of earths solar energy is a visible ray, the rest is divided into two types:

1. (UV) Ultraviolet.
2. (IR) Infrared **(IESNA, 2000).**

2.1.1.1 Sources of daylight:

The amount and the quality of available light for lighting in any building is defined by the regions climate condition its located in. Patterns of available daylight are to be changed by elements such as neighboring landforms, formations and vegetation. The different conditions of light can perceptual different environments and architectural environments.

<u>There are three basic daylight resources:</u>

1. Widespread light through clouded or slightly clouded skies.
2. Outright sun light through partially or clear skies.
3. Reflected through natural or manmade light.

- ❖ **Light as a source from the sky:**

The sun rays pushes through the earth's atmosphere, a fraction is sparse by dust, water halitosis and other particles. The sparse acting in cooperation with clouds equals sky light, Skies are divided into three types:

1. Clear sky.
2. Semi cloudy sky.
3. Cloudy sky **(IESNA, 2000).**

The amount of sun rays apportionment could change depending on the sky condition, if the sky is semi cloudy, the sun rays apportionment is different from one area to the other, if the sky is cloudy, the sun rays are either overshadowed by the clouds or reflected weakly on surfaces **(Egan, 2002).**

- ❖ **Direct sunlight:**

Semi cloudy skies are also semi clear, sunlight and clear skies each perform differently even when together in comparison to semi cloudy skies. In the clear skies, the sun itself is the main source of light, but it cloud be affected by the air thickness or mass, which is in turn affected by atmosphere and solar altitude **(Egan, 2002).**

- ❖ **Reflected light:**

The sun rays light up surfaces, which leads to the creation of second light sources. Colored surfaces then are considered the second brightest light source after the sun in this situation, however in sunny days they are considered the predominant source in the area.

Light could be reflected from the ground in certain occasions is considered important too, for example, light reflected from the windows to the furniture represents 10 – 16% of the light that comes through said window **(IESNA, 2000).**

Perpendicular inverted light is plentiful on shady building sides, Perpendicular inverted light is in its highest impact regarding solar light when it's at low sun angularity, such as winter seasons and high altitudes **(Egan, 2002).**

2.1.1.2 availability of daylight:

Calculating light can be remarkably complicated when it comes to daylighting compared to artificial lighting situation. Definition of accidental light on skylights and windows must consider time related characteristics of the sky and sun, while taking in consideration the locative relationship between daylighting openings such as windows in housing units and the sun.

To sum it up shortly, availability of daylight could be defined as the amount of light given from the sun and sky to a certain location, in a certain time, sky state and date **(IEA, 2000).**

Availability of daylight data and neutralization produces values that are not immediate, due to that immediate light maybe different exceedingly when compared to calculative methods according to availability of daylight. To calculate availability of daylight in a certain location, there is certain values that must be specified, which are **(IESNA, 2000)**:

1. <u>The location of the site:</u> a value that is easily obtained from any atlas.
2. <u>Time:</u> heliacal time is specified from the standard normal time(time of daylight), by the correction of both the site longitude inside of a time frame of a zone and time equation.

3. <u>The solar position:</u> the determination of the sun position be specifying the solar altitude and azimuth.
4. <u>Sunlight:</u> Considering the sun as a source point that supplies constant light in a point at a specific place that is deemed normal to the sun usual direction and near the orbit of earth.

2.2 Previous studies:

2.2.1 Balancing energy and daylighting performances for envelope design: A new index and proposition of a case study in Hong Kong:

The study was conducted in Hong Kong, China year 2017. The aim of the study was to find a balancing point between energy and daylighting performance through the execution of a simulated work and a questioner.

Hong Kong is considered the highest populated city in china thus conducting the study in it can majorly benefit in the results it might produce, thus resulted in the high consumption of the two main elements in current living conditions which are creating both a livable, energy and daylighting efficient buildings, which lead to the surfacing of three questions:

1. Should energy consumptions be reduced to the lowest rate possible?
2. Can the lighting comfort environment be quantified ?
3. How to create an energy efficient method according to lighting comfort environment?

Thus, in order to design an energy efficient lighting, we have to reduce the energy consumption static or dynamic façade features that are often adopted for envelope design, An automated control strategy of inside slat-type blind was proposed while taking in consideration visual comfort, and an energy saving of 24.6% could be achieved. The sensitivity analysis have concluded a window to wall ratio and slat angle as highly influencal factor for energy performances regardless of the façade orientation, as well as weather changes have been found to be an affecting factor.

a previous research before this one have proved that 10% of energy consumption can be fixed by changing the windows size, except when it comes to energy saving then it is advised by the Hong Kong government to implement façade features (balconies, sunshades and reflectors), thus concluding the first question answer that it is understandable to lower the environmental pressure under reasonable comfort conditions. And in order to answer the two other questions the researcher tested the quantify luminous comfort that was achieved throw the questioner and simulation work, The benchmark of this metric will be established for high-rise residential buildings.

The questioners were issued throw mail and was used in a high-rise residential buildings and 108 applications proved sufficient to be used leading to reveal specific existing data such as floor level, shading devices. etc, Fig (12).

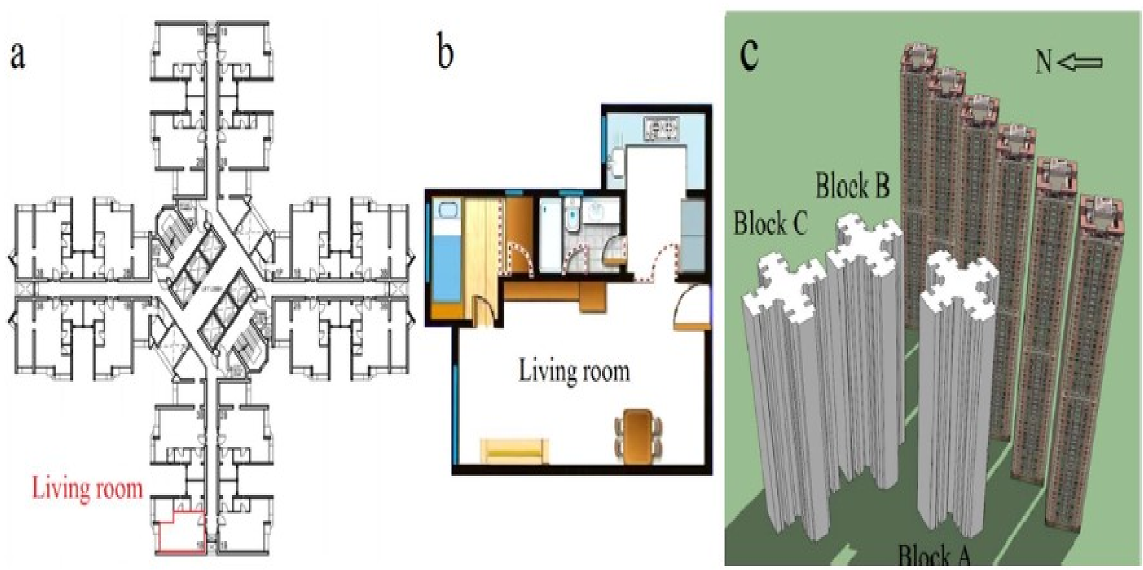


Figure (12) Simulations based on the questioner results

However, when using the simulation program a building model was made with 40 storey's and 16 units on each floor level according to the real conditions, and to determine the difference between every unit a group of (3x3) of building blocks is built, which is closed to real condition and The center block is the target building which the units are built in, Fig (13).

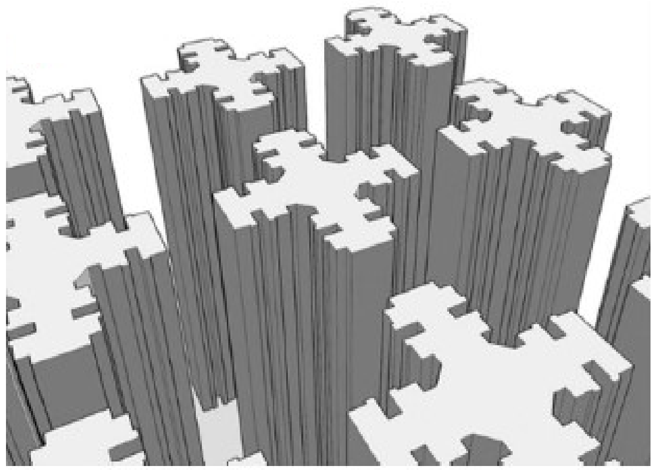


Figure (13) Example of the distributed simulation units

Since there is 640 units in every building block it is important to study the daylighting and energy performance of the basic units, the basic units are built based to the features of the unit except when it comes to the orientation and floor level then it differs because the neighborhood rooms are divided based on the self-shading which leads to the separation of the 16 units into two groups, Fig (14):

1. inner ring: which is more sensitive to self-shading, contains eight units.
2. outer ring: which is not so sensitive to self shading, contains eight units.

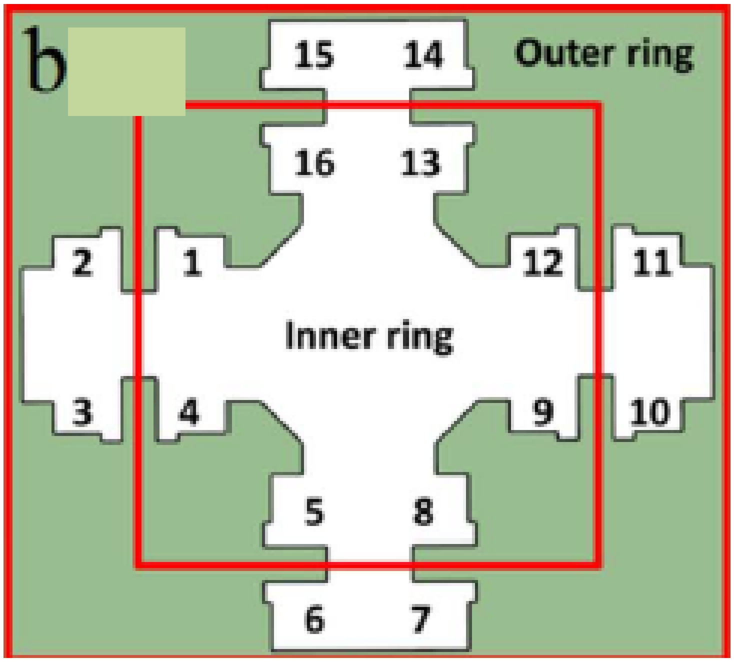


Figure (14) A figure that explains how was the units distributed into two groups

In the end there will be 96 combinations of different units with each unit the daylighting and energy performance will be different from one another, Fig (15). in order to do the simulation program that will be used is Dayism and EnergyPlus.

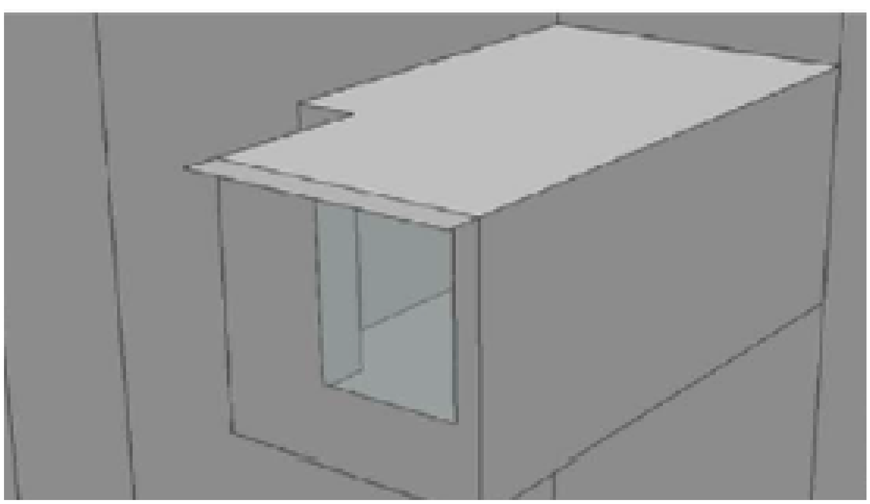


Figure (15) A figure that shows one of the units living room

Based on the methodologies that were used to conduct the study, the results led to the study of the existing relationship between objective daylight metric and subjective feeling.

The first methodology the survey used the leveling approach of (1: strongly dissatisfied; 2: dissatisfied; 3 neither dissatisfied nor satisfied; 4: satisfied; 5: strongly satisfied), as well DA300 presents a strong relation with luminous comfort level. This trend can be described as narrow scope at the high comfort level side and wide scope at the low comfort level side. The value of this metric is relative concentrated from the residents with the highest luminous comfort level, and this scope becomes wider with the decreasing of the comfort level, Fig (16).

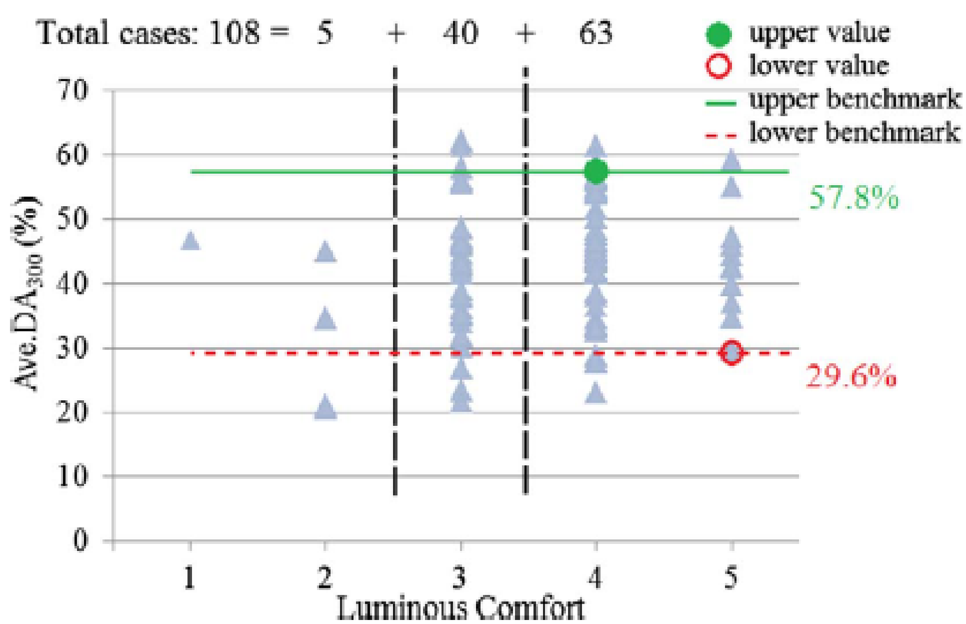


Figure (16) A two sided relation between lighting comfort and Ave. DA300

DA300 was achieved through the simulation of Dayism, which it was proven to represent the daylighting comfort level from the real site questioner , as well as all of the Ave.

DA300 results in 96 cases are shown in, Fig (17). Each group contains 16 units in a certain ring and a certain distance among buildings.

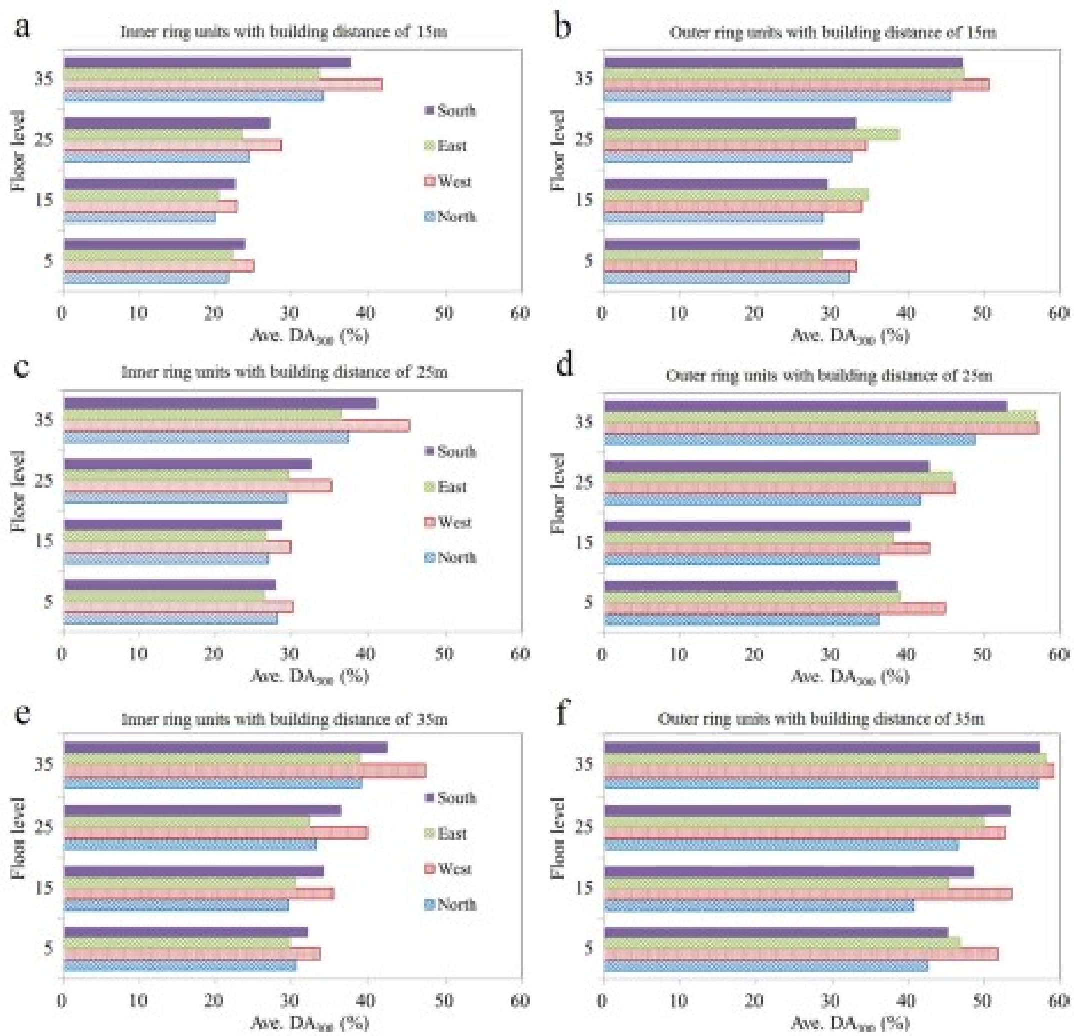


Figure (17) Ave. DA300 of all the cases

In some other high-rise residential buildings, some outer units and high floors might need to shade the excessive amounts of lighting that enters the room , however in public housing it is needed to prohibit direct sunlight and solar heat gains by merging the public housing with overhangs outside each units' living room to perfect the performance of the overhang, two scenarios are proposed based on the dimensions of the configuration, Fig (18).

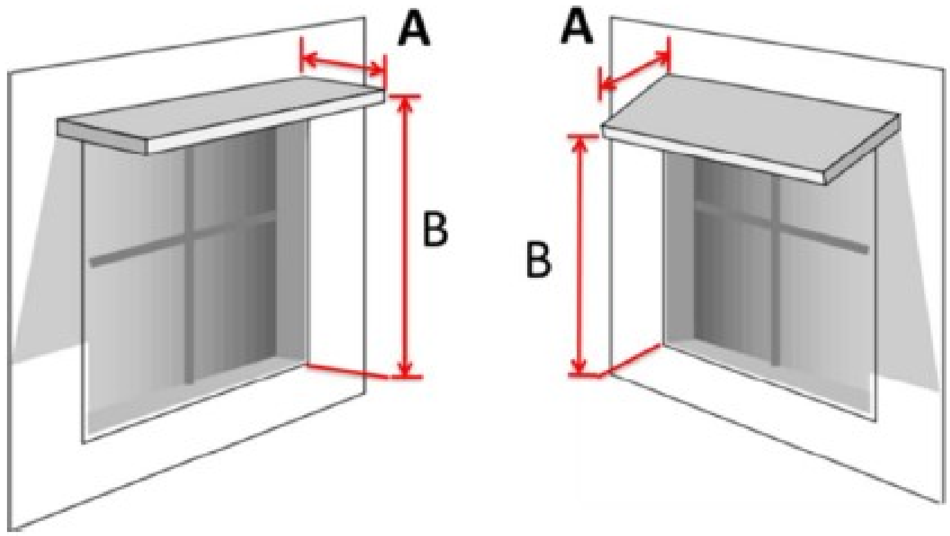


Figure (18) Arrangement of an overhang

In the end a set of results were concluded as the following:

1. The tested unit that face the directions of west and south face higher levels of Ave. DA300 and exhaust more AC power, In the other hand northern units gain the lowest benefits of Ave. DA300 and the eastern units always process the lowest annual lighting energy.
2. providing a supplemental window opening is a greater method than increasing the single window size for all orientations, so it is preferable to open a second window opening in the units living room, regardless it is was big or small.

3. extending the overhangs will settle the daylighting performance and luminous issue by reducing their performance, as it is a much better method than making the overhangs titled down.
4. Embracing shading systems for the units facing north will lead to growth in lighting energy, as well as the energy exhaustion. Which leads to the need to use internal shading in place of any other shading scenario's for envelope design.

Throw out the whole research of indoor daylighting and energy performance, another issue-glaze property was not addressed, thus it could be used later in future researches to help choose a suitable glazing type in future researches.

2.2.2 A study of the daylighting performance and energy use in heavily obstructed residential buildings via computer simulation techniques:

The study was conducted in Hong Kong, China year 2006. The aim of the study was to simulate solutions through energy plus simulator on excitant residential flats that are confronting many large sky hindrances, since most of the buildings are built very built very close to each other to accommodate to the high rising rates of populations it lead to the finding that said buildings have less than the normal needed exposure of daylighting throughout the day which results on the users relaying on electrical methods of lighting.

The researcher has estimated the daylighting performance based on (DF) Daylighting Factor, and in order to study the simulations correctly he have divided the (DF) into five elements:

1. Building area and orientations:

   it was established that in Hong Kong, there is a strong orientation influence on outdoor luminance rooms that are directed to the south or south-east receive huge amounts of light and for long hours which proves to be useful and common.

2. Glass type:

   Glass and tinted glass with common light transmittance rates of 0.85 and 0.5, and are usually used in residential apartments, with a common rate of thickness of 5-6mm,with a recent growing interest in using for residential areas.

3. Window area:

   It is well known as Window-to-Wall ratio (WWR), which as acknowledged as the ratio of the total area of window to the overall gross external wall area (including windows), however, residential areas with lower population density tend to have much bigger windows than the high populated areas with (WWR) of 35%.

4. Shading:

   Shading tools shade windows to prevent sun light from breaking through but allow common daylight throw. Thus, projecting windows can expand the room space and magnify the total space without the (WWR).

5. External obstruction:

   This element affects daylighting in two situations:

   a. Amount of sky light being blocked or not.
   b. Color of the outer surface that can be considered as reflected light from the blocked buildings.

After wards, the program Energy Plus was used and the reason why it was picked for the research was because of its accuracy and its ability to provide a lot of options when it came to designing features, as well as its ability to fenestration In total, four sky types with three non-isotropic luminance patterns based on empirical models included.

The study sample (residential high-rise building) layout has been studied which resulted in the conclusion that most of residential high-rise building have 4-8 rooms flats per floor due to the parallel design, it makes little to no change in the building orientation design, Though the building that was used in the simulation program haves 6 flats per floor which is the most basic design in Hong Kong, Fig (19).

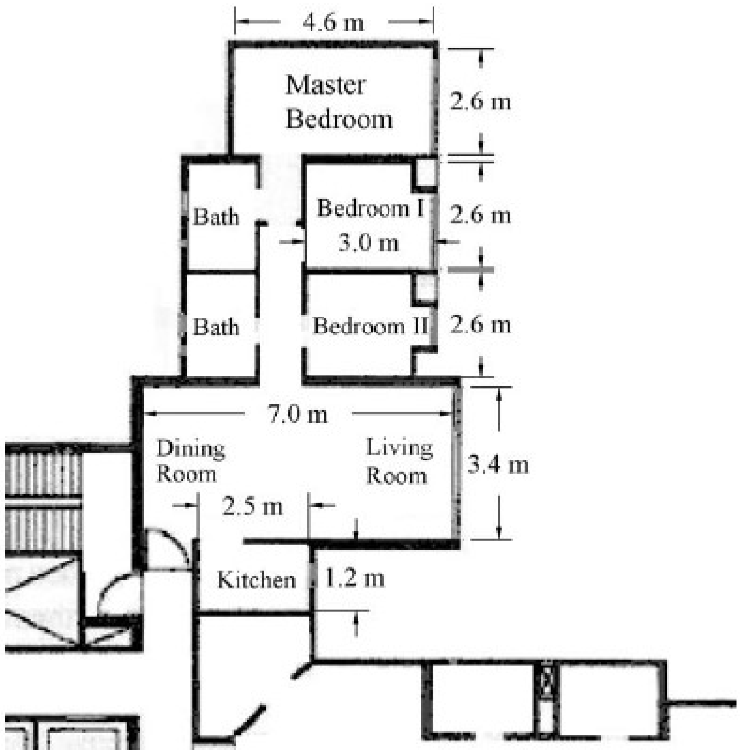


Figure (19) An example of the basic local unit

In the following table, the researcher have listed the parameters of daylighting calculation, Table (2):

	Living room	Master bedroom	Bedroom A	Bedroom B	Kitchen
Width (m)	3.4	2.6	2.6	2.6	1.2
Depth (m)	7.0	4.6	3.0	3.0	2.5
Height (m)	2.7 for all rooms				
Glass area in the window (m^2)	3.7	2.6	2.2	1.6	0.7
Window sill height (m)	0.85 for all windows				
Transmittance of the window including frames	0.6 for all rooms				
Average reflectance of the interior surface	0.5 for all rooms				
Reflectance for ground and external obstructions	0.2				

Table (2) parameters of daylighting calculation

The simulation program itself manages hour-by-hour procedures by using 8760 hours of previously measured weather data, though the data itself changes from a year to another thus the need to create a weather database arises.

Throughout the research calculations, A progressive reoccurrence classification of the indoor lighting can signal the percentage of the working year, thus it was conducted on the hour-by-hour simulation of the interior lighting for living/dinning room of the top floor, Fig (20).

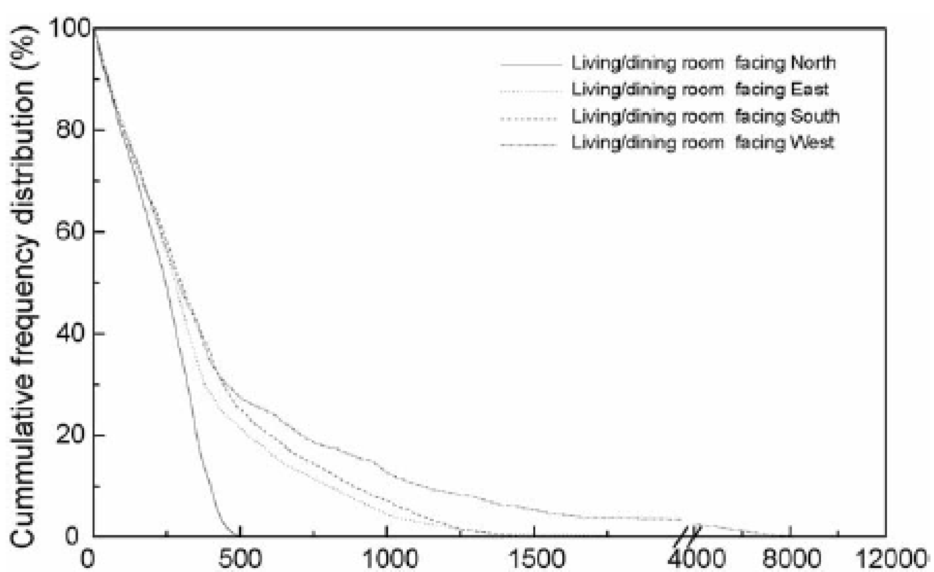


Figure (20) results of hour-by-hour simulation of the living/dinning room

By the end of the study the research has concluded that the indoor lighting standards in the kitchen and dining/living room on the first floor were below the normal level most of the day, which leads to the conclusion that most of high-rise residential buildings flats have low and poor daylighting which leaves them to depend on artificial light.

2.2.3 A Study on Window Configuration to Enhance Daylight Performances in Apartments of Dhaka:

The study was conducted in Dhaka, Bangladesh year 2015. The aim of the study was to windows arrangements in Dhaka residential stored buildings to reduce electrical expenses by using questioners and simulations made by: ECOTECT, DAYISM and RADIANCE, and to estimate and compare the impact of different sized windows on daylighting.

The researcher has picked a four stored building to conduct the study in with only one street in front of it that goes straight, Fig (21).

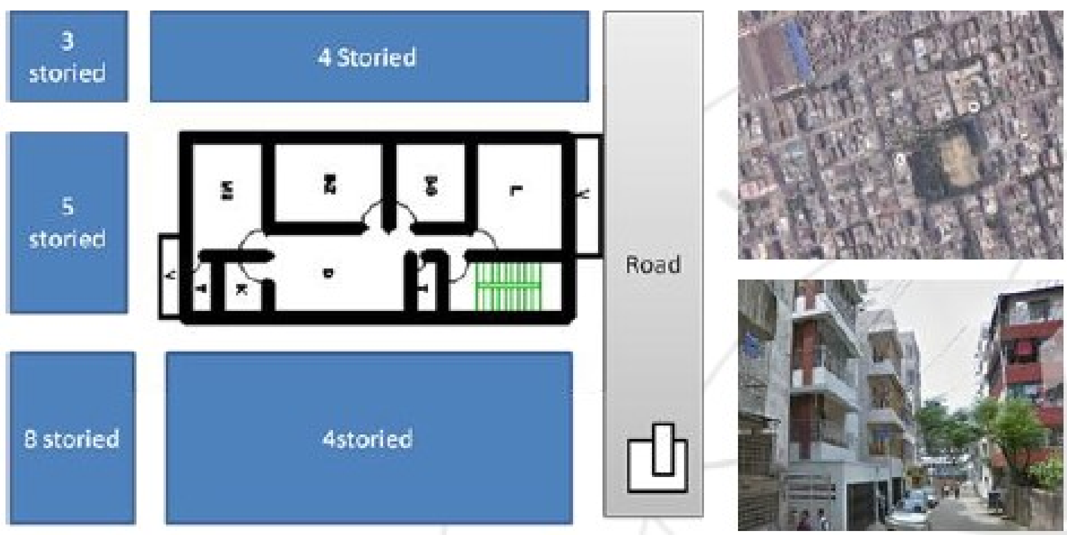


Figure (21) Location of the case study/sample and site

A bedroom was used that is located at the south side of the first floor with two windows direct to the south and the door located north of the room, the bed is directed to the point 2C in the grid, Fig (22).

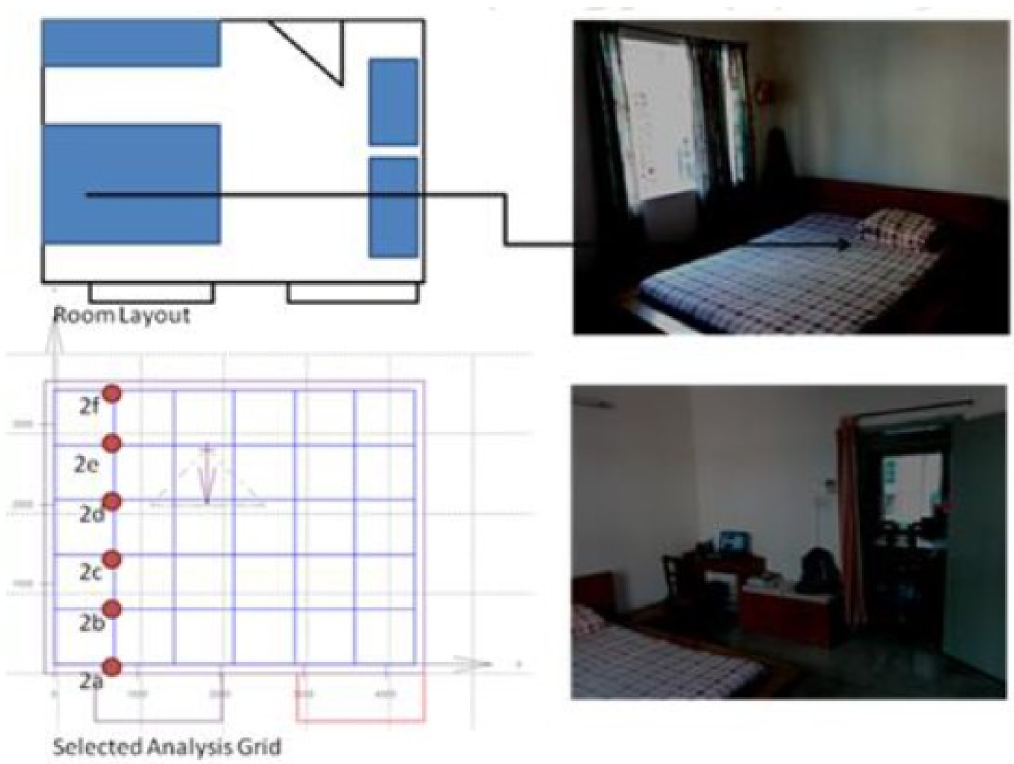


Figure (22) Room design that was picked for the case study with selected analyses grid

The room that was picked for the study was simulated digitally into the simulation programs, while changing the windows arrangement based on a previous literature review and so various models were created, and even through windows are important for daylighting analysis, glass types was involved into the simulation study as well.

Visual attributes and applied simulation parameters in Dayism are organizes into the following Table, Table (3), (4).

Model optical surface properties Building element	Surface optical properties
Window	Double glazing, 0.78 light transmission
Ceiling	85% reflectance
Internal wall	75% reflectance
Floor	60% reflectance
External Wall	45% reflectance

Table (3) Physical attributes of the case space that was used in the simulation program

Ambient bounces	Ambient division	Ambient sampling	Ambient accuracy	Ambient resolution	Specular threshold	Direct sampling
5.0	1000	20	0.1	300	0.1500	0.200

Table (4) Applied simulation parameters in DAYISM

The assessments were based on the following parameters:

- ✓ Location: Dhaka (longitude: 90.4125° E; latitude: 23.8103°N).Time: 6:00 AM – 6:00 PM (12 hour) for the whole Year.

After using Radiance and Dayism simulation programs, it was found that changing the windows arrangement improves the lighting status in all simulated four cases, Fig (23).

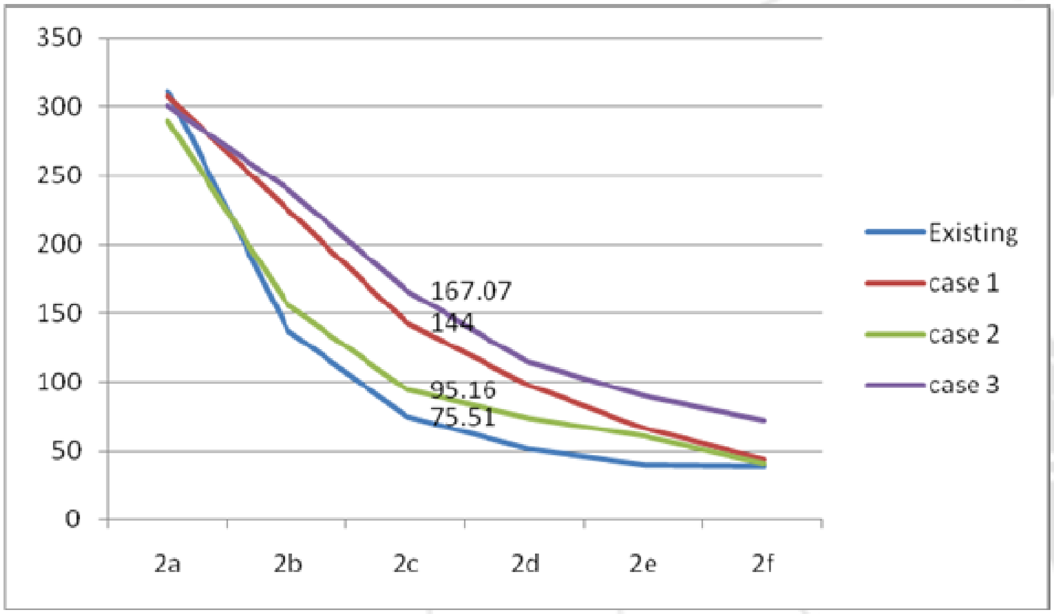
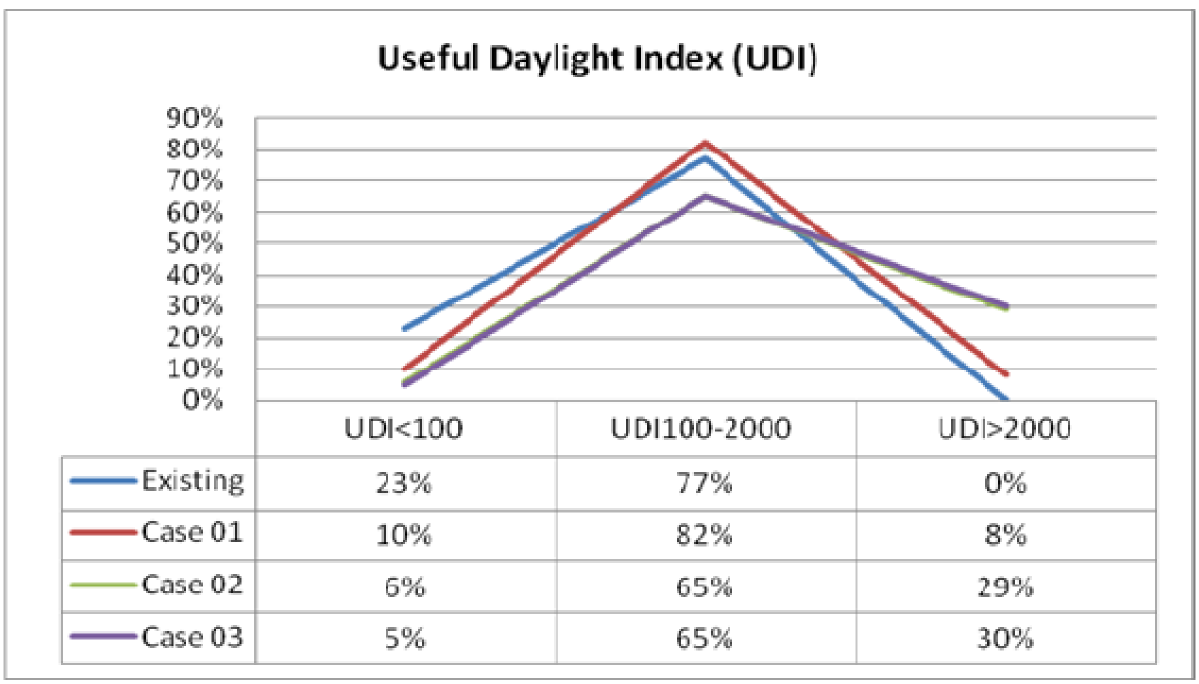


Figure (23) Results of the simulated four cases

And through Dayism simulation program, a comparison was extracted that analyses the Useful Daylight Index (UDI), Fig (24).



	UDI<100	UDI100-2000	UDI>2000
Existing	23%	77%	0%
Case 01	10%	82%	8%
Case 02	6%	65%	29%
Case 03	5%	65%	30%

Figure (24) Useful Daylight Index comparison results

By the end of the study the researcher has concluded that by lowering the window sill and height which reduces the density and uniformity, however installing a high window where shading can become a light shelf allowing light in all the while improving both the lighting standard and its likeness, though further studies are advised in the future.

2.2.4 Analysis and prediction of daylighting and energy performance in atrium spaces using daylight-linked lighting controls:

The study was conducted in Hon Kong, China year 2012.The aim of the research was to high light and proof the importance of daylighting in decreasing visual disturbance and to minimize the use of electricity by the reasonable use of daylighting equipment like photoelectric lighting controls which can influence any buildings electrical use by decreasing it.

The academic building that was chosen for the study was a targeted-built building with 13 floors, located in a manufacturing area in Hong Kong over the southern shore in the semitropical district with the latitude of 22.3N and the longitude of 114.2E, surrounded in three directions (north, south and west), a highway facing the east, a skylightand a surrounded atrium to gain daylight and naturalistic ventilation by environmental saving measurements, Fig (25).

The building skylight shapes 40% of the plan area obstruction (PAO),(PAO) is known as the proportion or percentage of the roof blockage that is being viewed perceptively with a central point of infinity, fig (26). The decrease of light is due to the glazing which ranges around 20% (10% structure and 10% glazing).

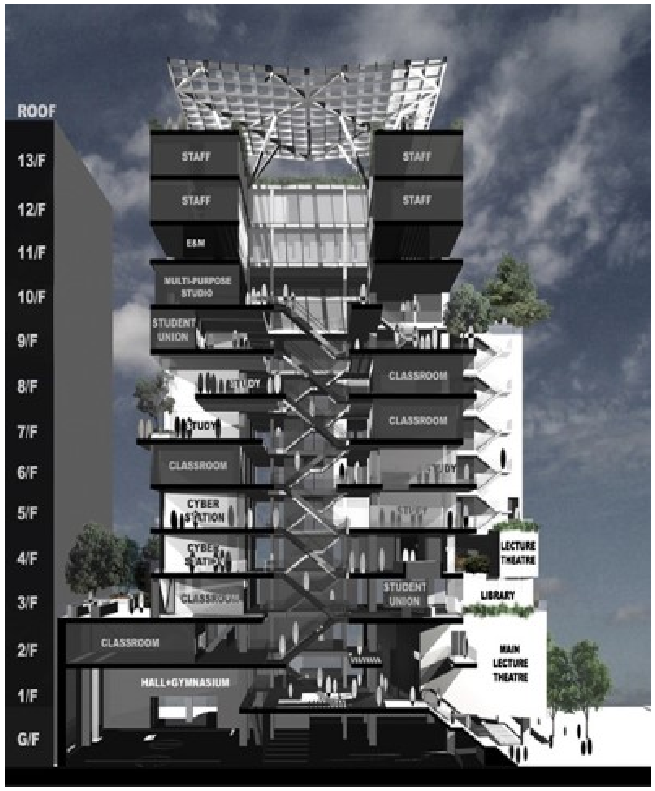


Figure (25) A vertical view of the building of choice

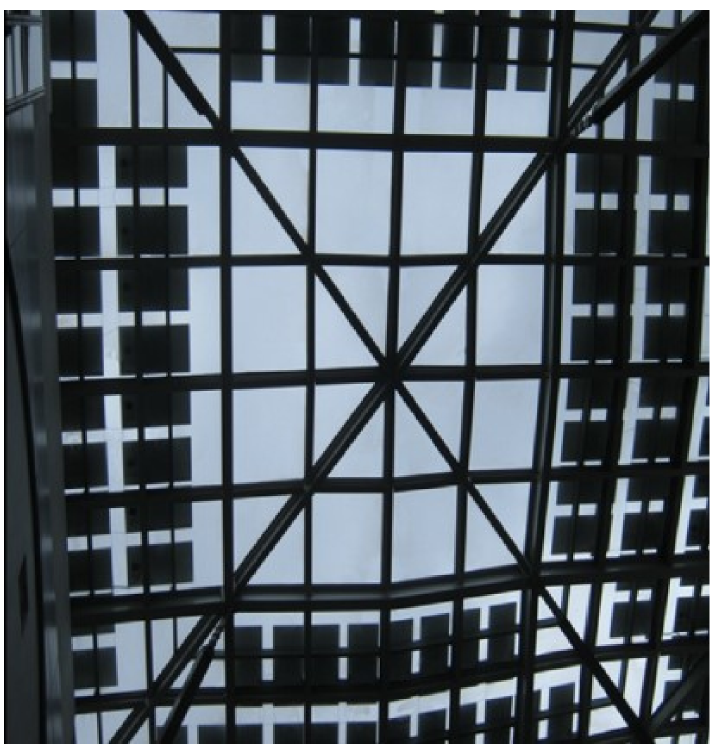


Figure (26) A view of the buildings skylight and plan area obstruction

The researcher used the ninth floor hallways at first to evaluate the daylighting execution and energy based on lighting linked daylight controls, the atrium hallways were used to circulate a lighting system that includes 67 ceiling-mounted, energy-efficient T5 fluorescent tubes that is regulated electrically ballast that can lower the lamps light easily and regularly by a dimmable high frequency through various classrooms in the ninth floor, with a power that is rated between 14 W to 35W range, Fig (27).

The lighting/luminance levels of the electrical light were measured at night (at 8:00 pm) when occupants were mostly going to use them and active in the hallways, the hallways of the ninth floor were four, in the middle of their way were recorded and lighting/luminance was about 200 lx.

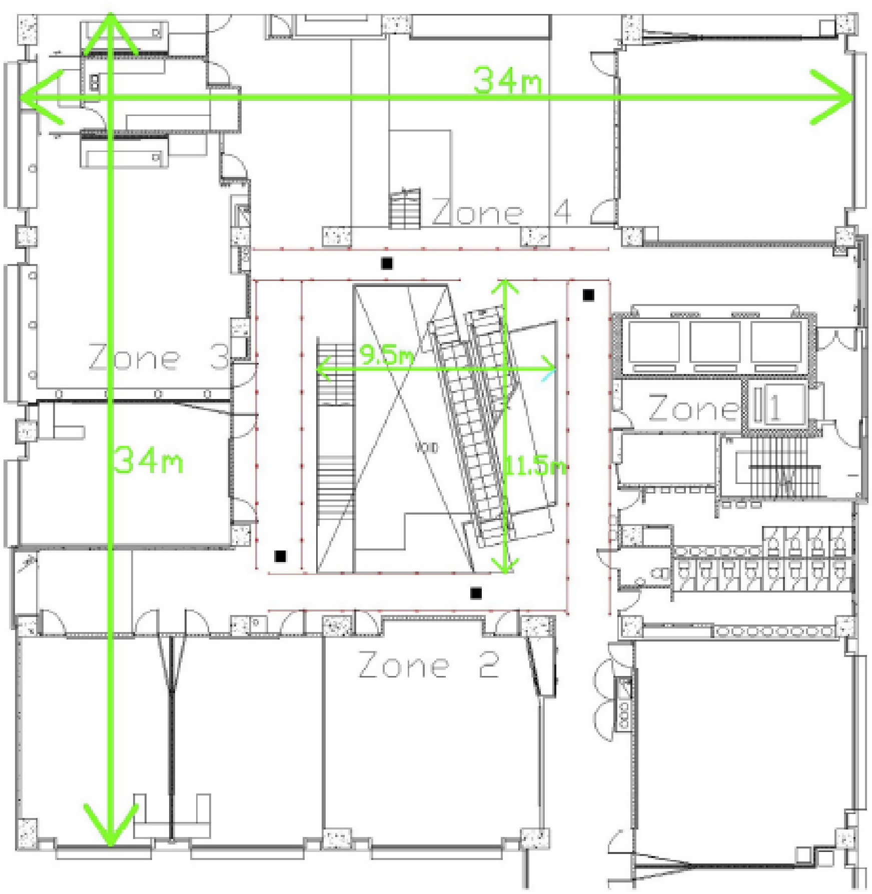


Figure (27) A plan of the photoelectric sensors located in the ninth floor

To measure the accurate minimal pre-set light levels throw the hallways, a photoelectric adjustable sensor with a range measure or 4 - 1600 lx was assigned on each of the four hallways to record strength of the light with the distance of 15.4 m between the atrium and the sensors, which resulted in finding reflected light and daylight the forms a closed circulation control that is dim, and to the hallways being narrow a single-area control was considered efficient.

The lighting/illuminance levels were recorded every day from 9:00 am to 6:00 pm as well with the separation of five minutes between every record from January to June 2012, thus the researcher have discovered that the daylighting illuminance begins to increase in the morning and reaches its highest peak in the noon and beings to decrease in the afternoon, Fig (28).

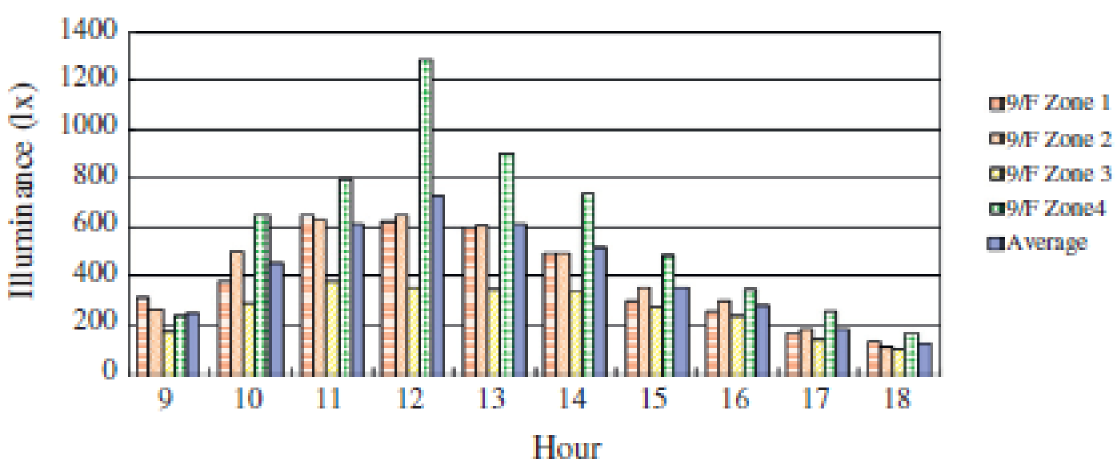


Figure (28) A graph that explains the hourly change of daylight illuminance

In the other hand daylighting illuminance was measured from January to June as previously mentioned which lead to the discovery that daylighting illuminance, from January to May the heat rose up due to the lack of rain, however when the time frame reached June the heat decreased due to the high chances of rain.

The lighting in the forth zone was higher in the other zones that were tested monthly with the maximum of 887 lx in month May and the minimal of 222 lx in the third zone through January, Fig (29).

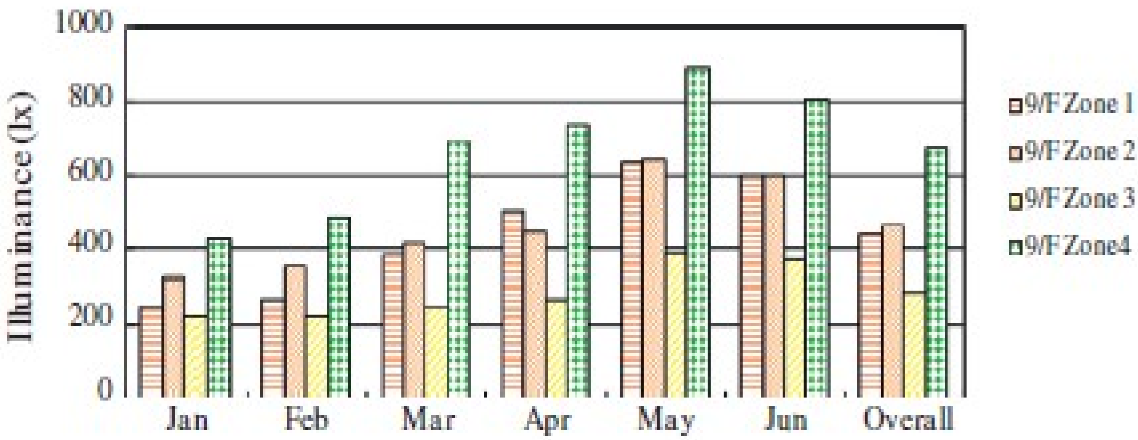


Figure (29) A graph that explains the monthly change of daylight illuminance

Generally speaking, the daylighting illuminance in all four zones ranged from 267 lx in the third zone to 658 lx in the forth zone, which concludes the total illuminance was at 452 lx, which indicates that third zone illuminance levels were the lowest in all the zones, probably due to the lift room which is located in the eastern area of the roof ,Fig (30).

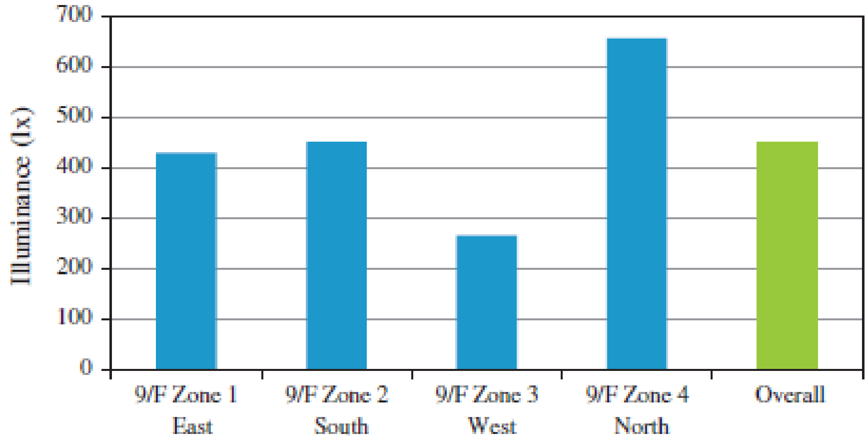


Figure (30) A graph that explains the general change of daylight illuminance

The researcher have distributed photoelectric light sensors throughout the other floors to check if the results were the same which resulted in a some similar range to the ninth floor if not lower, fig (31).

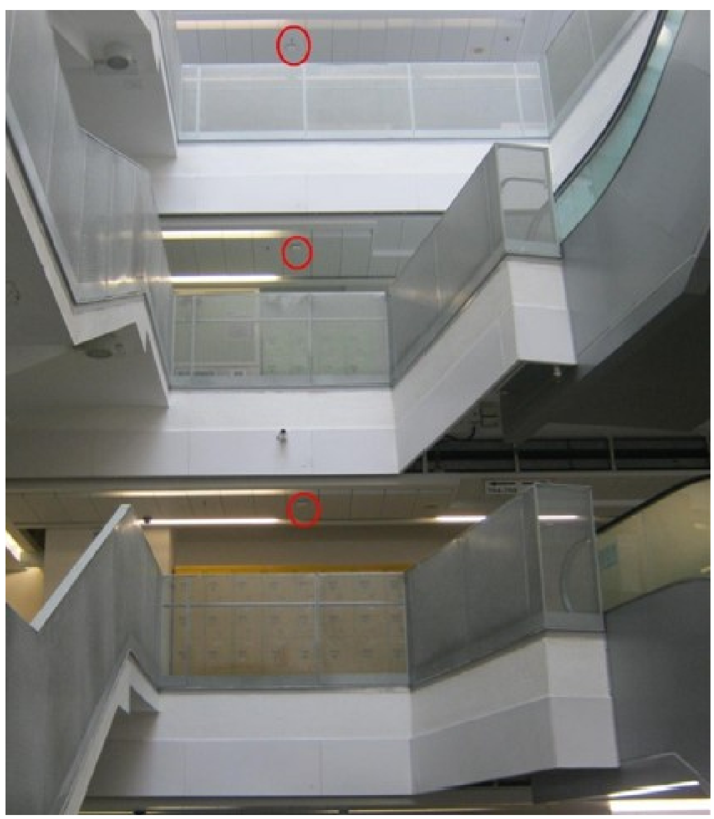


Figure (31) A picture of the photoelectric sensors being distributed in the other floors

In the end of the research, it was proven that atrium is needed in order to achieve the full benefits of daylighting by using active lighting controls, which resulted in the building used for the study to yield daylight throw out all the thirteen floors, the finale result is 43,003 kW h potential energy being saved throw a year which also supports the installation of daylighting related controls in hallways which can lead to a huge amount of energy being saved, the research in general can help future projects and investors ..etc, to develop energy saving methods and strategies.

2.2.5 Optimal design of residential building envelope systems in the Kingdom of Saudi Arabia:

The study was conducted in Kingdom of Saudi Arabia within 5 cities: Riyadh, Jeddah, Abha, Tabuk and Dhahran year 2014. The aim of the research was to conduct a thorough analysis to ameliorate residential buildings energy performance in KSA by improving the residential buildings envelope elements, which are: wall insulation, roof insulation, window area, window glazing, window shading, and thermal mass.

The improvement procedure was set up on life cycle expenses and energy savings. As mentioned previously, 5 cities were chosen as 5 climate areas to test ideal packages of energy efficacious measures for a residential building in the specified areas.

The reason the researcher have choose said areas is because they are one of many cities in KSA that are exposed to a lot of sun light which leads to high temperature during the summer and leads residence to accumulate high demands of air conditioning, During the year 2010 Kingdom of Saudi Arabia used around 65% of electrical energy which is higher than the world by 47%, which can lead to endangering the Saudi Arabian oil exports income.

The reason behind using the building envelope components: wall insulation, roof insulation, window area, window glazing, window shading, and thermal mass, is because these components affects thermal leisure inside the building.

In order to estimate a perfect residential building design for the residences in Kingdom of Saudi Arabia, a basic prototype from the residential buildings is to be chosen to test which was a (Villa) based on a study in 2010 that concluded that around 40% of Saudi residence prefer to live in one.

The researcher used a program called EnergyPlus to carry out the studies test throw an energy simulation of a whole building, as well as creating a foundation line energy example for a separated single family housing unit (Villa) to help with the different energy adequate options to update Villa's in Kingdom of Saudi Arabia, as well as setting an air conditioning system criteria's for the foundation line model, Table (5).

Characteristics	Description
System type	Cons. volume DX air-cooled A/C system with electric heating
Thermostat type	Two-position with dual (heating and cooling) set point
Thermostat setting	72 F for heating and 76 F for cooling
Min. supply air temp.	55 F (average)
Heating and cooling	Available throughout the year
COP	2.17
Ventilation	None

Table (5) the foundation line for the air conditioning system criteria for KSA villa's

A rendering of the prototypical model was created by the researcher, Fig (32), in order to test the Villa's energy use located in the 5 main cities, each floor was tested separately in order to categorize it as an individual thermal area while inserting a thermostat in the second floor to control the heat in both areas.

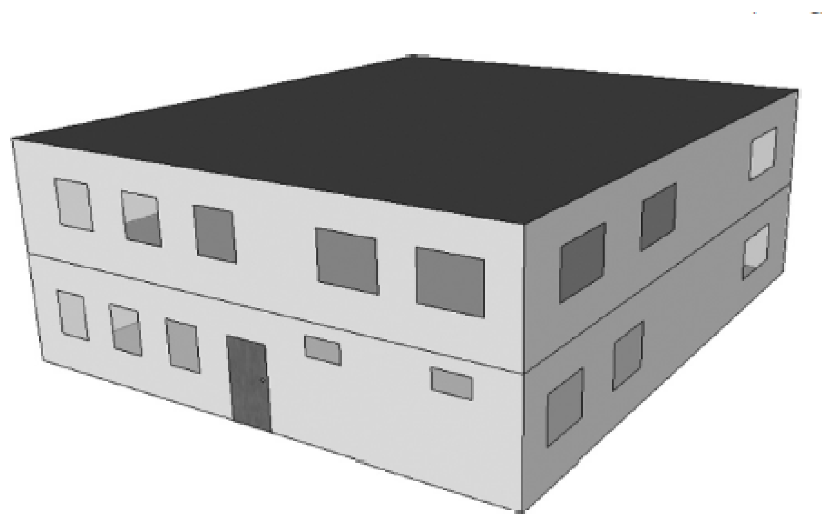


Figure (32) A rendering of the prototypical model

The simulation in Riyadh resulted in the following consumption levels, Fig (33):

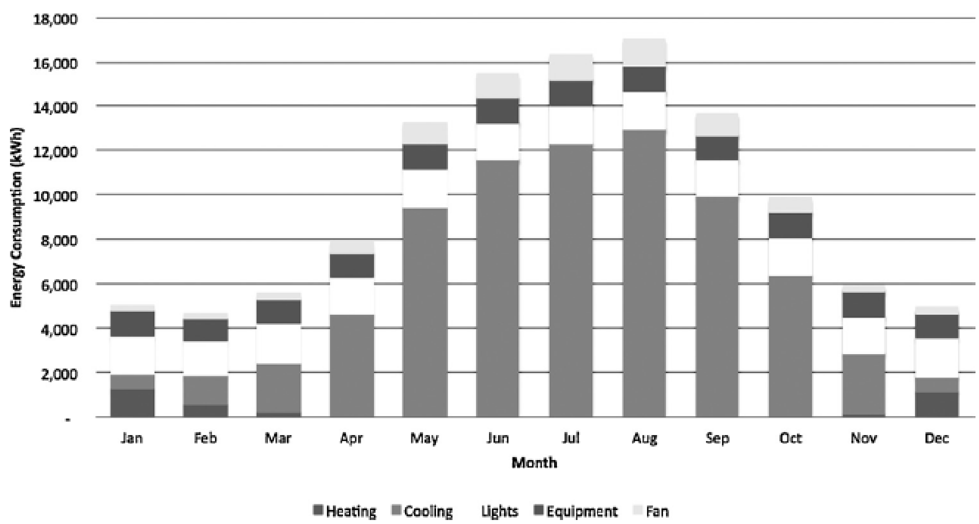


Figure (33) Results of the monthly rendering of energy consumption in Riyadh

As predicted, most of the electrical energy that was used is a result of air conditioning usage, as it represents 66% or energy usage in any Villa in Kingdom of Saudi Arabia, Fig (34).

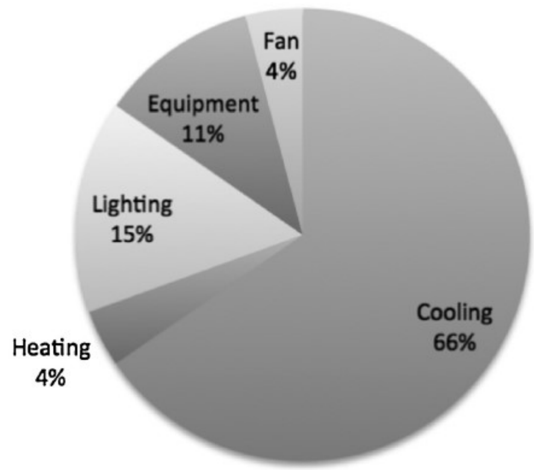


Figure (34) A pie chart that explains the electrical energy usage in a villa located in Riyadh

The researcher have used the same simulation in Jeddah, Dhahran, Tabuk and Abha, and then compared the results of all five of them, which resulted in the discovery that the most area that its residence uses more energy for air conditioning is Jeddah, while the least one is Abha, I the other hand the area that uses more energy for space heating is Riyadh in winter and the least one is Tabuk, Fig (35).

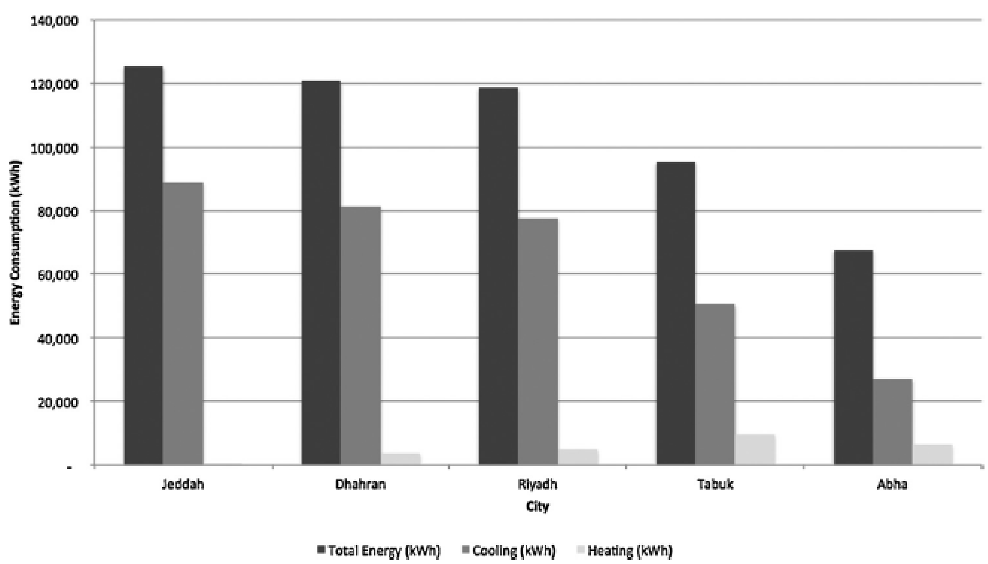


Figure (35) A chart that compares the total energy, air conditioning and space heating used in the 5 cities

The simulation results of the total energy, air conditioning and space heating coordinates with the day to day heat and cooling for the five cities, Table (6).

City	CDD (°C-days)	HDD (°C-days)
Jeddah	6587	0
Dhahran	5953	142
Riyadh	5688	291
Tabuk	4359	571
Abha	3132	486

Table (6) day to day heating and cooling in the five city

In accordance, the researcher divided the 5 cities based on users annual energy waste distribution into pie charts that simplifies the usage in percentage, Fig (36).

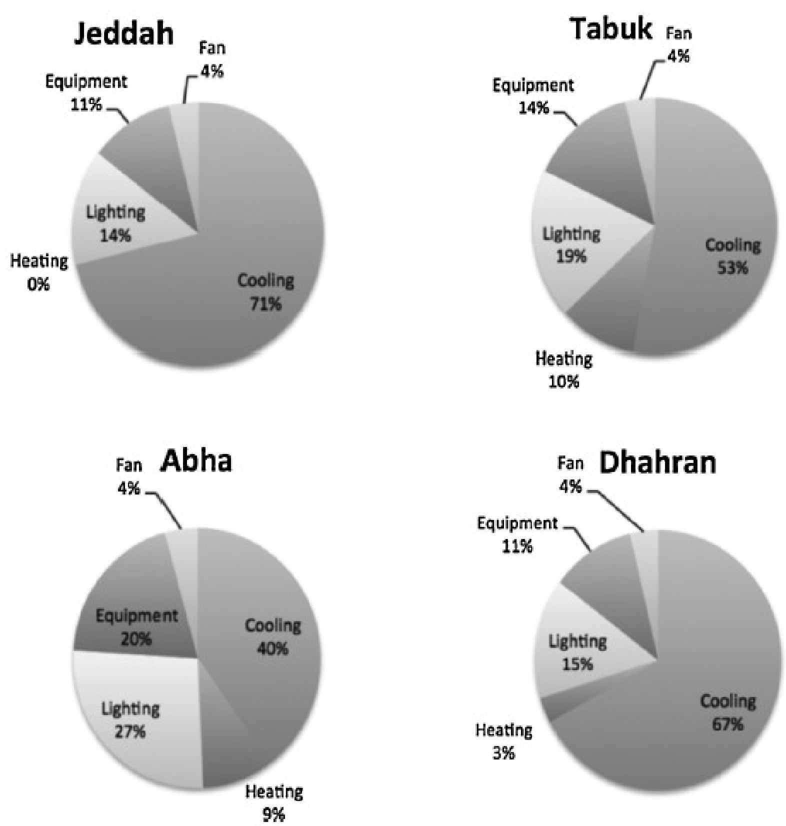


Figure (36) Pie charts that explains users annual energy waste distribution

Specifying the perfect selection of residential buildings demands detailed and thorough thermal and provident analyses to guarantee the perfect design criteria. For example, applying a specific thermal insulation to the outer walls and the building roof may not be a provident idea due to the detraction return of applied insulation.

Residential building envelope sensitiveness was tested as well, which lead to discovering that the villa's outer walls and roof insulation show the same mannerism throughout Kingdom of Saudi Arabia weather with almost all of the energy provision is established by the implementation of the first R-5 insulation, Fig (37).

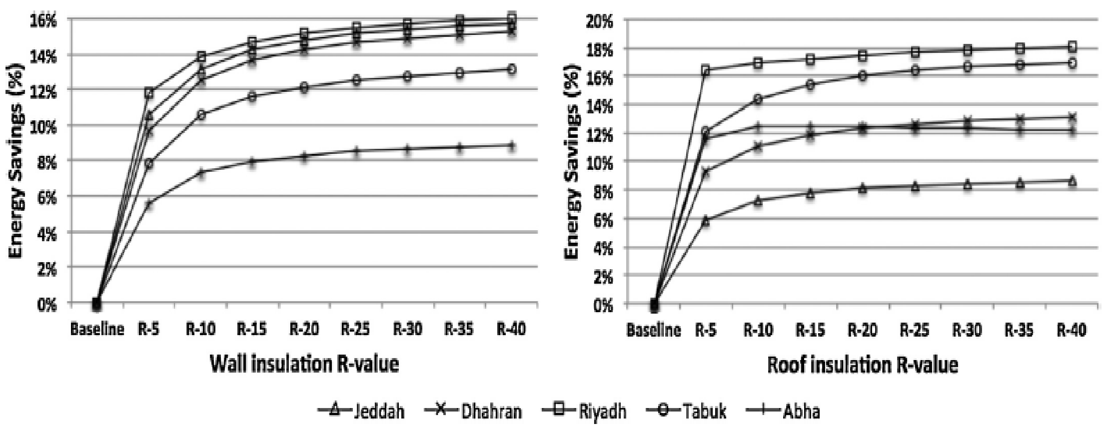


Figure (37) Energy provision through the implementation in villa roofs and outer walls in 5 KSA cities

The researcher experimented wither the insulation of either roof or outer walls is effective as insolating both in Jeddah and Riyadh cities, which lead to determining that the latter option is better, Fig (38).

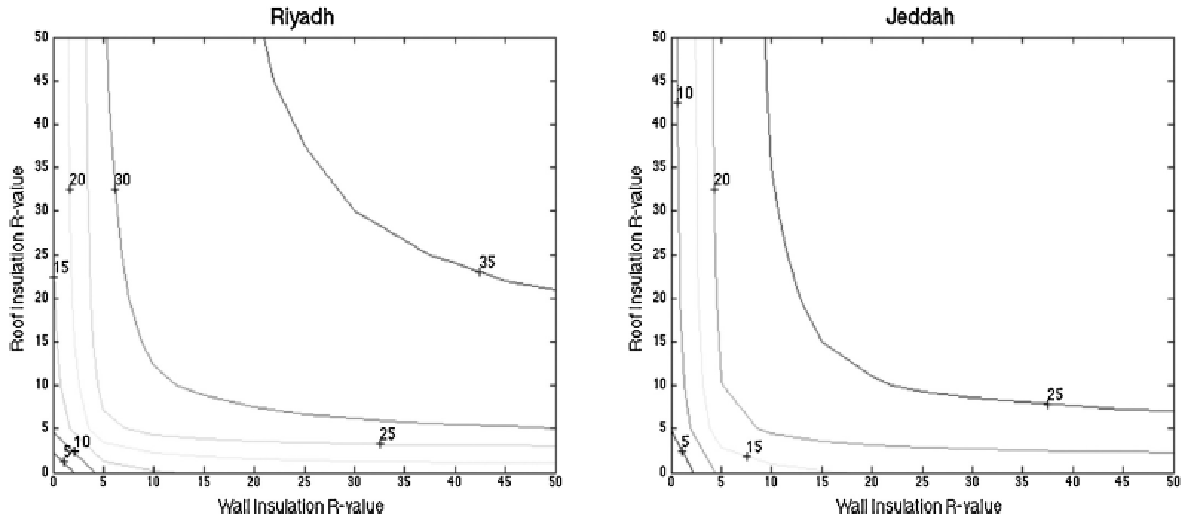


Figure (38) testing both option and comparing results

Applying window shading to gain energy saving are tested on all 5 cities as an overhanging function, Fig (39). The result was that lowest overhang shade is in villa's located in Dahran.

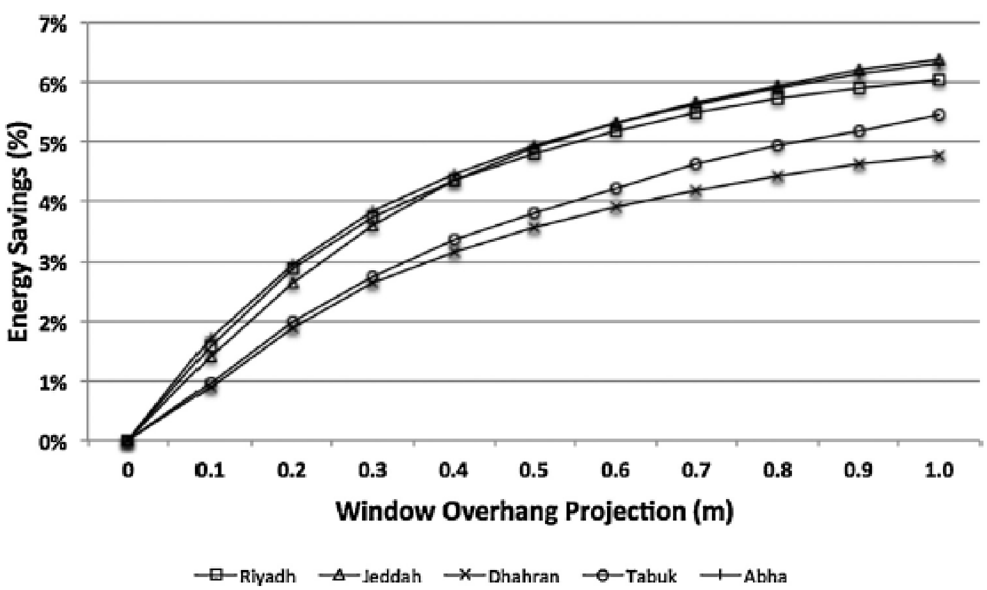


Figure (39) The effect of the window overhang shading on the annual energy consumption in villas located in five cities within KSA

In the end of the research, we have concluded that significant annual savings can be achieved by KSA on: (i) energy cost subsidies, (ii)national oil consumption, and (iii) investments for new power plants. The sensitivity analysis has indicating that the impact of electricity rate is significantly higher than the initial costs for energy efficiency measures on the optimal building envelope systems.

2.2.6 Parametric analysis of alternative energy conservation measures in an office building in hot and humid climate:

The study was conducted in Dammam, Kingdom of Saudi Arabia year 2005. The aim of the research was to explore the effect of alternative energy conservation measures on the required energy amounts of office buildings in humid-hot climates, The researcher believed that other researches efforts should not be focused on AC designs and its improvements but instead combine it with the focus on the building itself and its design.

The study was conducted on a 6 story newspaper office building that was chosen as a case study, the building was established year 1998, located in Dammam city, angled 261 towards North and 501 towards East, with the total floor area of 12,500 and total height of 5.25 m, 200 mm concrete walls, 50mm insulation type polyutherine, double glazed windows with air space of 12mm and coefficient shading of 0.3 and 0.7 of transmittance, the HVAC system that was used by the newspaper office was constant air volume (CAV) with the total of 24 (AHU) air handling units that serve various area of the office building and cooling provided by chilled water that is projected through 4 reciprocating chillers. The researcher studied each zone within the office building in a physical manner with the collaboration of building personnel to obtain data regarding the building equipment, occupancy and lighting, the propose behind such action was to attain details of thermal characteristics of the envelope while detailing the buildings physical characteristics, Table (7), and its operational ones as well, Table (8).

Component	Description
Wall	200 mm concrete 50 mm polyutherine insulation Inside and outside layers U-value = 0.36 W/m^{2}k
Roof	200 mm concrete 50 mm polyutherine insulation Inside and outside layers U-value = 0.36 W/m ^{2}k
Glazing	Double-glazed 6/12/6 mm Blue color U-value = 3.5 W/m^{2}k Shading coefficient = 0.3 Transmittence = 0.7
People (number of people)	271
Lighting	325 W/m^2
Equipment	455 W/m^2
Type of lighting	Flourecent
Ventilation rate	7.5 L/S/person
Infiltration rate	0.2ach
HVAC system	Constant volume system Total AHU'S = 24 Each AHU power rating = 7600 W Number of zones = 24
Chillers	Type = reciprocating Capacity = 736 KW Number of chillers = 4 Water supply temperature = 7 °C Water return temperature = 13 °C
Set point temperature	22–25 °C (summer) 20–22 °C (winter)

Table (7) the buildings physical characteristics

Floor name	Zone name	Lighting power density (LPD) W/m^2	Equipment power dendity (EPD) W/m^2	NOP number of people
Ground	Developing sect.	25	25	15
	Ladies sect.	10	10	7
	Advertising sect.	15	35	10
	Canteen and Training sect.	10	10	25
First	Computer sect.	20	30	20
	Mosque	5	5	10
	Publication sect	20	30	25
	Editing sect.	20	30	15
Second	Political sect.	20	30	15
	Assistant editor Sect.	20	30	15
	Local news sect.	20	30	15
	Sports sect.	20	30	15
Fourth	Assistant Managing director	20	16	16
	Accounting sect. and meeting room	20	20	20
	Administration	20	16	16
	Maintenance sect.	20	10	10
Fifth	Managing director	10	10	6
	Meeting room	10	10	6
	Chief editor	10	10	5
	Office	10	10	6

Table (8) the buildings operational characteristics

The personal equipment of the office building was calculated as well, such as: various sized printers, personal computers, Xerox and scanners machines, the calculations were made while following ASHRAE recommendations, as well as calculating the equipments power densities and the total of employees working within the building, Table (9).

Month	Days	Electric energy (kWh)
Januray	31	303148
February	28	287591
March	31	321329
April	30	335193
May	31	375885
June	30	387987
July	31	429496
August	31	441000
September	30	410327
October	31	373418
November	30	358390
December	31	309252

Table (9) the average of the buildings monthly consumption

The researcher studied the total of the monthly energy consumption of the office building for 4 years, Figure (40). It turns out, the electrical energy is mostly used in summer seasons in contrast to winter seasons when its least used which results in a variation of the utility bill throughout the 4 years due to it, the researcher have calculated the average of the office building energy consumption, Table (10).

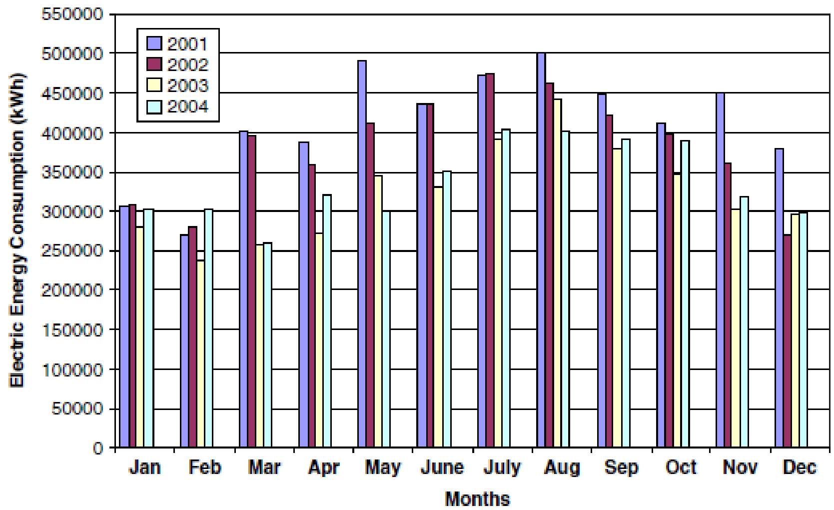


Figure (40) 4 year monthly energy billing data

Year	$kWh/year.m^2$
2001	410
2002	377
2003	315
2004	330

Table (10) 4 year annual energy of the office building

The simulation program that was used for the research was Visual DOE which is a program that conforms and studies the balance between users flexibility and the ease of use with the regard of different levels of simulated backgrounds and skills. the simulation program haves 4 components of study, the interface window of the user, HVAC data and the building itself. The original monthly energy consumption of the case study was 22%, so a series of trials were conducted that manipulated the behavioral estimated parameters input, for ex: the temperatures set point, the schedule of use and the infiltration rate, Table (11) the reason said trials were conducted was try and match the base case energy consumption with the utility bill of the year of study.

Base case (double-glazed 6/12/ 6 mm)	Low-emittance glazing (double-glazed 6/12/6 mm)
$U = 3.5\ W/m^2K$ SC = 0.3 SHGC = 0.26 Transmittance = 0.7 Color = blue	$U = 1.8\ W/m^2K$ SC = 0.14 SHGC = 0.12 Transmittance = 0.7 Color = silver

Table (11) the buildings glazing system characteristics

A set of energy conservation measurements (ECM) were studied and classified into groups of: the no cost measurement, the major investment measurement and low cost measurements.

1. *The no cost measurement:* it's the measurement type that could be added in both behavioral and operational means without any system or building changes required and doesn't cost additional billings, it is divided into 3 measures:
    a. <u>ECM no. 1: temperature set point:</u>

       This type of ECM, was tested through the use of Visual DOE 4.0, the temperature was set at 25 C for summer season and 22 for winter in comparison to the base case which was 24 C in summer season and 20 at winter which led as a result to the reduction of 3% of the annual energy consumption, Figure (41).

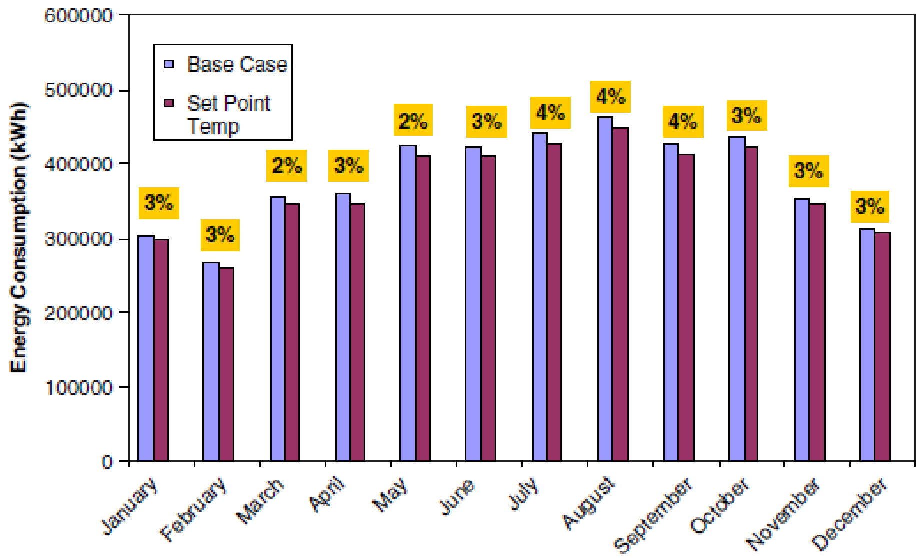


Figure (41) the result of the ECM testing of the temperature set point

b. ECM no.2: set back of nighttime:

This type of ECM, was focused on readjusting temperature of the area within night time since its unoccupied from 11:00 pm to 7:00 am, while setting the indoor temperature to 28 in summer season and 16 in winter, which resulted in the reduction of 5% of the consumed energy in summer, Figure (42).

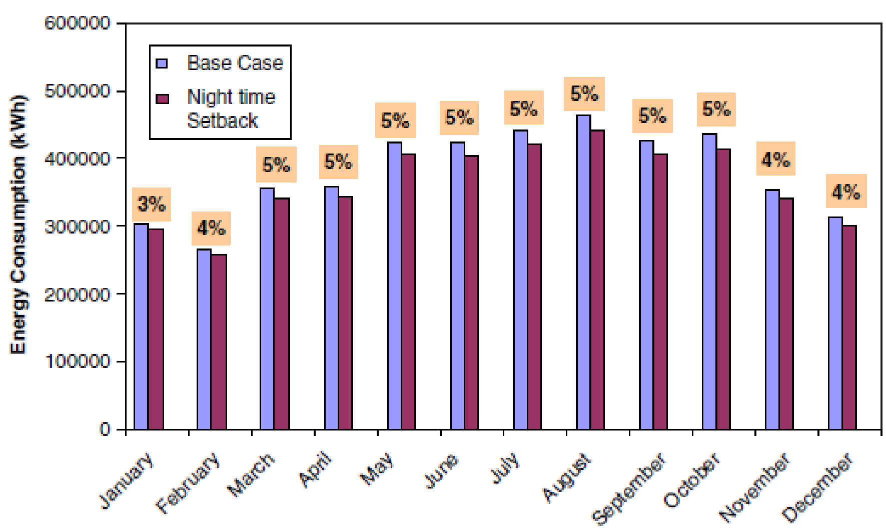


Figure (42) the result of the ECM testing of the nighttime setback

c. ECM no.2: Lighting and scheduling equipment:

This type of ECM is usually not applied or not given much consideration, but in reality it is a very important ECM, the test consisted of opening all appliances' throughout the unoccupied hours using DOE 4.0, then closing certain were turned off in another testing which resulted in the achievement of 5% of the total monthly energy saving, Figure (43).

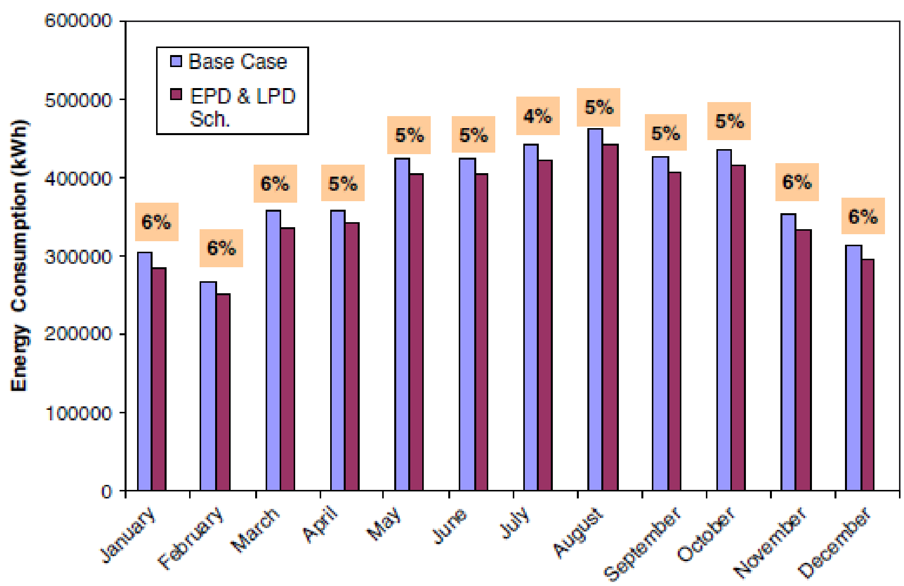


Figure (43) the result of the ECM monthly energy savings

2. Low cost measurement: this type of measurement could be added into behavioral and operational changes but will require high or little added cost and it is divided into 3 measures:

a. ECM no. 1: roof and wall insulation:

This type of ECM tested the polyutherine insulation and changed it from 50mm thickness and a U-value of the roof is 0.35W/m2C to 75 mm of thickness and 0.26W/m2C which ultimately resulted into 1% of energy savings, Figure (44) , Figure (45).

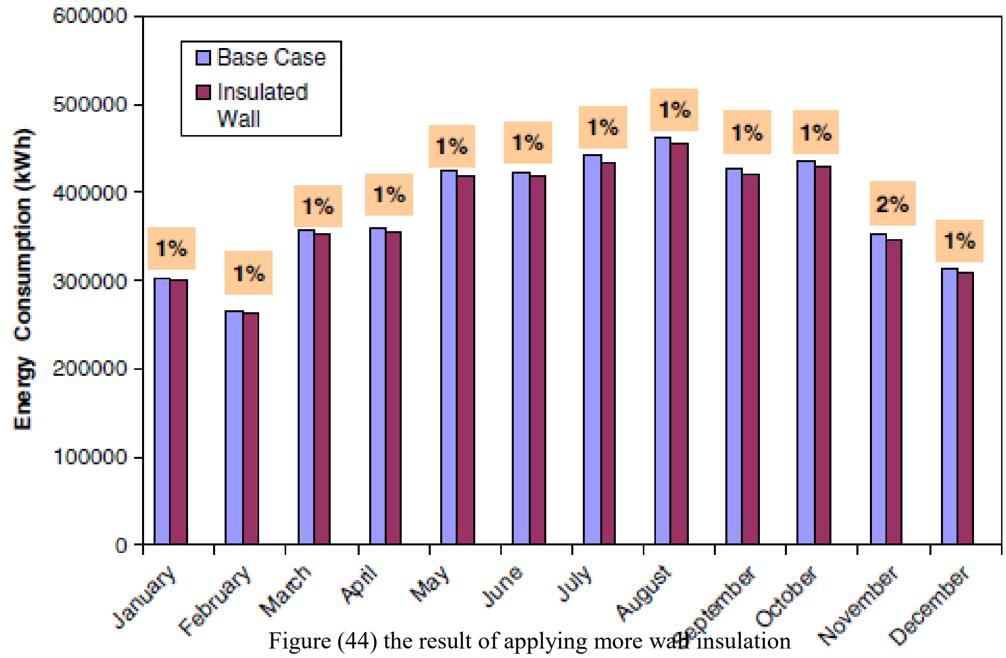


Figure (44) the result of applying more wall insulation

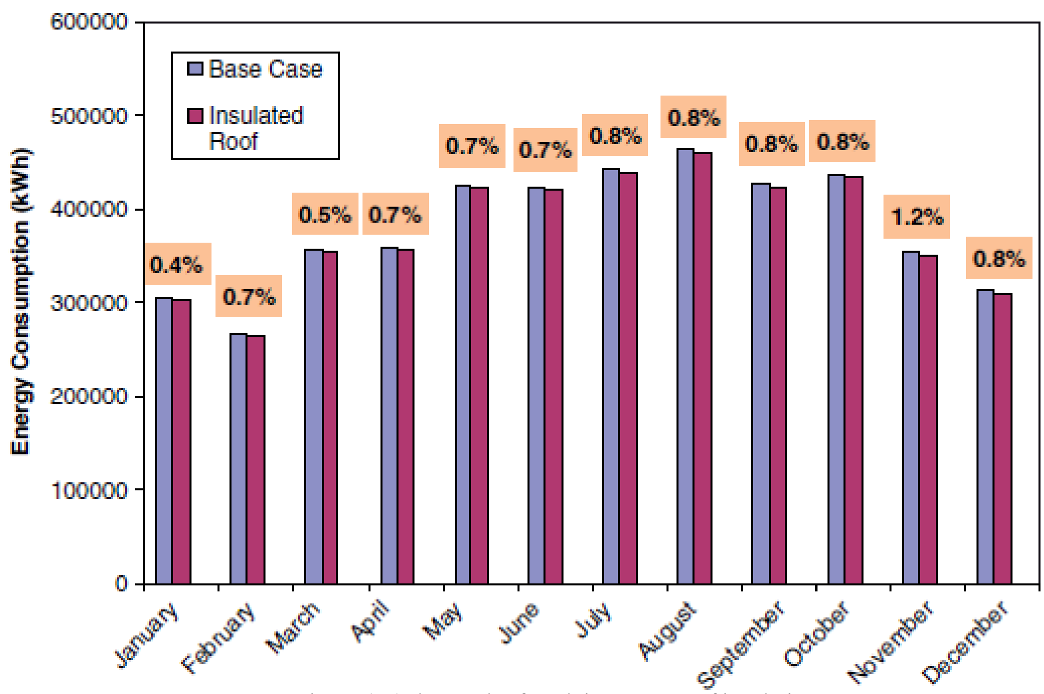


Figure (45) the result of applying more roof insulation

b. ECM no. 2: an efficient glazing system:

This type of ECM focused on changing the windows into a more efficient type which was high R value and low emissive, which are types of window glass that is both beneficial in minimizing energy consumption and improving the indoor comfort, the researcher used 0.3 of the glazing coefficients and 0.7 of the solar transmittance which resulted of an average 7% reduction on energy use and around 8% minimization in the summer season, Figure(46).

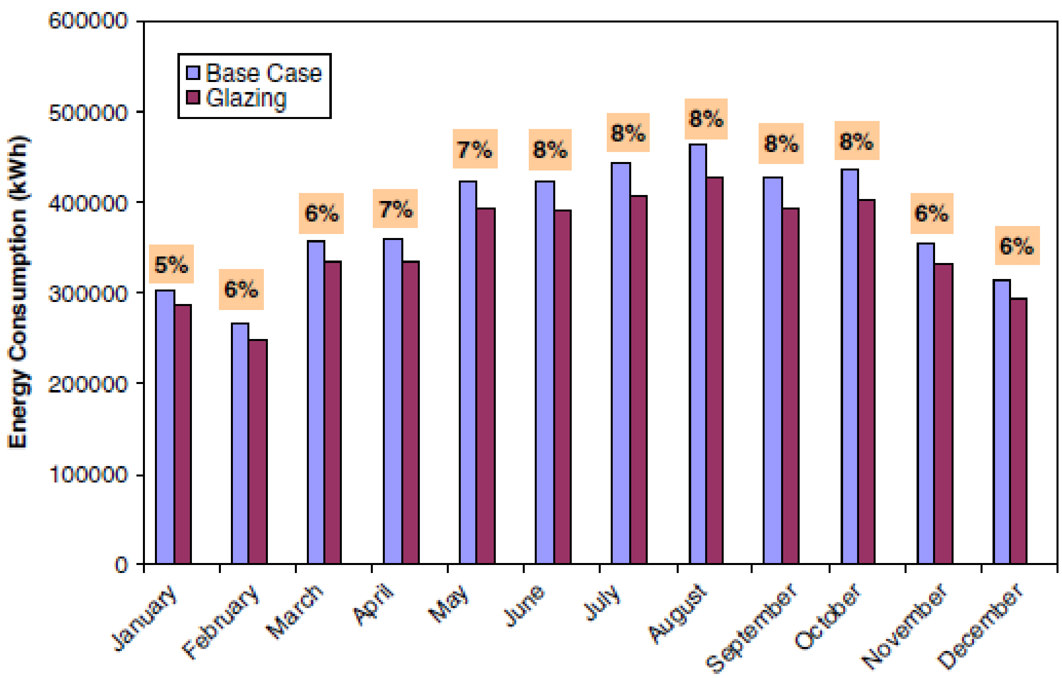


Figure (46) the results of using Low e glazing while affecting the monthly energy use

After the series of simulations, the researcher have achieved a new arrangements for the previous system, Figure (47).

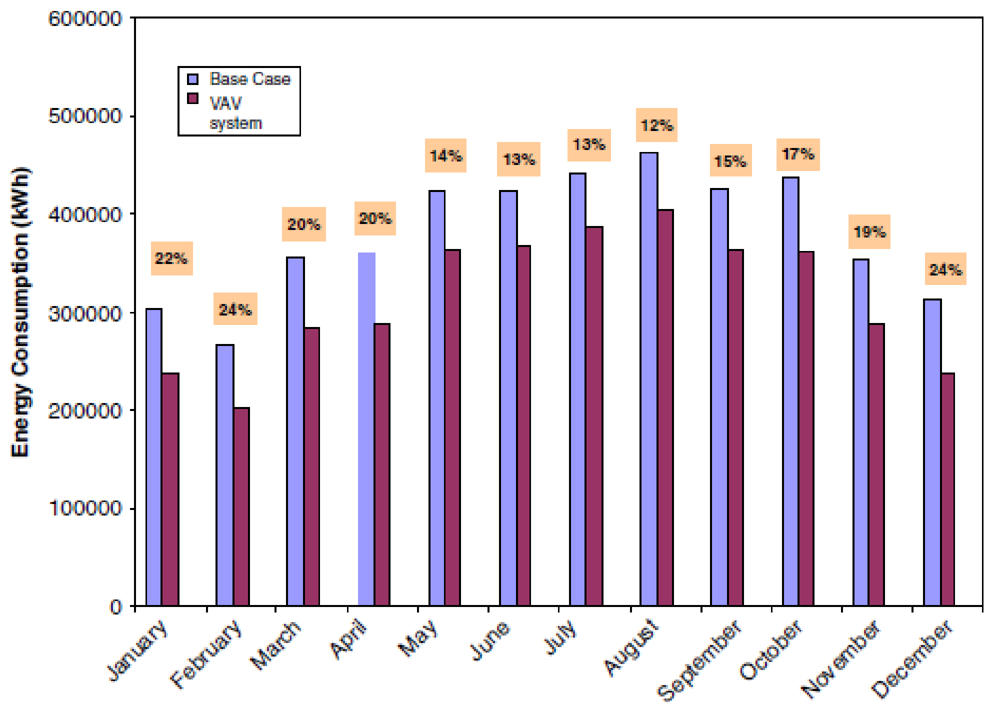


Figure (47) a simulation that shows the results of using the newly created arranged system

The researcher recommended the following:

1- Implying a night time set back is crucial.

2-adjusments of lighting and equipment is highly important be turning it off within unoccupied times or low occupied times as well.

3- A dimming control panel is recommended to be installed and regulated that will help in benefiting from daylight and the reduction of energy waste.

4- It is advised to use low e double glazing windows for a higher energy efficiency specifically in large buildings that are glazed in hot climate.

5- It is advised to use fluorescent lamps of 34W or use it after exciting buildings lamps die out or become burned.

6- AC system plays a significant role in energy consumption specifically is summer season, so using VAV system is recommended.

2.3 Research approach:

Throughout investigating, there was a significant lack in regards of specifying daylighting systems type that could be applied into Kingdom of Saudi Arabia housing units which made it all the harder to conduct the study, thus replacing it with more foreign systems applied in other countries in order to achieve results.

However, when it comes to the characteristics of daylighting systems there are many options to apply in Saudi Arabian housing units, For example: the application of an atrium in a residential building in Hong Kong china which have greatly improved the energy consumption used by the residents in the building, as well as the relocating and resizing of windows can help as a daylighting system that reduces energy, as it can be considered a method to apply in hot climates such as Kingdom of Saudi Arabia as the strong sunrays can provide heat in winter or light in the summer in general, but it is important to remember that instillation of windows or insulation is not the only method to insert daylighting or to reduce energy waste, but through an integrated plan that consists of improving elements design and the usage of an interactive systems as shown in the literature review examples.

The implementation of sufficient ambient light supplied from daylighting alone can greatly minimize electrical energy waste, as well as fenestration which is important to take in consideration in the designing faze to make sure that the windows don't cause the occupancies glare or discomfort, thus the usage of glaring treatment devices like curtains or blinds is required to exist.

Daylighting is not just listing components to install, it goes beyond that, it demands a series of precise and unified designs process in order to succeed , the reason why is because it includes important decisions that revolve the building itself as a whole and not a part, such as: roof, building form, climate ...etc.

2.4 The research softwares:

2.4.1 Autodesk Revit simulation software:

Auto desk Revit is an informative building modeling software used by landscapers, architects and structuring engineers in general, Fig (48).

Figure (48) Auto desk Revit logo

The software allows users to design and create structures and buildings and its elements in 3D, draft it in 2D where detailed work flow is needed, such as elevation detail drawings and access information of said design through the model database, with a 4D capable BIM that haves tools used for planning and tracking different stages of the buildings life cycle.

The reason for using this program is because Revit software provides a service called: Insight Lighting Analysis that provides various analyzed results of lighting and daylight that helps the user document light related results throughout the design. The program itself is used to analysis SDA and ASE based on LEED v4 EQc7 opt1.

2.4.2 eQuest simulation software:

eQuest software is a popular free energy model that leads to professional results, by allowing users to execute detailed analysis without the need of extensive background in regards of energy topic through the combination of (EEM) energy efficiency measure and graphical displayed results, fig (49).

Figure (49) eQuest logo

eQuest is built based on the DOE 2 simulative engine, The reason for choosing this program is because eQuest is a software that provides energy access of results throughout all the developing stages of a building.

CHAPTER 3

METHODOLOGY

3.1 Introduction:

To achieve a sensible energy and daylighting conserving residential building design in hot climates in Kingdom of Saudi Arabia (KSA), 150 residents living in residential buildings is chosen as a prototype with almost the same features in order to estimate their daylighting/energy performance based on the user's opinions.

3.2 An Inclusive literature review:

A thorough literature revision will be conducted to study housing units (Villa's) in Kingdom of Saudi Arabia. The literature will cover areas of Daylighting systems in KSA, Characteristics of daylighting systems, Methods to apply to daylighting systems in hot climates in KSA or Middle east and Residential building characteristics in KSA.

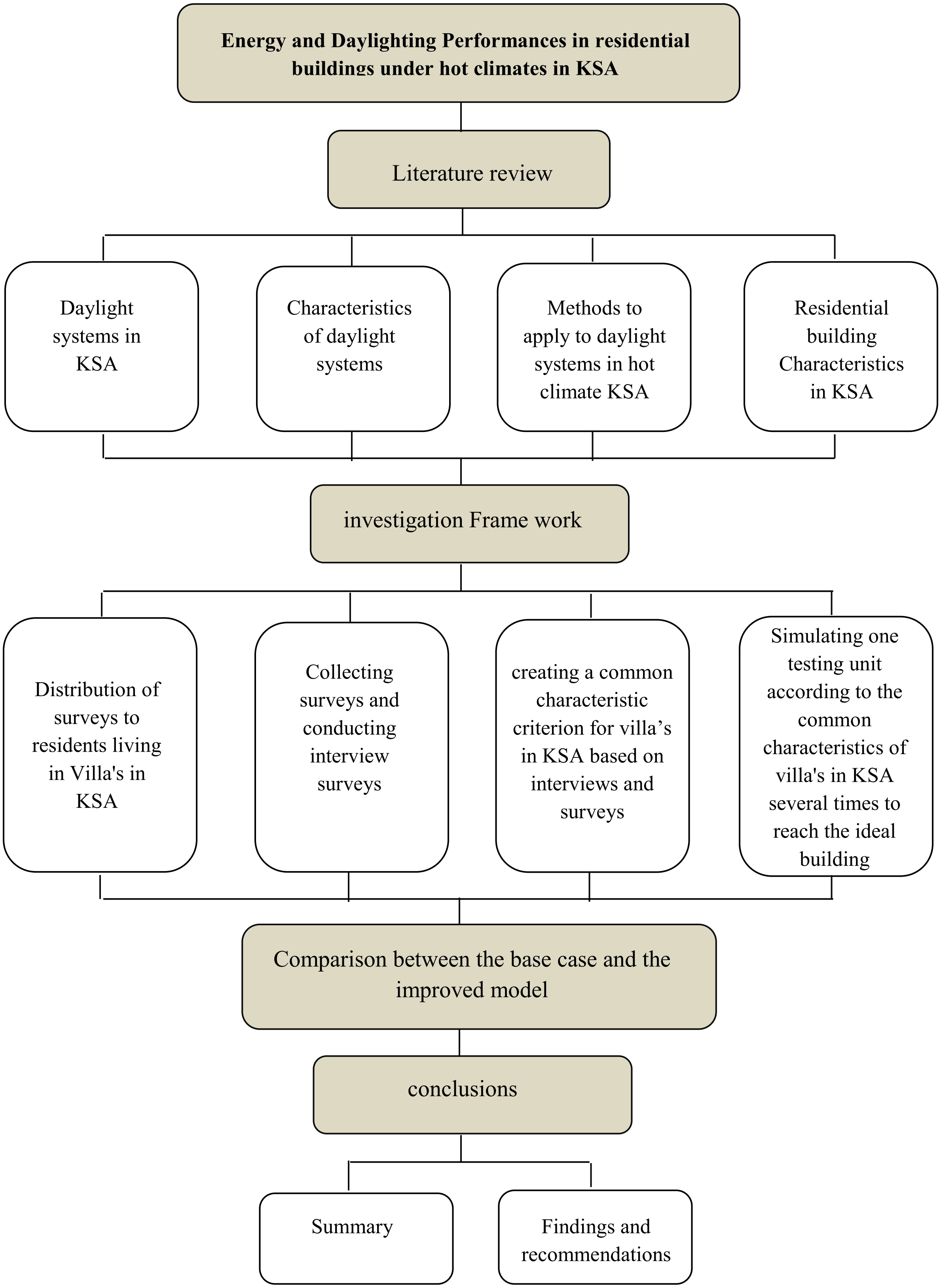


Figure (50) A map of the research methodology

3.3 Developing an investigation frame work:

a. Creating a Questionnaire and distributing it:

The first step that is needed to be done is to find out the measurements of the three main rooms in any residential space which are: Bed room measures and Living room measures, as well as asking the users of the residential buildings questions that relate to their behaviors within the space, daylighting exposure ...etc. and to achieve the following information a Questioner is conducted that cover 5 main sections:

i. *Section 1: General information (Not mandatory).*
ii. *Section 2: Materialistic Information (Mandatory).*
iii. *Section 3: Sensation Towards Daylighting (Mandatory).*
iv. *Section 4: Human Demeanor (Mandatory).*
v. *Section 5: Illumination Comfort (Mandatory).*

i. *Section 1: General information (Not mandatory):*

It involves common information that is not Mandatorily is required to be filled out, which are the following: Age, gender and city.

ii. Section 2: Materialistic Information (Mandatory):

It involves physical information that is related to the 2 main rooms that are considered the most active zones in any housing units: bedroom and living room, the questions that are listed in this section are information that are required in order to conduct the simulation that cover the following aspects:

1. size of the rooms.
2. Direction the room was built.
3. Window sizes in the rooms.
4. The amount of window sky view is obscured.

iii. Section 3: Sensation Towards Daylighting (Mandatory):

It involves non-physical information related to daylighting that affects the user of the housing units in order to understand the influence it haves of the residents which will lead to the inspiration of finding methods to improve living conditions for them and it will cover the following aspects:

1. Amount of natural light that enters throw out the day without the interference of manmade lighting.
2. Rooms that haves the best lighting distribution to the user.
3. Rooms with the most natural lighting throw out the seasons.
4. Users opinion in the rooms lighting.

However, afterwards the information will be narrowed down to evolve the following elements to understand the negative affects the housing unit haves on its residents:

1. Heat discomfort.
2. Glare.
3. Poor eyesight.
4. The ability to control manmade lighting.
5. Users opinion in the rooms lighting quality.
6. Physiological comfort.

iv. Section 4: Human Demeanor (Mandatory):

It involves a study of the normal residents' actions inside the housing unit, the significant importance of this section resides in understanding what are the actions that haves an effect in the lighting or the lighting comfort within the housing unit.

v. Section 5: Illumination Comfort (Mandatory):

In the last section it involves a closing/general question that requires the resident's opinion.

b. <u>Collecting surveys and conducting interviews:</u>

After collecting the survey results, a series of interviews through surveys will be conducted on 25 specialists and designers, the purpose behind these interviews was to extract additional information's for the criterion of the common characteristics of villa's in KSA, the interviewing survey will cover 2 main aspects:

i. Section 1: General information (Not mandatory).

ii. Section 2: Materialistic Information (Mandatory).

i. Section 1: General information (Not mandatory):

It involves common information that is not Mandatorily and is not required to be filled out, which are the following: Age, gender and city.

vi. Section 2: Materialistic Information (Mandatory):

It involves physical information that is required in order to fully grasp the buildings characteristics, and its involves the following questions:

1. What type of window glass do you usually use when designing a window for a Villa?
2. What are the common dimensions do you usually use when designing a Villa floor?
3. What are the usual materials you use when building the Villa's external walls?
4. What are the usual materials you use when building the Villa's roof?
5. What are the common recommended lighting levels you recommend ?

c. <u>creating a common characteristic criterion for villa's in KSA based on interviews and surveys:</u>

After conducting the survey and interviews, the results will be filtered and combined in order to make a characteristic criteria measurement for villa's in KSA to use as a measuring tool for the simulation.

d. <u>Simulating a testing unit in KSA according to the specialists and designers opinion:</u>

In this step, a base case will be chosen according to the characteristic criterion measurement that exists in one of the chosen cities for the study, then a series of parameters will be run through it in order to create the idle building by finding the best parameter type from the following:

i. *Window to wall ratio:*

   Is the measurement of s specified areas percentage and dividing it with the buildings glazed area in total, Window to Wall Ratio or WWR will be tested throw these following scales of choose:

   1. *Annual Sunlight Exposure:*

      Annual Sunlight Exposure or ASE in a scale that specifies the over excessive amount of direct sunlight a space receives, which may lead to glare (visual discomfort) and thermal discomfort.

   2. *Spatial Daylight Autonomy:*

      Spatial Daylight Autonomy or SDA is a scale that specifies the amount of adequate daylight a specific space receives. In particular, it explains the minimum luminance level percentage a floor area receives for the minimum annual hours that are occupied percentage.

ii. *Shading:*

It is a method that minimizes a buildings pinnacle of heat gain and cooling necessities and ameliorate the quality of natural light of the building's interior, as well as improving the users visuals into a comforting state by monitoring glare and minimizing contrasted ratios. In this research, two methods were used to simulate various times which are:

1. *<u>Overhang shading devices:</u>*

Overhang shading devices are an over extended section beyond the window frame that are designed with specified measurements in order to block high levels of sunlight from reaching certain sections of the roof within a normal day, however in the winter, the sunlight is directed in a lower angle and is allowed inside in order to warm the house.

2. *<u>Window shading fins device:</u>*

Window shading fins device is a device that is able to redistribute and redirect the natural sunlight throw a certain space or an area.

iii. *Glazing:*

Glazing is the conductance of window instillation, Its importance lies on the fact that whichever type is chosen is mostly responsible for 26% - 30% of heat loss or gain within a residential building.

❖ *Low - Emissivity coating:*

Low - Emissivity coating or Low-e is a type of glass that controls the transfer of heat through it, this type of glass usually cost more than the regular type of windows by 11% - 15% but it saves up energy around 32% to 50% more than the normal one, Low-e is a thin microscopic glass and it is invisible virtually, This type of glass is mainly used into the base case simulation.

a. *Single tinted glass:*

This type of glazing uses gray or bronze glass that is tinted, the reason why is to minimize solar heat as well as minimizing visible rays of light, this type of glass is important because it haves the ability to control glare.

b. *Double - glazing, tinted glass:*

The second type of glazing uses gray or bronze glass with 2 glass lites and outer glass layer that is gray or bronze as well while the inner layer is clear, An air gap separates said two layers.

When comparing double glazing to single glazing, we discover that double glazing haves the ability to get rid of half of the energy consumption or loss due to the fact that an air space exists between the two layers of glass.

the sole purpose of the tinted gray or bronze glass is to minimize heat gain as previously mentioned while reducing visible rays of light.

c. *Double - glazing, clear glass:*

The third type of glazing is very similar to the second one (Double - glazing, tinted glass) in its design except for the fact that it uses clear glass instead of tinted gray or bronze, which allows access of high visible rays of light and high gains of solar heat.

d. *Double tinted glass:*

The forth type is very similar to the third type (Double - glazing, clear glass) in terms of characteristics and usage except it uses double layers of clear glass.

e. *Double-Glazed, Medium-solar-gain Low-E Glass:*

The fifth type of glazing is often called spectrally selective low-E glass, because of its ability to minimize gains of solar heat while preserving high visual transmission, minimize heat loss and allow access of solar gain which makes it suitable for various of climates.

3.4 Conclusions:

The last step is divided into summarizing the process of the research and to setting a set of recommendations and findings that was established throw the research.

CHAPTER 4

Investigating the characteristics of the typical Saudi housing unit (Villa)

4.1 Introduction:

Throughout this chapter, developing an investigation frame work for a villa (housing unit) in KSA located in the three cities: Dammam, Al-Khobar and Al-Ehsa will be required, throw the development of the common characteristics of Villa's in KSA that will represent the main aspect of finding the idle common residential building (Villa), In order to define such characteristics, a survey was developed and distributed randomly on 150 people living in the 3 said cities.

In spite of the challenges that were faced such as: restricted time frame and the lack of association from the villa residents, 81 residents have successfully cooperated in answering the survey.

The results were collected afterwards and a series of interviews were conducted with 13 specialists to achieve Supplementary information, thus the collected information was filtered to achieve the common characteristics of villa's located in KSA.

4.2 The survey contents and results:

Originally, 150 surveys were distributed on residents living in villa's in: Dammam, Al-Khobar and Al-Ehsa, but only 81 have complied to cooperate, after conducting the survey on the case study sample, the following results were acquired:

a. <u>Section 1: general information:</u>

The first section in the survey revolves around general information that is considered not mandatory of the people to answer, which are:

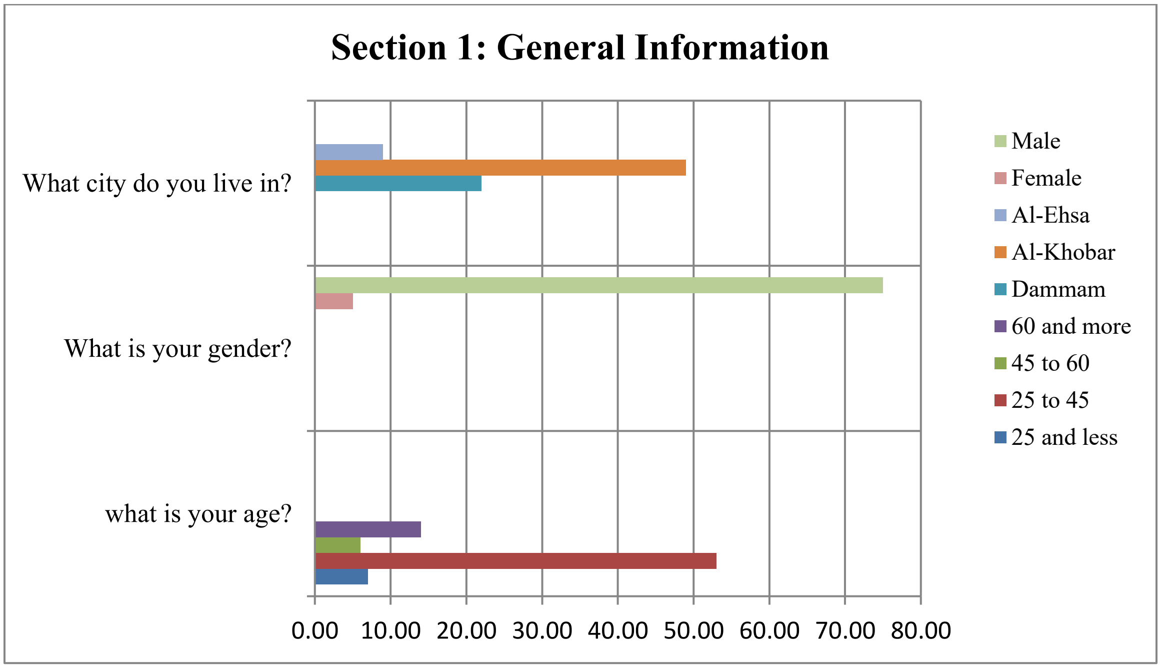


Figure (51) Section 1: general information chart

- Villa owners age ranges between 25-45 years old, and any age younger can rarely have the economical ability to own a housing unit of said size.
- Most males in the Saudi community are independent and can own a housing unit (Villa), however females can't in most cases.
- Most villa residents live in Al-Khobar due to it being more well planned, easier to locate the amenities when needed and modernized, when comparing Al-Khobar with Dammam city, the later city loses because of its congested streets due to the huge number of residents and the constant unrelated renovations, Al-Ehsa however, is lacking due to it being remote.

b. <u>Section 2: Materialistic Information:</u>

This section revolves around questions that relate to physical information of the housing unit (Villa) that the answering person lives in, which are:

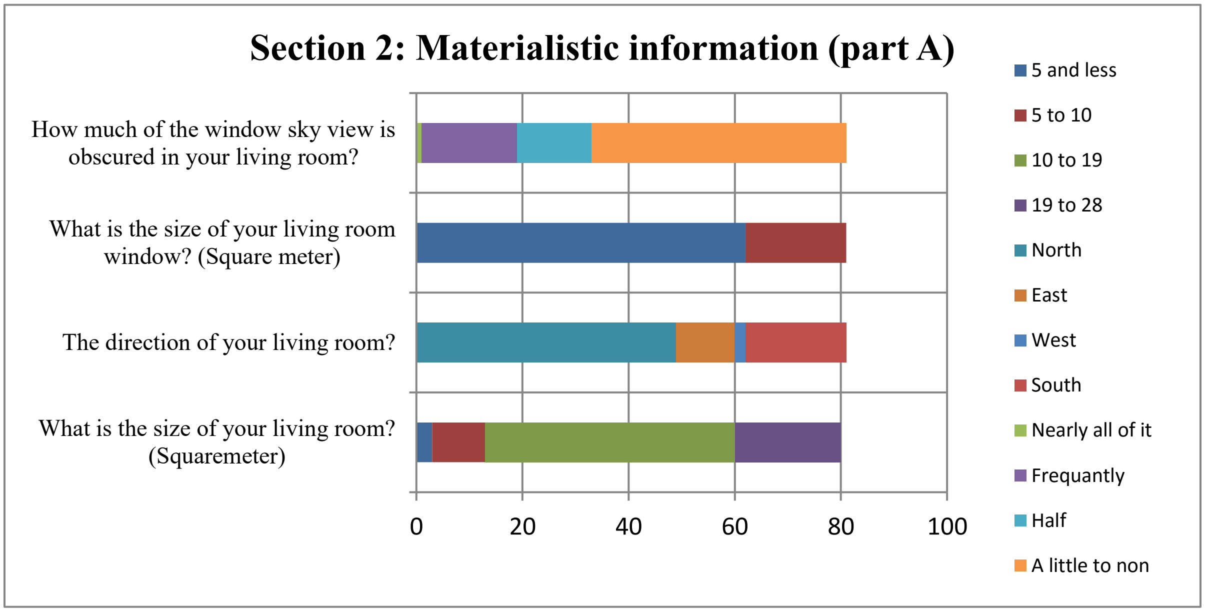


Figure (52) Section 2: Materialistic Information chart

- It is very common for Saudi Arabian families to have large living rooms which are usually called “Majlis”, due to it being used as a socializing area for the family members, the common size of 10 to 19 is an instigation of a fitting area for 6 to 7 family members.
- Most Villa’s in Saudi Arabia face the direction North based on the common architecture North direction in the world when planning a housing unit or a building, the importance of the direction lies in determining the sun direction and wind, since determining either elements is important to help determine the air flow and light to incorporate them in providing a better environment for the residents.

- Most Saudi Arabian families don't understand the importance of a window, since the highest result is 5 and less m^2 which is not nearly enough to allow heat gain or loss resulting in a lacking natural light environment.
- The importance in this question lies in the physiological comfort of the villa's residents, since a little to non-view is obscured it gives the resident a sense of comfort to have a natural view to look at occasionally away from the modernized views.

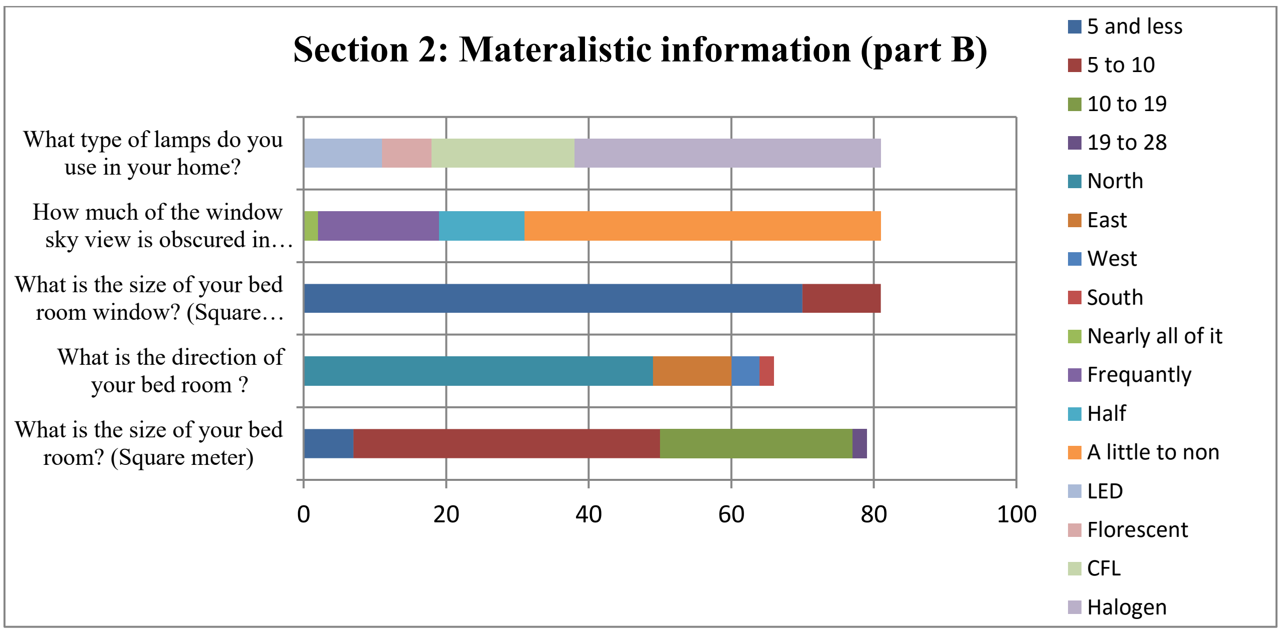


Figure (53) Section 2: Materialistic Information chart

- Saudi Arabian families commonly opt to own a conveniently sized bedroom, as they usually use it for one function which is sleeping, thus sizes of bedrooms are usually around 5 to 10 m2.
- As previously mentioned, Most Villa's in Saudi Arabia face the direction North based on the common architecture North direction in the world when planning a housing unit or a building, which applies to bedrooms as well.

- As previously mentioned, most windows in Saudi Arabian Villas are 5 and less m^2 in size which gives us a clear indication of the lack of understanding in Saudi Arabian families about the importance of natural light to re circulate heat through out any room.
- The importance in this question lies in the physical comfort of the Saudi Arabian families by being exposed to natural light first thing when they wake up to give the natural human body a daily dose of sun ray and energy.
- This question is important because it shows if a lot of energy is being wasted on lighting, around 53% of people answered the survey saying that they use halogen lamps which is not a very energy friendly option since said lamps uses a lot of electric energy, heats up fast and are too bright to use around the Villa since some rooms must require a lower lighting setting.

c. Section 3: Sensation Towards Day lighting:

This section revolves around question with a non physical nature that relate to the feelings of the person living in the housing unit (Villa) and their behaviors and their choices that effect it, which are:

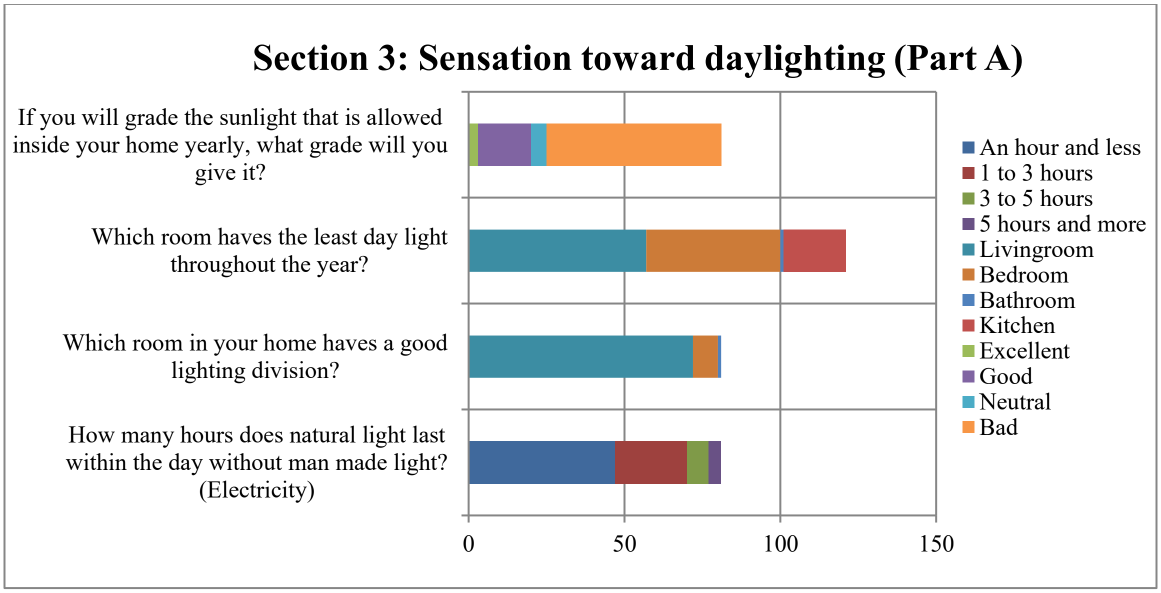


Figure (54) Section 3: Sensation Towards Day lighting chart

- A lot of Saudi Arabian families lack concern regarding the topic of natural light, the reason why might have to do with the naturally high sun rays that the Kingdom of Saudi Arabia is known for, a lot of people prefer to use artificial light (lamps) over natural light (sun) in Kingdom of Saudi Arabia.
- Around 89% of the people agree that the most well devised room when it comes to lighting is the living room, the reason why was as previously mentioned that living rooms in Saudi Arabian families holds a significant cultural importance thus when its being constructed, they pay a lot of attention to it in every aspect.

- Since most Saudi Arabian families use living rooms in a daily basis, it is very common to close the curtains constantly to avoid sun heat thus resulting in the lack of daylighting throughout the year because the users try to protect themselves from the heat of the sun and glare.
- around 69% of the people agree that the rating of the yearly sunlight in their homes is bad which gives us the understanding that a lot of people realize the lack of daylighting in their homes but think the whole idea itself is problematic.

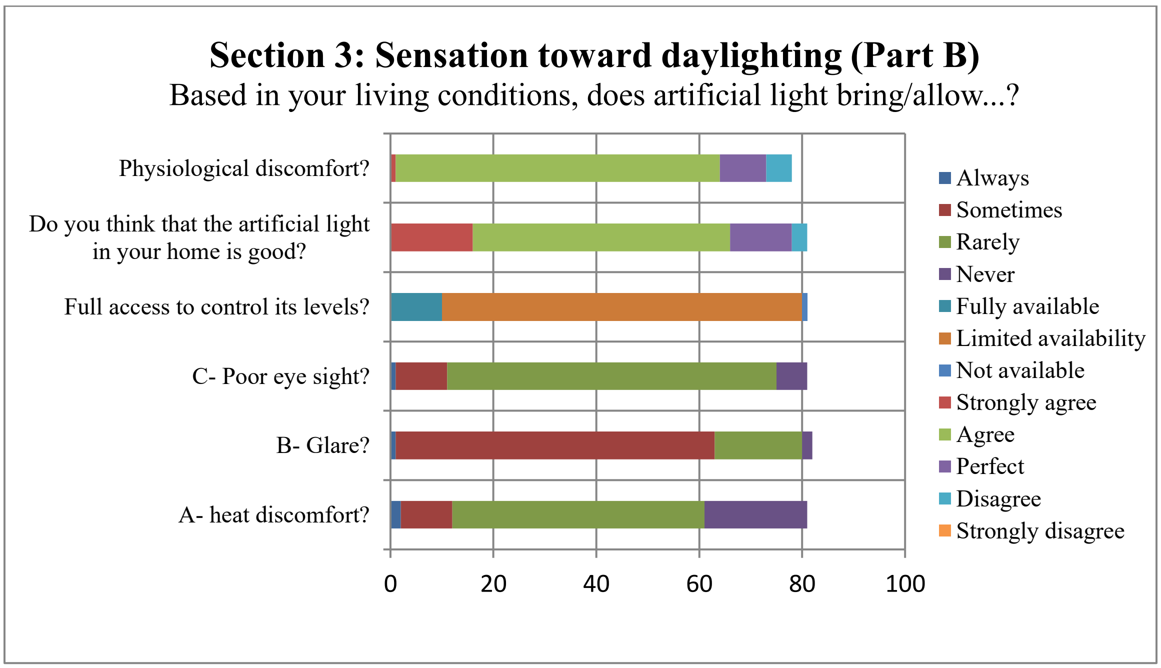


Figure (55) Section 3: Sensation Towards Day lighting chart

- Saudi Arabian families think that being exposed to normal sunlight could be problematic due to the strong sun rays in the country throughout the year, that is why they prefer the usage of artificial daylighting because it barely affects their heat comfort, which is supported as evidence by 60% of people agreeing to said excuse throw the survey.

- Due to 53% of people answered the survey saying they use halogen lamps, it is expected to say that most Saudi Arabian families suffer from glare, because Halogen "as previously mentioned" are strong lit lamps which is bound to affect the users and bother them occasionally.
- Halogen lamps have a strong lighting capability which can lead to the lack or the nonexistent poor eye sight related issues.
- Not a lot of Villa's in Kingdom of Saudi Arabia provide lighting switches that control light levels and can either raise it or lower it according to the residents preference or usage of a room, thus "Limited availability" is an indication that families in Kingdom of Saudi Arabia don't use such function which could be bothersome when more than one person is using a room and requires a different light setting.
- Around 62% of Saudi Arabian families living in Villa's agree that the artificial lighting in their homes is good which supports our previous explanations perfectly.
- Not a lot of people who answered the survey understood the meaning of it, "Physiological discomfort" was supposed to address wither the residents of the housing unit "Villa" are physiologically discomforted or not, however 78% answered that they do, which doesn't add up to the previously answered questions.

d. <u>Section 4: Human Demeanor:</u>

This section revolves around the human actions that the resident living in the housing unit (Villa) does on a daily bases that might affect the housing unit (Villa) life span, which are:

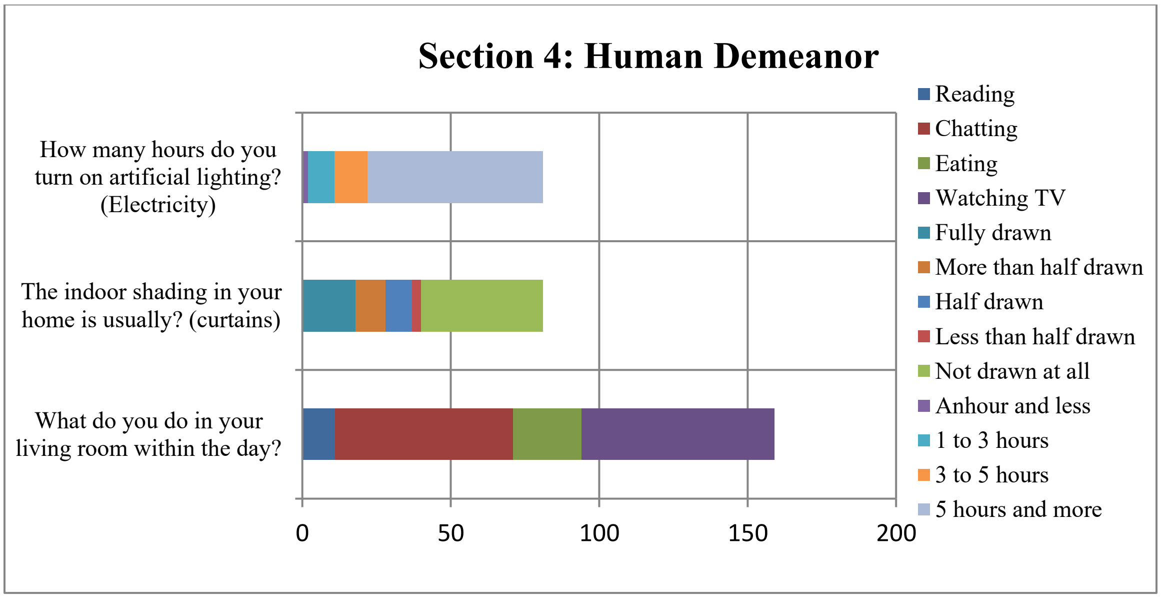


Figure (56) Section 4: Human Demeanor

- Most Saudi Arabian families view the living room as a social gathering within a housing unit of any kind, thus most activities will focus on either watching TV (which 65 people have answered with said answer) or chatting (which 60 people have agreed on).
- Around 51% of the Saudi Arabian families that live in Villa's prefer to not draw their curtains (shading) due to their privacy preferences.
- 73% of Saudi Arabian families living in Villa's use artificial lighting around 5 hours and more, because they rely on it more than natural light which isn't healthy for the normal human being, since studies show that a normal human

should be exposed to 30 to an hour of natural day light every day in order to improve mood and concentration levels in the normal human being.

❖ If you have the chance, what are the things that you will change in your home to allow more day lighting in?

This question mostly revolved around giving the person answering the survey the free liberation to express their opinions of things they possibly might want to improve in their homes, the results mostly revolved around the following answers: either resizing the villa windows or rearrange the furniture and room placement.

e. Section 5: Illumination Comfort:

This section revolves around one question which is the general satisfaction of the housing unit (Villa) resident to understand their over idea of comfort related to the topic of lighting, the question goes as follows:

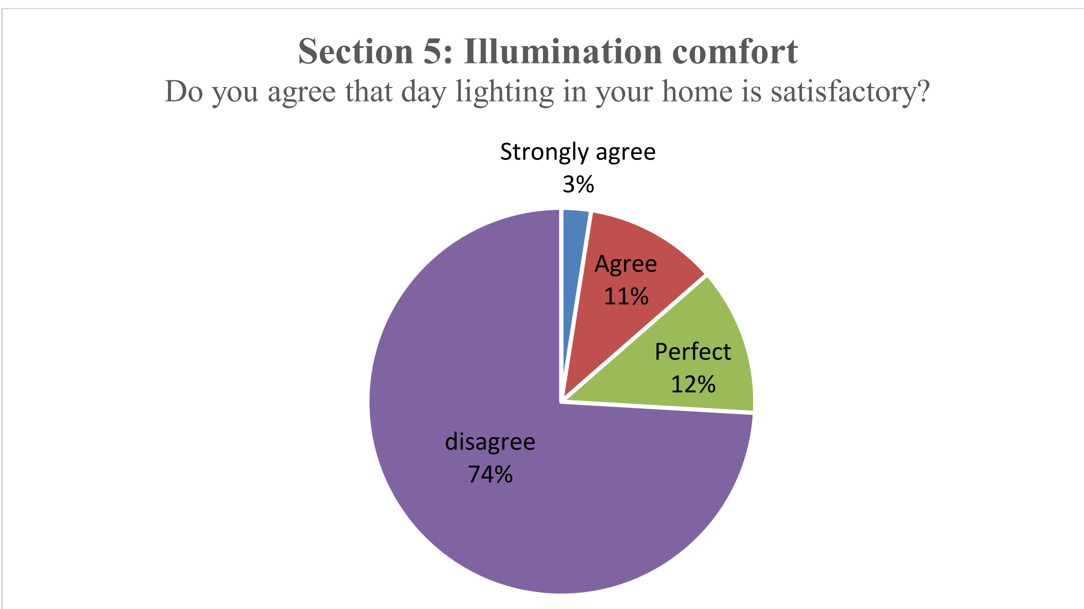


Figure (57) Section 5: Illumination Comfort

74% of people answering the questioner answered that daylighting in their homes is "Disagreeable", which gives an indication that a lot of families are trying to find more better methods to save up energy in their homes but un aware how.

❖ *Survey results and discussions:*

As previously mentioned, the reason behind conducting the survey was to collect information about the common characteristics of villa's located in the three cities in KSA, in the survey information was divide into materialistic information (simulated in chapter 5) and non materialistic information that focuses on the physiological affect it leaves on the residents which are the following aspects from the survey, table (12):

Main required aspects	**Results**
Direction of house in general	75% is north
Heat discomfort	60% rarely
Glare	76% sometimes
Poor eyesight	79% rarely
Full access of controlling artificial lighting levels	86% limited availability
Physiological discomfort	78% agree
Usual activities	65% watching TV, 60% chatting
Shading (curtains) are usually..	51% not drawn at all
The amount of hours using artificial lighting	73% 5 hours and more
Satisfactory level of yearly daylighting	74% disagreeable

Table (12) Survey main aspects results

4.3 Conduct interviews with specialists living in villas in kingdom of Saudi Arabia:

After conducting the survey a series of interviews through additional surveys were done. Originally, 25 interviews were supposed to be conducted with specialists and designers but only 13 agreed to do it, the reason behind the interviews was to extract additional information about the common Villa characteristics, building materials, number of occupants …etc, from the experienced designers, specialists and project managers so we can achieve the additional information that will guide to achieve the common characteristics of villa's in KSA.

4.3.1 Results and discussion:

Combining both the surveys and interviews results creates the common characteristics for a villa in the three cities: Dammam, Al-Khobar and Al-Ehsa located in Kingdom of Saudi Arabia which could be described as Conventional villa characteristics in KSA:

1. Number of floors must be 2.
2. The total height of the villa must be around 7.0 m.
3. the total floor dimensions must be 15.0 m x 17.5m.
4. The Gross Floor Area or (GFA) must be 525m, which is the total of length and width of the inner building walls and multiplying it by measurements length and width to achieve square footage, and finally we multiply it by the number of floors existing in the building.
5. The Gross Wall Area or (GWA) must be 455 m, which is achieved by measuring columnar height and horizontal range of the wall, then multiply it with each other, after that calculate any doors and windows then subtract the result.
6. The window area must be 13.29% of the total gross wall area which is 455m.
7. type of glass is single pane window, which is the most commonly used in KSA.

8. The External walls must be the following measurements:

   a. 20 mm of plaster in the outer area of the building.

   b. 200 mm of concrete that is hollowed block.

   c. 20 mm of plaster in the inner area of the building.

9. The roof must be the following measurements:

   a. 10 mm built up roof.

   b. 150 mm concrete roof slab.

   c. 12.7 mm inner plaster.

10. The floor must be around 150 mm slabbed on grading.

11. Contains 6-7 residents which is the common number in Villa's.

12. The artificial lighting must be:

    a. kw in the lower floors.

    b. 2.0 kw in the upper floors.

The following measurements could be summarized in the following table, table (13):

Characteristics of residential buildings chosen as a case study sample in KSA	
Floors	2
Height	7.0 m
Dimensions of floors	15.0 m x 17.5 m
GFA	525
GWA	455
WA	13.29% out of 455
Glass type	Single window pane
External walls	Outer plaster = 20 mm Inner plaster = 20 mm Hollowed concrete block = 200 mm
Roofing	Built up roof = 10 mm Concrete roof slap = 150 mm Inner plaster = 12.7 mm
Flooring	Grade on slap = 150 mm
Occupants	6-7
Lighting	Lower floors = 3.0 kw Upper floors = 2.0 kw
Lamp type	Halogen
Direction of the villa	North
Living room size	10 – 19 m^2
Bedroom size	5 – 10 m^2
Window size	5 – 1 m^2

Table(13) Characteristics of residential buildings in KSA

4.4 conclusions:

Through the extraction of the common characteristics of residential buildings in KSA, we have also understood that a significant number of Villa residents are not satisfied with the current artificial lighting in their homes, since as though they don't have a deep understanding of the daylighting benefits, they do understand the significant affect its lacking does.

A lot of residents complain regularly from the high amounts of resources being wasted to maintain artificial lighting since it consumes huge sums of money and can have a noticeable health affect.

Chapter 5

THE DEVELOPMENT OF THE BUILDING LAYOUT

5.1 Introduction:

Throughout this chapter a series of simulations on a base case based on the criterion of the common characteristics of housing unit (Villa) in Kingdom of Saudi Arabia, in order to create the idle energy conservative and daylighting friendly housing unit (Villa).

The study will be conducted on a villa located in Dammam city that fits the conventional criterion of villa's located in KSA in the three cities: Dammam city, Al-Ehsa city and Al-Khobar city.

5.2 the chosen building that will be simulated specification:

As previously mentioned a building located in Dammam city that fits the resulted characteristics of the conventional villa's in KSA will be simulated various times in order to reach the idle building.

The buildings shape is square with an area of 295 m^2 (16.4 m x 18 m), with the height of approximately 8 m (each floor is around 3.5 m), with the height of each window is 0.9 m and width is 0.7 m which results in the total of 0.63 m^2 window (13 windows in the ground floor and 13 in the first floor), the total of 14 rooms (without counting the bathrooms), total of window to wall ratio is 3.4% in the whole building and with the window glass type being Single window pane, figure (58) and figure (59).

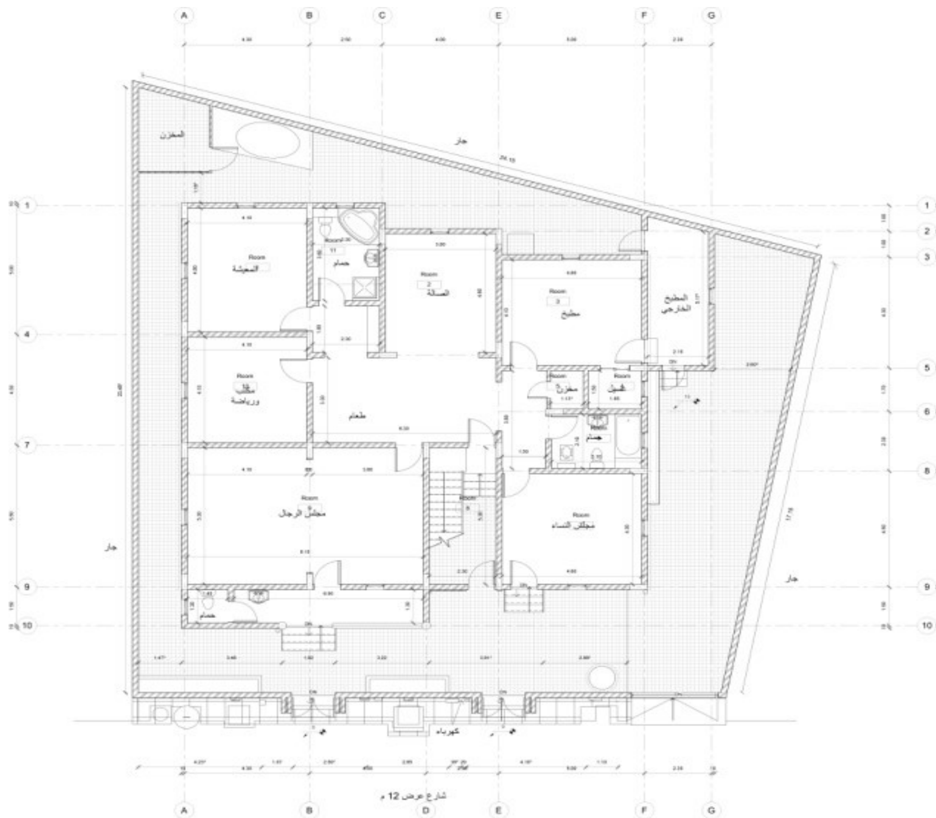


Figure (58) ground floor plan

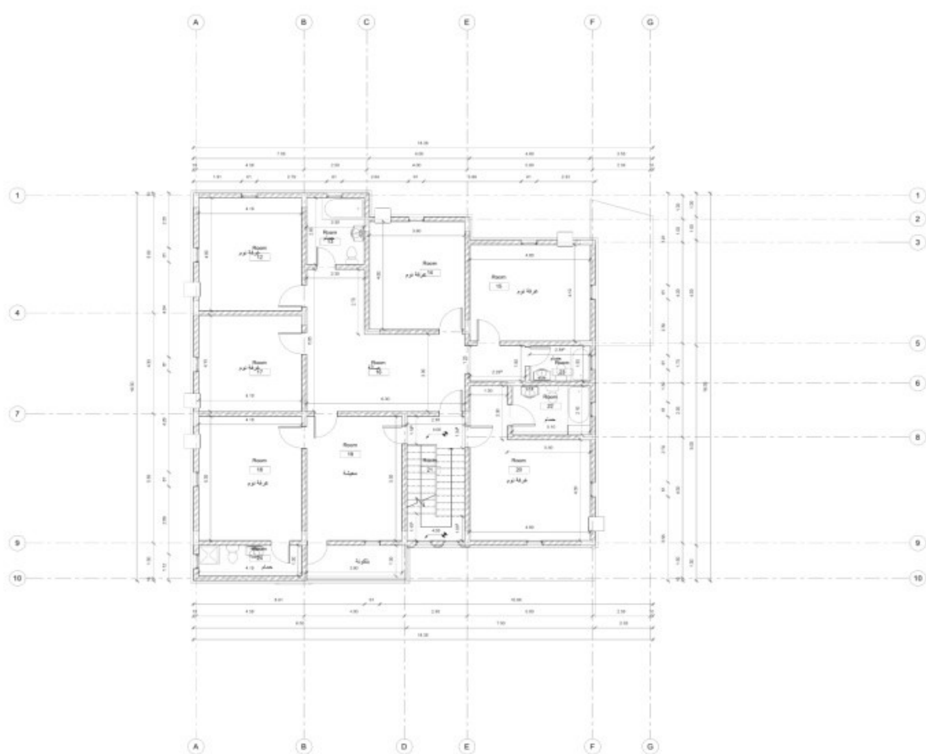


Figure (59) first floor plan

the villa's specifications could be summarized into the following table (14):

parameter	specifications
location	Dammam
Building type	Residential (villa)
Number of floors	2
Number of occupants	6 - 7 residents
Height of floors	3.5 m
Height of windows	0.9 m
width of windows	0.7 m
Number of rooms	14 rooms without counting the bathrooms
WWR	3.4%
Ground floor + first floor area	590 m^2
Building area	295 m^2
Type of window glass	Single window pane

Table (14) Building of choose specifications

5.3 Chosen parameters for the simulation:

The simulated building will be run throw a series of parameters in order to achieve the idle design in each one of them, the main parameters that are chosen to reach the idle villa are:

1. Window to wall ratio:

   Window to wall ratio or WWR for short is the measurement of the percentage area specified by dividing the building's total glazed area by its exterior envelope wall area, which could be summed up throw the following equation:

$$\text{WWR (\%)} = \frac{\sum Glazing\ area\ (m2)}{\sum Gross\ exterior\ wall\ area\ (m2)}$$

The importance behind studying the window to wall ratio is because it haves a huge influence on the buildings: cooling, heating, views, lighting in general, ventilation and naturalistic milieu regarding access for and to daylight, WWR is measured throw the following scales:

a. *Annual Sunlight Exposure:*

Annual Sunlight Exposure or ASE for short is the scale that portrays the over excessive amount of direct sunlight a space receives, which may lead to glare (visual discomfort) and thermal discomfort.

In short it is the measurement of the percentage of the floor area that at least receives 1000 lux for 250 hours at least that are occupied throughout the year, which is written as (ASE 1000,250).

The importance of ASE lies on the fact it functions as an indicator of any possible visual discomfort (glare) and possible thermal discomfort, but it doesn't directly measure them, it measures the direct sunlight instead which may lead to possible speculations, which could be summed up throw the following equation:

$$ASE = \frac{\sum_{j=1}^{N} A(j)}{N} \quad \text{with} \quad A(j) = \begin{Bmatrix} 1 : a_j \geq T_y \\ 0 : a_j < T_y \end{Bmatrix}$$

Annual sunlight exposure is measured or rechecked throw:

❖ <u>*Daylight Glare Possibility:*</u>

Daylight Glare Possibility or DGP it is explained as when the luminance proportion within the viewing range of a normal observer surpasses the restful functional range of a normal eye, e.x.: blinding white highlights and bounced/obscured stray light. it is a very hard measure because it depends heavily on each individuals preferences, positioning, what is the task that is being carried at the current situation and reflection, DGP could be explained throw the following law:

$$DGP = 5.87 * 10^{-5}\, E_v + 0.0918 * log_{10}\left[1 + \sum_{i=1}^{n}\left(\frac{L_{s,i}^2 * \omega s, i}{E_v^{1.87} * P_i^2}\right)\right] + 0.16$$

b. *Spatial Daylight Autonomy:*

Spatial Daylight Autonomy or SDA for short is the scale that portrays the amount of adequate daylight a specific space receives. In particular, it explains the minimum luminance level percentage a floor area receives for the minimum annual hours that are occupied percentage.

The importance of SDA lies on the fact that it functions as an aiding tool that helps in designing that haves sufficient daylighting, SDA is a great predicting tool as it predicts actual as-constructed performance of daylight, which could be summed up throw the following equation:

$$sDA = \frac{\sum_{j=1}^{N} S\,(j)}{N} \quad \text{with} \quad S(j) = \begin{Bmatrix} 1 : s_j \geq \tau t_y \\ 0 : s_j < \tau t_y \end{Bmatrix}$$

2. Shading:

It is a method that minimizes a buildings pinnacle of heat gain and cooling necessities and ameliorate the quality of natural light of the building's interior, as well as improving the users visuals into a comforting state by monitoring glare and minimizing contrasted ratios, which results to maximized productivity and satisfaction of the users. In this research, two methods were taken into consideration with various measurements to simulate various times in order to achieve the idle villa in KSA, which are:

a. *Overhang shading devices:*

Overhang shading devices are an over extended section beyond the window frame that are designed with specified measurements in order to block high levels of sunlight from reaching certain sections of the roof within a normal day, however in the winter, the sunlight is directed in a lower angle and is allowed inside in order to warm the house.

Its importance lies on its size, one scale shorter in the summer and an over excessive amount of sunlight will enter the home which may lead to overheating and glare, in the other hand one scale longer in the winter and the space will be darker, gloomy and cloud for the user to stay in.

b. Window shading fins device:

Window shading fins device is a device that is able to redistribute and redirect the natural sunlight throw a certain space or an area, the importance of this method doesn't lie on the luminance of a space but on the distribution of said luminance in a range of vision that defines the luminance environment quality.

similar to vertical shading devices, window shading fins device mostly focuses on improving the use of west and east direct sunlight exposure and to increase the value of the insulation used in the building.

The shading methods that were chosen to be used in the simulation, doesn't only focuses' on improving the daylight exposure but it also minimizes the energy usage.

3. <u>Glazing:</u>

Glazing is the conductance of window instillation, Its importance lies on the fact that whichever type is chosen is mostly responsible for 26% - 30% of heat loss or gain within a residential building.

It is important to choose the right type of window that suits the climate that the user lives in, according to the common characteristics of villa's located in KSA the base case glass type that is used through the series of simulations is:

- *<u>Low - Emissivity coating:</u>*

  Low - Emissivity coating or Low-e is a type of glass that controls the transfer of heat through it, this type of glass usually cost more than the regular type of windows by 11% - 15% but it saves up energy around

32% to 50% more than the normal one, Low-e is a thin microscopic glass and it is invisible virtually.

The simulations will be based on the low - emissivity coating glass type but it will be changed according to the testing in order to achieve the idle type of glass and frame that will aid the building in minimizing energy consumption and while allowing more daylight inside the building.

The following glazing types were chosen according to the most commonly available glazing types in the Saudi Arabian market, which are the following:

a. *Single tint glazing:*

   It is a glazing type that uses a tinted glass to minimize excessive heat, this type of glass is important because it haves the ability to control glare with the U-Value of almost 1.00 W/m2.K using metal frames.

b. *Double - glaze, tinted glass:*

   It is a glazing type that uses tinted glass, with 2 glass lites and outer glass layer that is gray or bronze while the inner layer is clear with an air gap that separates the glass layers, this type of glazing haves the U-value of 0.56 to 0.7 W/m2.K while using metal frames with thermal breaks.

   Compared to single tint glazing, double tinted glazing haves the ability to reduce half of the energy consumption or loss due to an air space that exists between the two layers of glass.

c. *Double - glazing, clear glass:*

It is a glazing type that is very similar to double tinted glazing in regards to most of its design elements except for the fact that it uses clear glass instead of tinted which leads to allowing easier access of light and high gains of solar heat, this type of glazing haves the U-value of 0.56 to 0.7 W/m2.K while using metal frames with thermal breaks.

d. *Double tinted glass:*

The forth type is very similar to the third type (Double - glazing, clear glass) in terms of usage except it uses double normal glass's, this type of glazing haves the U-value of 0.71 to 0.99 W/m2.K while using metal frames.

e. *Double-Glazed, Medium-solar-gain Low-E Glass:*

The fifth type of glazing is often called spectrally selective low-E glass, because of its ability to minimize gains of solar heat while preserving high visual transmission as well as minimize heat loss and allowing access of solar gain which makes it suitable for various of climates, this type of glazing haves the U-value of 0.41 to 0.55 W/m2.K while using metal frames with thermal breaks.

5.3.1 Discussion:

Based on the parameters that were chosen, we will study the simulated building through the following software's: Revit (Daylight analysis) that is used to study the WWR which changing its measurements will lead to finding the best daylight exposure according to the ASE scale (which will verify the DGP) and sDA scale, Equest will be used to test various shading devices, glazing and frames in order to study its affect on energy performance and find the best method.

To achieve said results, an investigative frame work was needed to help find the best method to save energy and increase daylight exposure, a series of measurements (M) was created which resulted in the creation of the following table (15):

The investigation frame work		
Ms	***Variable***	***Short description***
M1	Changing Window to Wall Ratio	The simulation was run 10 hours a day (in the daytime) from 8:00 am to 6:00 pm, from January 1st to December 31th for seven days a week testing different WWR percentage.
M2	Changing the window glazing and framing type	The simulation will test out various types of window glazing and frames to achieve the most energy conservative type compared to the base case which is "Low-e coating".
M3	Testing various shading devices methods	The simulation will test out various types of shading devices methods to achieve the most method that allows sufficient daylight exposure and save energy.
M4	Comparing and filtering results according to the base case	The results of the simulated measures will be each compared separately in order to filter the results and reach the idle villa design.

Table (15) the investigative frame work

5.4 discussions and results:

5.4.1 Validation:

To approve that the study is close to reality, a comparison between real life case and the base case (utility bill and simulation in terms of consumption during the year) y using utility bill dated from the year 2017 to 2018, which resulted in the following, table (16):

A comparison between real life case and the base case				
Month	Real life case results		Base case results (simulation results)	
	Kwh	S.R	Kwh	S.R
Jan	3204	475.65	4140	745.2
Feb	3804	295.4	4020	723.6
Mar	3056	227.25	5110	919.8
Apr	3628	277.8	6220	1146
May	6075	680	7980	1674
Jun	5966	851.45	8030	1689
Jul	10658	1892.4	9020	1986
Aug	8803	1592.55	9390	2097
Sep	7898	1137.75	8080	1704
Oct	6260	903	7540	1542
Nov	5139	542.8	5310	955.8
Dec	2862	201.2	4540	817.2
Total	67353	9077.25	79360	15999.6

Table (16) A comparison table between the real life case and the base case

In order to explain the result and comparisons, a graph was made as the following:

1. <u>A comparison based on cost (S.R):</u>

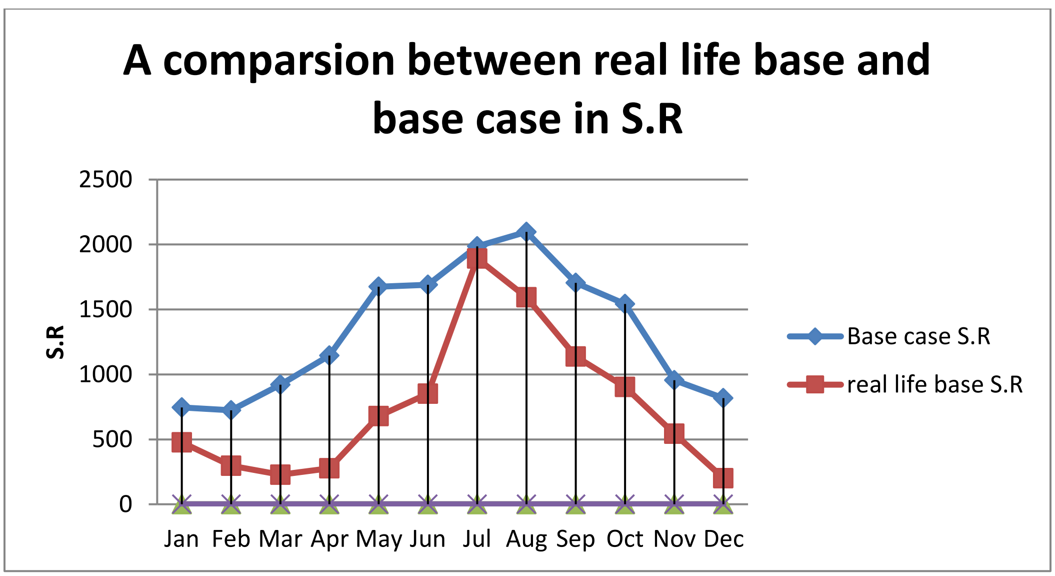


Figure (60) A comparison graph between the real life case and the base case in S.R

In the following graph we have compared the real life case to the base case according to cost (S.R), which is in the real life case is significantly less than the base case in the peak months of the year (between July to October) where the electricity demand is at its highest.

To sum up the results we can explain in a simpler manner by comparing the total cost of each the base case and the improved model as follows, figure (61):

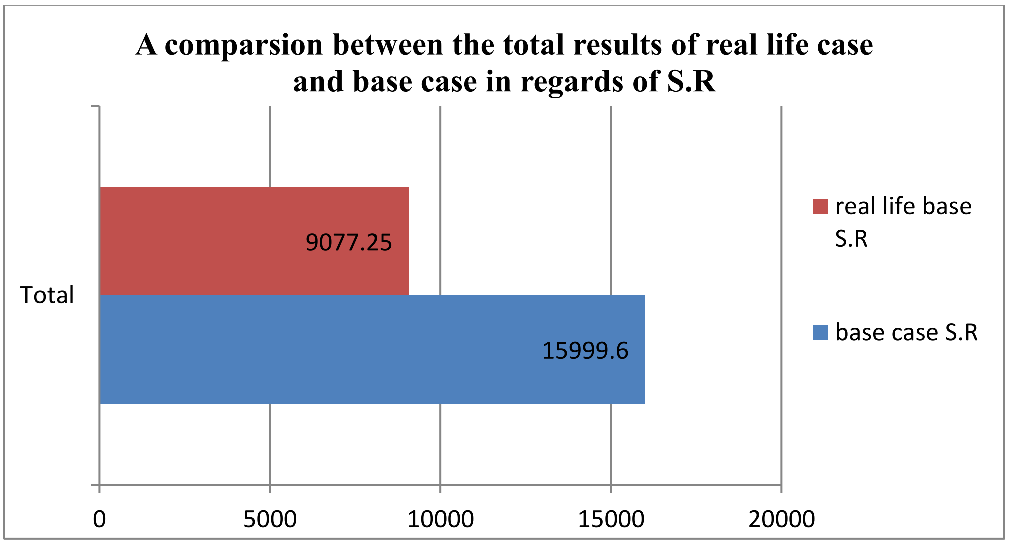


Figure (61) A comparison graph between the total of the real life case and total of base case in S.R

The total cost of the real life case is less than the base case cost, and to define such results we use the following equation:

$$\frac{9077.25-15999.6}{15999.6} * 100 = 43.3\%\text{ riyal}$$

the reason behind the result being low is because the electric bills were done in the year 2017 to 2018 which was less costly than the year 2019.

2. A comparison based on kWh:

In the following graph we have compared the real life case to the base case according to kWh, which in the real life case is more than the base case in the peak months of the year (between July to October) where the electricity demand is at its highest.

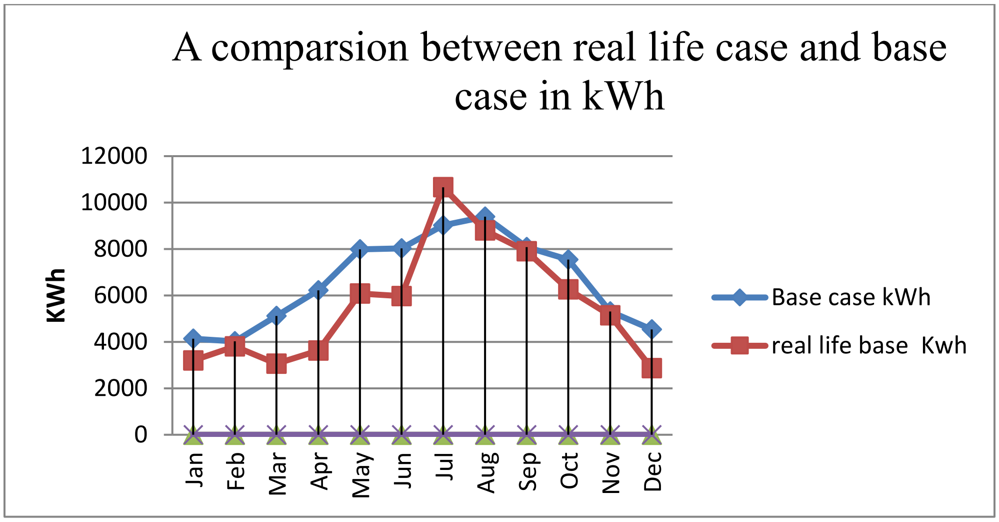


Figure (62) A comparison graph between the real life case and the base case in S.R

To sum up the results we can explain in a simpler manner by comparing the total cost of each the real life case and the base case as follows:

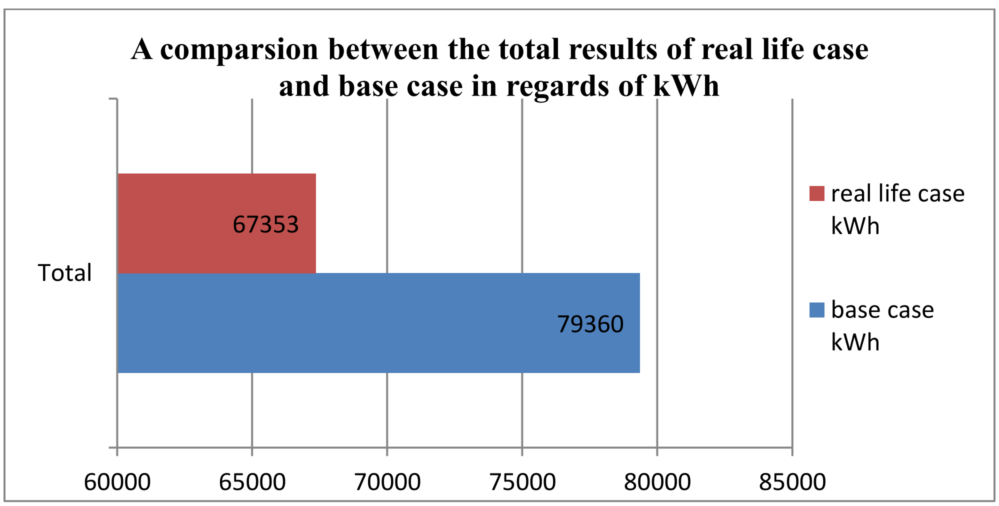


Figure (63) A comparison graph between the total of the real life case and the base case in S.R

The total kWh of the real life base is less than the base case kWh, and to define such improvement we use the following equation:

$$\frac{67353 - 79360}{79360} * 100 = 15\%\ \text{kWh.}$$

the difference between real life and the base case is 15% in kWh.

5.4.2 Base case:

1. Energy performance:

   Throughout this aspect, a thorough study was in need to understand the base case energy performance throughout the testing period, the following table lists down all the input data that is required in order to do so, table (16):

Characteristics of the base case building of the simulation		
Variable	Motif	worth
Location	Climate information	Dammam, Saudi arabia
Hedge	Wall	**Isolated concrete masonry block:** • (25 mm plastered, 200 mm Separated CMU, 200 mm plaster) • (U-value= 0.54 w/m^2 K)
	Roof	**Separated slab by polystyrene board:** • Layers: (50 mm limestone "gravel", 50 mm polystyrene, 4 mm water proofing bitumen membrane , 300 mm concrete heavy weight "R/C") • Properties: (U-value=0.24 w/m^2 K)
	Glazing	**Single low E glass:** • Layers: (Single low-E panel: 4mm) • Properties: (U-value= 3.67 w/m^2 K)
Light	The density of the light power	27.3 W/m^2
	The system of lighting	Tubes type Fluorescent
	Operation hours	24
equipment	The density of the equipment power	13 W/m^2
HVAC	Systems	Package
	The temperatures set point	19 C
	Operation hours	12
Occupants	Number of occupants	8 (approximately 18.6 m^2/occupants)

	Heat that is gained from the occupants	27 W/m^2

Table (16) the energy performance input data for the base case building characteristics

a. *Annual energy consumption:*

Annual energy consumption is the yearly amount of energy that is being wasted to power up a housing unit, building ..etc. In the following table, we have acquired the results of the annual energy consumption of the base case, table (17):

Annual energy consumption of the base case	
	Electricity (kWh)
Space Cool	32,242
Hot Water	9,883
Vent. Fans	4,220
Pumps & Aux.	53
Misc. Equip.	24,947
Area Lights	7.176
Total	78,522

Table (17) Annual energy consumption of the base case table

The following table could be rearranged into the following graph, figure (64):

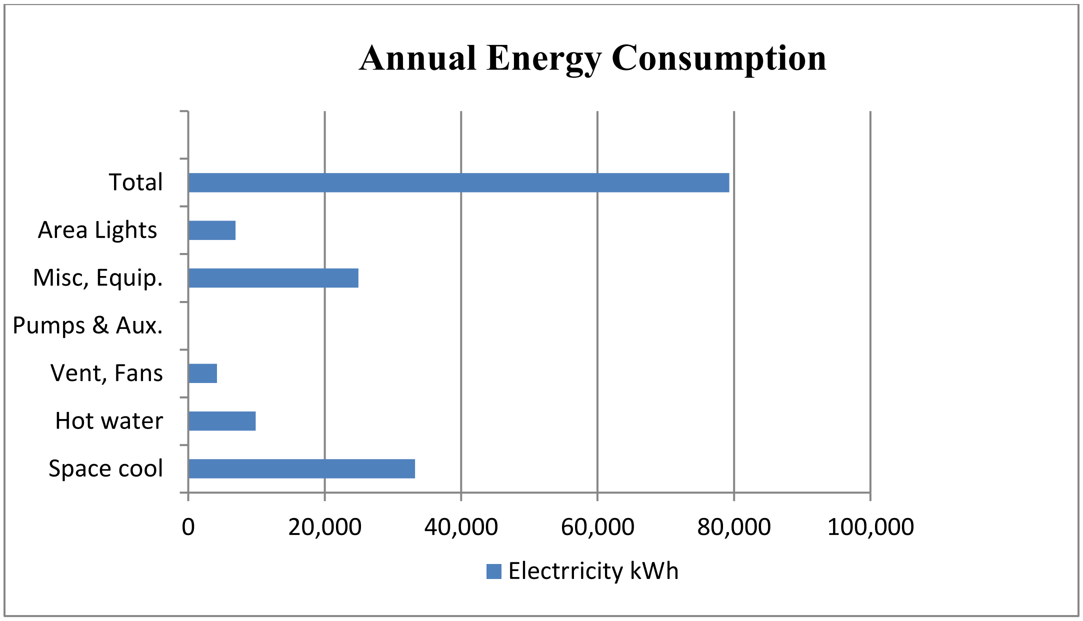


Figure (64) Annual energy consumption of the base case graph

The following graph is the result of studying the annual energy consumption through the base case villa located in Dammam city in KSA, the total energy use is 79,290 kWh with around 33,243 kWh being wasted on space cooling from the total of the annual consumed energy.

b. *Electric consumption (percentage):*

Electric consumption is a type of energy consumption that uses electricity to power it, to be specific it is the demand that is made by existing electric supplies.

The following pie chart, we have show cased the main appliances and their electric consumption in the base case, figure (65):

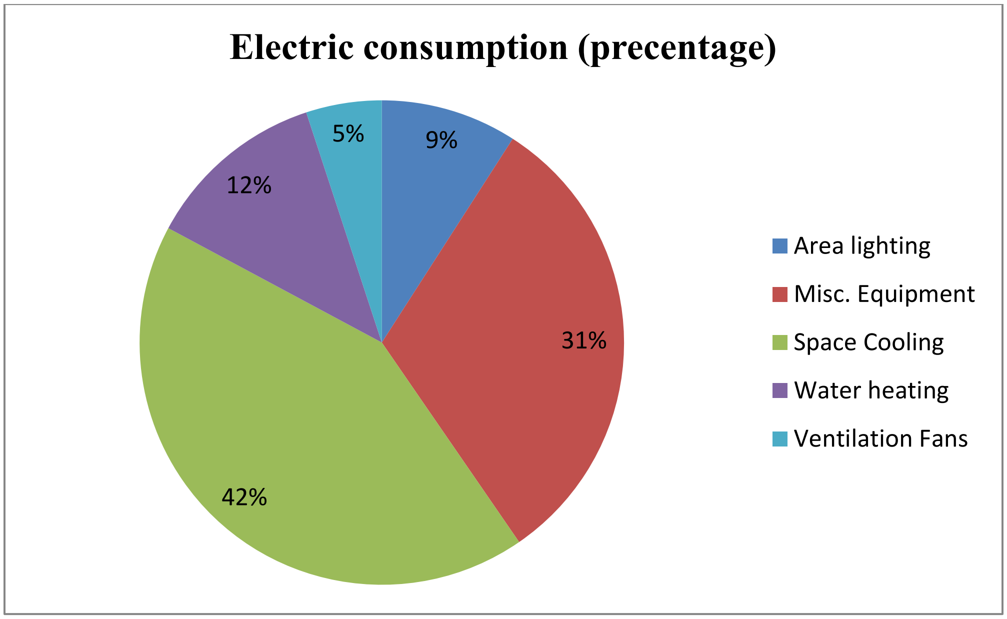


Figure (65) Pie chart that explains the electric consumption of the base case appliances

In following pie chart various energy consuming appliances were listed in order to compare between them and define the highest energy consuming one, with around 42% total of energy consuming, Space cooling (AC) was the highest energy consuming device due to the high temperatures in KSA the users will use Space Cooling devices (AC) in order to cool off from the strong sunlight throughout the duration of the year.

c. *Electric Consumption (kWh):*

Electric Consumption is a type of energy waste that uses electricity, The following graph explains the electric demand of every appliances located inside the base case throughout the duration of a full year, figure (66):

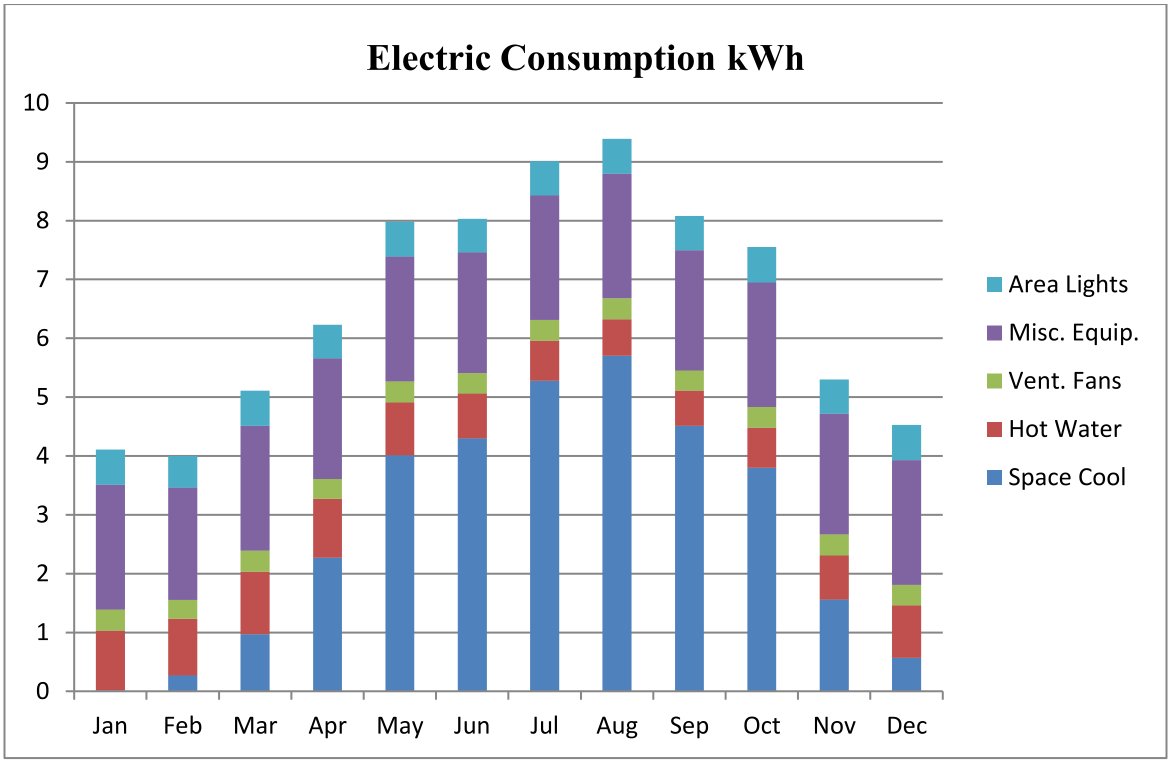


Figure (66) A graph that explains the electric demand of the base case appliances through the duration of a full year

The following graph explains the electric Consumption of each month throughout the year in order to understand the appliances that requires the highest electric energy and try to find ways in order to minimize its use or its waste, and once again the highest appliance with a huge amount of electric Consumption throw almost most of the months in a year is Space cooling.

5.4.3 Window to wall ratio study and comparison:

in this part, we will study several simulations in regards f window to wall ratio by changing the window sizes to achieve the idle size that will allow more daylight to reduce energy consumption.

5.4.3.1 WWR for base case:

The base case for the series of testing's was run through a simulation first in order to determine the flaws in its WWR to specify the improvements.

Measurements of the base case windows is: 0.7 m in width and 0.9 m in heights, with the following percentages according to the main orientations: North is 3.5%, South is 2.9%, East is 3.1% and West is 4.2, which results in the following:

figure (67) a simulation of the base case in order to test WWR according to sDA and ASE for the ground floor

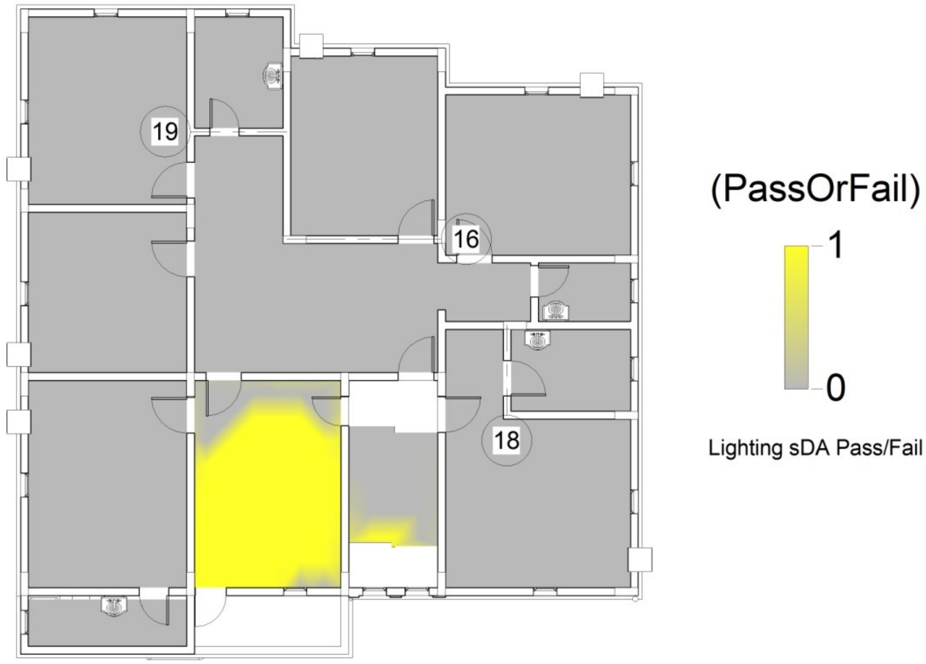


figure (68) a simulation of the base case in order to test WWR according to sDA and ASE for the first floor

Most of the rooms in the base case abide by the ASE (Annual Sunlight Exposure) percentage by varying between 0% - 10% except for one room which was the living room in the ground floor by 1% which is 11% in total.

In the other hand most rooms in the base case doesn't abide by the SDA (Spatial daylight Exposure) as most results are either 0% or less than the intended percentage frame which is 55% - 75% except for one room which was a bedroom in the first floor by 78% which exceeds the percentage frame by 3% which is in SDA law is explained by a preferred availability of daylight.

To summarized the results simply it could be explained in a general form as the following graph, figure (69):

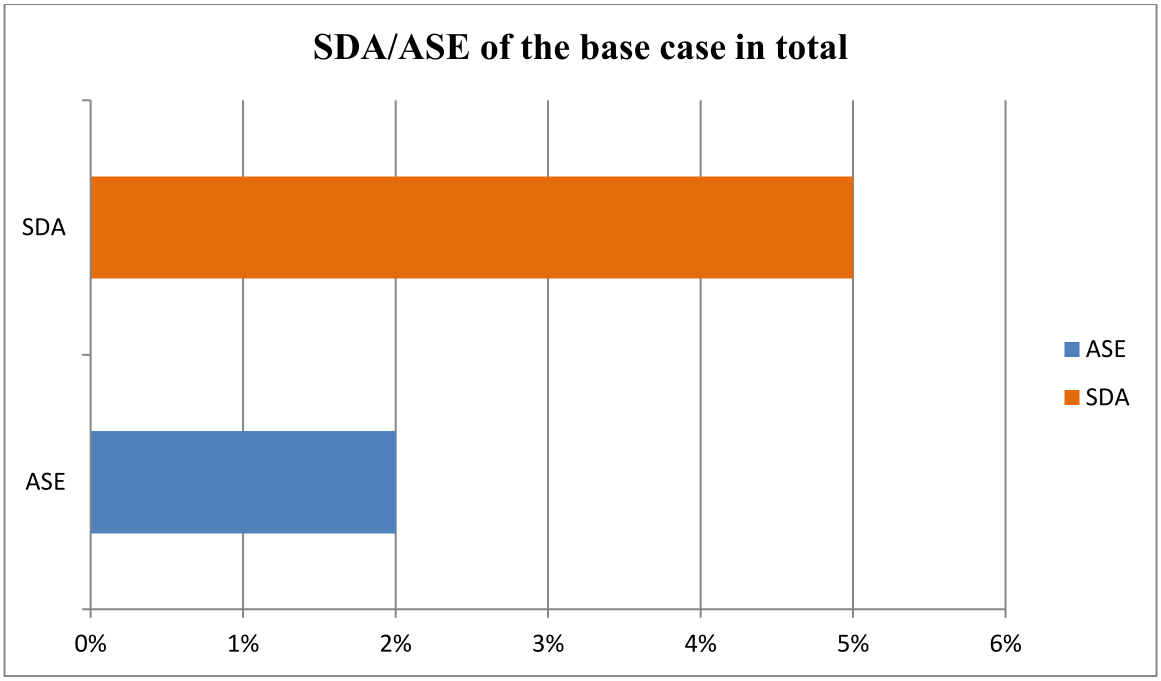


figure (69) a graph that explains the total of the SDA/ASE in the base case

In the graph, we can see that the total of rooms that actually use SDA is only 5%, which is not even nearly sufficient to the intended percentage frame that is 55% - 75%, in the other hand ASE reaches 2% which some its intended percentage that is the limit of 10% but the results made by the SDA indicates that the base case is very dark and doesn't receive any sufficient daylight.

<u>5.4.3.2 WWR of case study num. 1:</u>

Based on the simulated WWR base case a series of simulations is conducted to to find the idle WWR, the window sizes in the first case study were changed to: 1.2 m in width and 1.0 m in height, that led to the following percentages according to the main orientations: North is 7%, East is 3.5%, West is 6.1% and 5.6%, which resulted in the following, figure (70):

figure (70) a simulation of the first case study in order to test WWR according to sDA and ASE for the ground floor

figure (71) a simulation of the first case study in order to test WWR according to sDA and ASE for the first floor

Most of the rooms in case study one abide by the ASE (Annual Sunlight Exposure) percentage by varying between 0% - 10% except for three rooms varying between 1% - 4% over the expected limit, which is 11% to 14% in total.

In the other hand most rooms in the base case doesn't abide by the SDA (Spatial daylight Exposure) as most results are either 0% or less than the intended percentage frame which is 55% - 75% except for two rooms which were 13% over the percentage frame which equals to 89% that is explained in SDA law by a preferred availability of daylight and 6% above the minimum percentage frame which equals to 61% that is explained in SDA law by a good availability of daylight.

To summarized the results simply it could be explained in a general form as the following graph, figure (72):

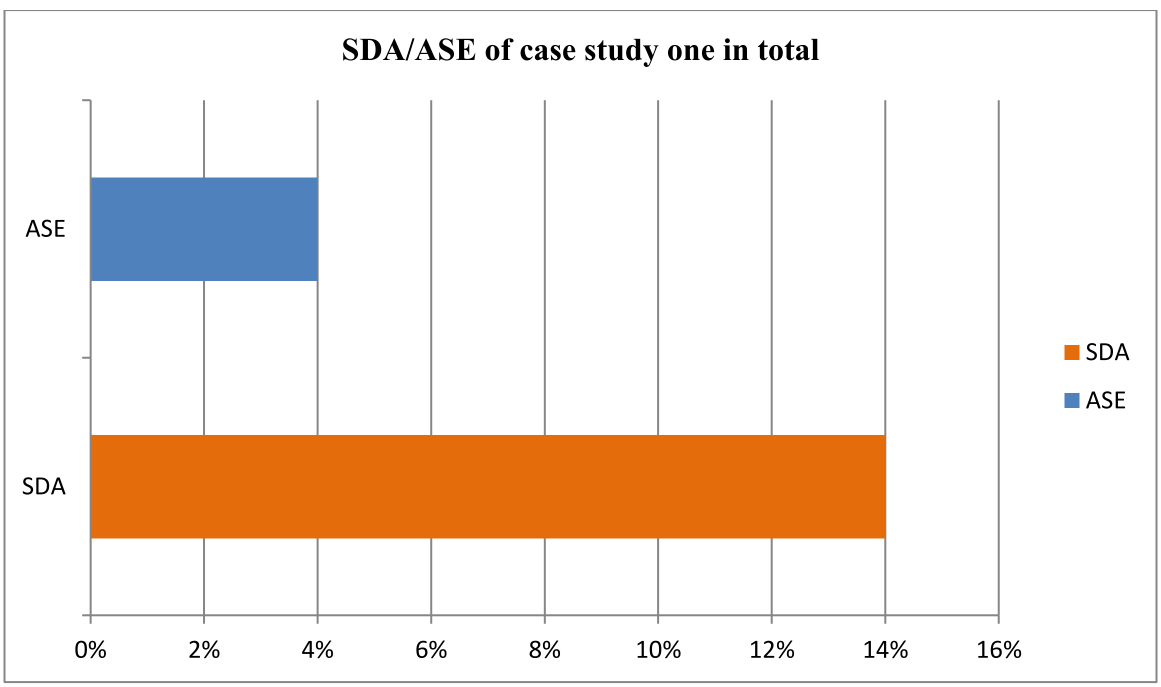


figure (72) a graph that explains the total of the SDA/ASE in the first case study

In the graph, we can see that the total of rooms that actually use SDA is only 14%, which is not even nearly sufficient to the intended percentage frame that is 55% - 75%, in the other hand ASE reaches 4% which some its intended percentage that is the limit of 10% but the results made by the SDA indicates that the base case is very dark and doesn't receive any sufficient daylight.

By resizing and changing the measures of the windows (WWR), we will affect the Annual energy consumptions depending on the size, which is as explained simply in the following graph, figure (73):

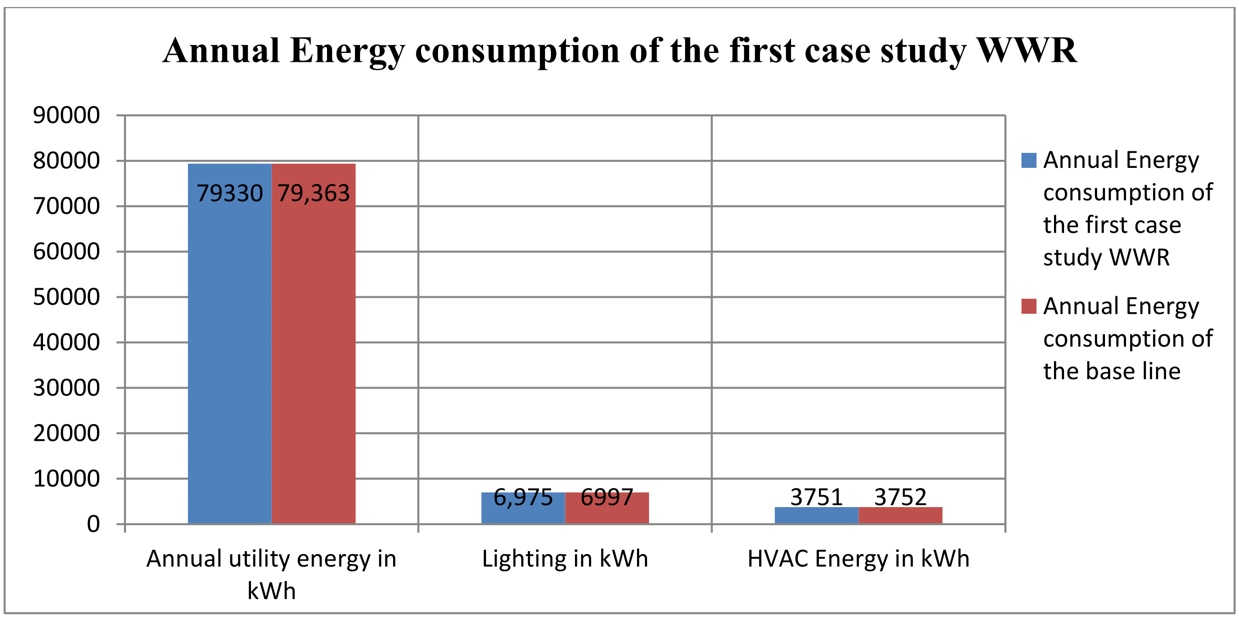


figure (73) a graph that explains the Annual energy consumption of the first case study WWR

The graph indicates the changes that happened in the first case study WWR, which was resulted in the following:

1. In the Annual utility energy in kWh we have saved 0.3% of energy consumption.
2. In the Lighting in kWh we have saved 0.1% of energy consumption.

3. In the HVAC Energy in kWh we have saved 0.2% of energy consumption.

<u>5.4.3.3 WWR of case study num. 2:</u>

Based on the simulated WWR base case a series of simulations is conducted to to find the idle WWR, the window sizes in the second case study were changed from the base case and first case study to: 2 m in width and 1.4 m in height, that led to the following percentages according to the main orientations: North is 14%, East is 7.5%, West is 15% and 13%, which resulted in the following, figure (74), (75):

figure (74) a simulation of the second case study in order to test WWR according to sDA and ASE for the ground floor

figure (75) a simulation of the second case study in order to test WWR according to sDA and ASE for the first floor

In the second case study, around 11 rooms out of 24 doesn't abide by the ASE (Annual Sunlight Exposure) percentage by varying between 0% - 10%, instead they vary from 11% - 39% which will create glaring issues and exposure to direct sunlight.

In the SDA method, 5 rooms out of 24 abide by the SDA (Spatial daylight Exposure) as they vary from 58% - 93% which aliens with the percentage frame of SDA that is 55% - 75% which leads to SDA law to a preferred availability of daylight and a good availability of daylight.

<u>To summarized the results simply it could be explained in a general form as the following graph:</u>

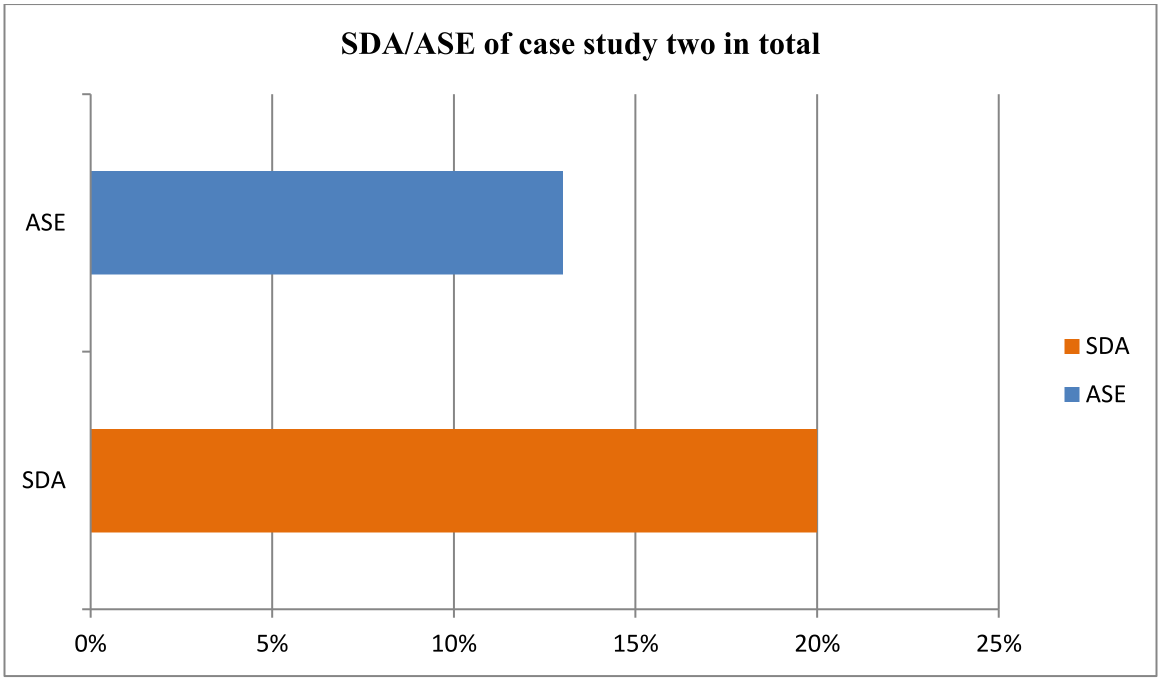


figure (76) a graph that explains the total of the SDA/ASE in the second case study

In the graph, it is shown that the total of rooms that actually use SDA is only 20%, which is a significant improvement compared to the firs case study but still not nearly enough the intended 55% - 75%, in the other hand ASE have reached 13% which is an a clear sign that it went over the intended limit of 10% which isn't a good sign and needs to be minimized in the next case study, in the end the results made by the SDA indicates that the base case is still dark and doesn't receive any sufficient daylight and that the ASE level is over the excepted limit.

By resizing and changing the measures of the windows (WWR), we will affect the Annual energy consumptions depending on the size, which is as explained simply in the following graph:

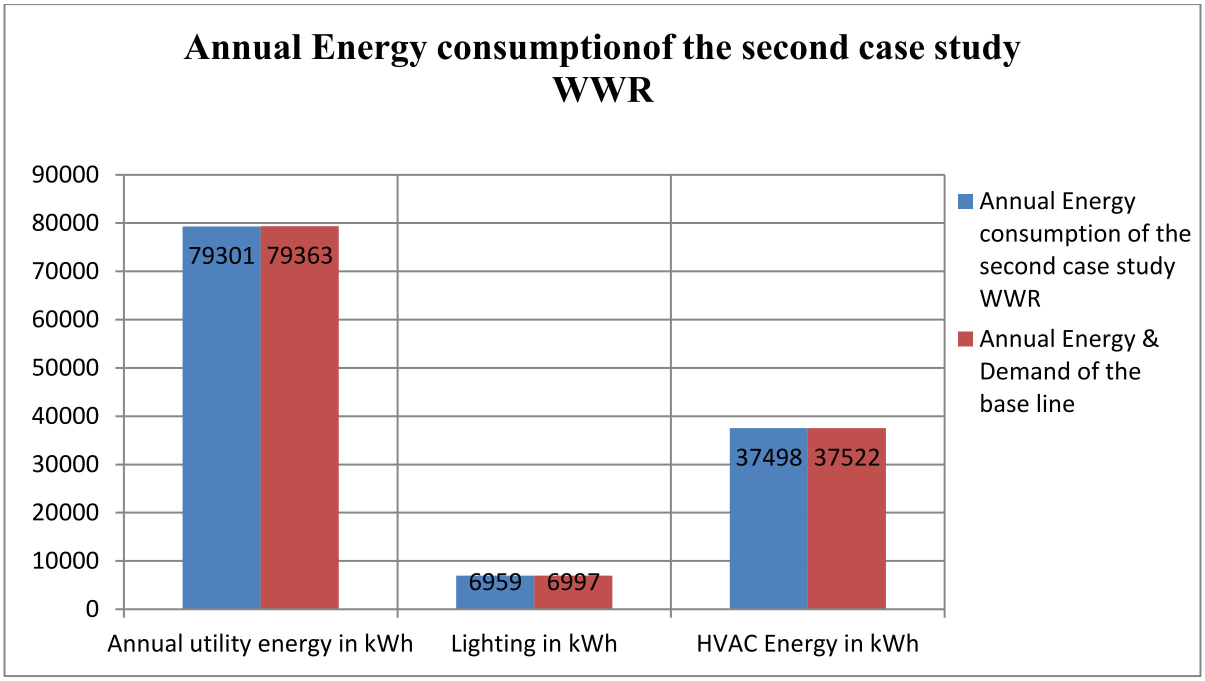


figure (77) a graph that explains the Annual energy consumption of the second case study WWR

The graph indicates the changes that happened in the second case study WWR, which was resulted in the following:

1. In the Annual utility energy in kWh we have saved 0.4% of energy consumption.
2. In the Lighting in kWh we have saved 1% of energy consumption.
3. In the HVAC Energy in kWh we have saved 0.3% of energy consumption.

5.4.3.4 WWR of case study num. 3:

Based on the simulated WWR base case a series of simulations is conducted to to find the idle WWR, the window sizes in the third case study were changed from the base case, first case study and second case study to: 2.8 m in width and 1.4 m in height, that led to the following percentages according to the main orientations: North is 19.5%, East is 12.5%, West is 20.8% and 18.3%, which resulted in the following:

figure (78) a simulation of the third case study in order to test WWR according to sDA and ASE for the ground floor

figure (79) a simulation of the third case study in order to test WWR according to sDA and ASE for the first floor

In the second case study, around 10 rooms out of 24 doesn't abide by the ASE (Annual Sunlight Exposure) percentage by varying between 0% - 10%, instead they vary from 13% - 39% which will create glaring issues and exposure to direct sunlight.

In the SDA method, 7 rooms out of 24 abide by the SDA (Spatial daylight Exposure) as they vary from 58% - 93% which aliens with the percentage frame of SDA that is 55% - 75% which leads to SDA law to a preferred availability of daylight and a good availability of daylight.

<u>To summarized the results simply it could be explained in a general form as the following graph:</u>

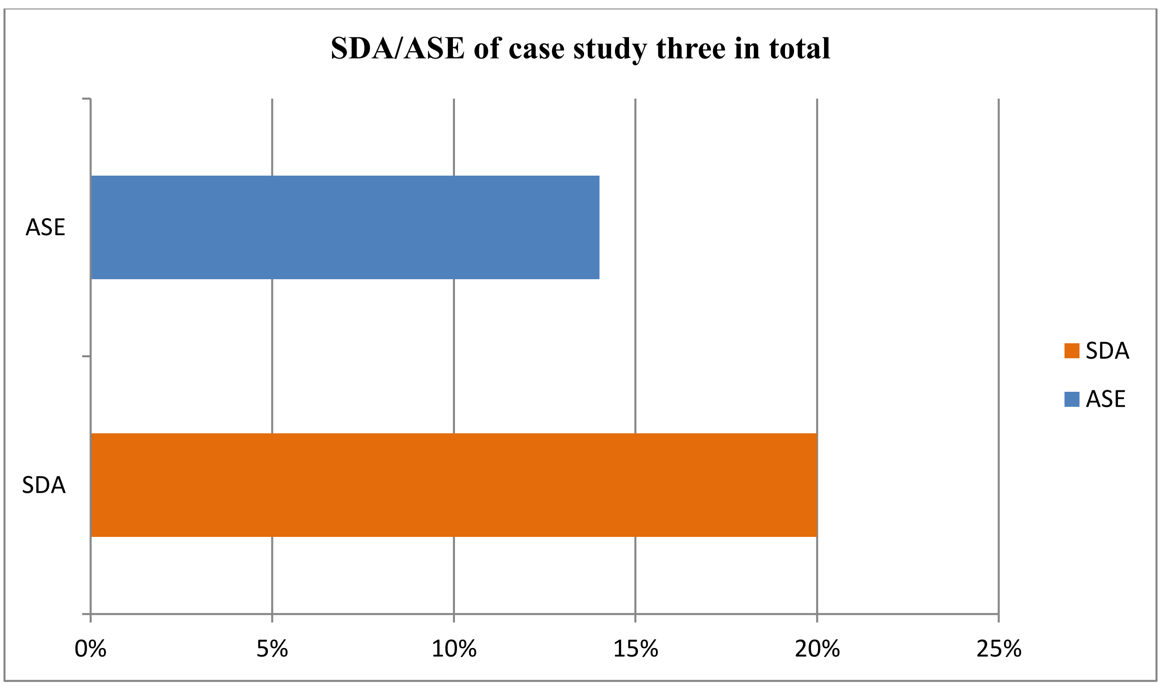


figure (80) a graph that explains the total of the SDA/ASE in the third case study

In the graph, we can see that the total of rooms that actually use SDA is only 20%, which is a significant improvement compared to the firs case study but still not nearly enough the intended 55% - 75%, in the other hand ASE have reached 14% which is an a clear sign that it went over the intended limit of 10% which isn't a good sign and needs to be minimized in the next case study, in the end the results made by the SDA indicates that the base case is still dark and doesn't receive any sufficient daylight and that the ASE level is over the excepted limit.

By resizing and changing the measures of the windows (WWR), we will affect the Annual energy consumptions depending on the size, which is as explained simply in the following graph:

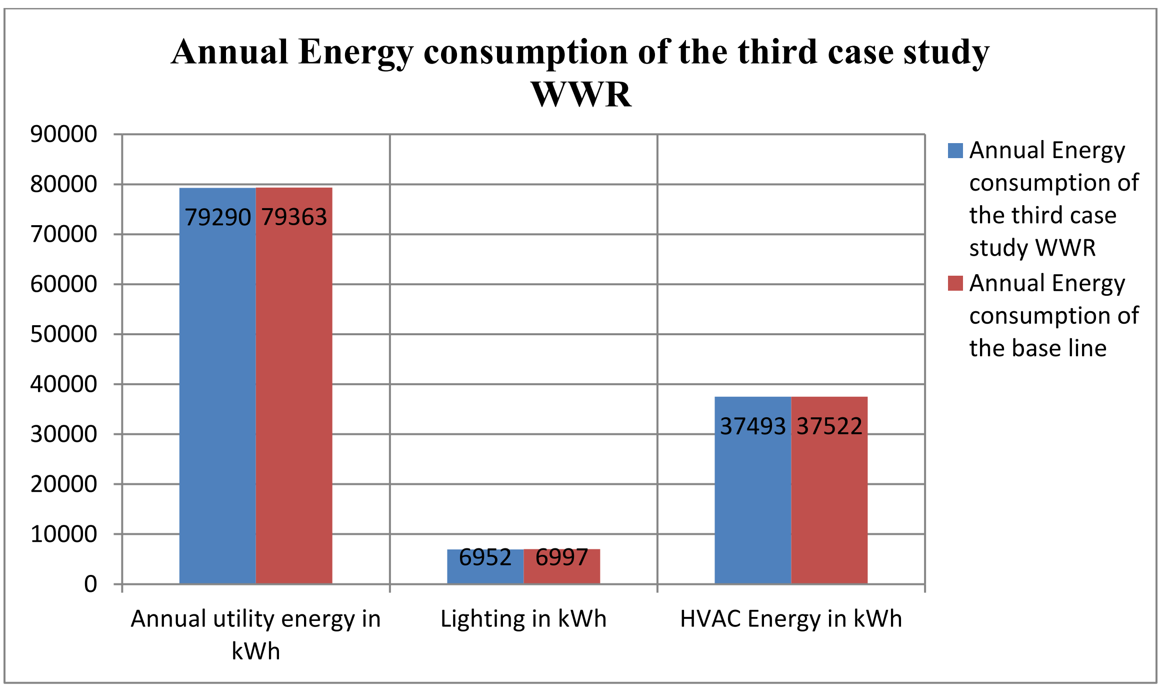


figure (81) a graph that explains the Annual energy consumption of the third case study WWR

The graph indicates the changes that happened in the second case study WWR, which was resulted in the following:

1. In the annual utility energy in kWh we have saved 0.6% of energy consumption.
2. In the Lighting in kWh we have saved 1% of energy consumption.
3. In the HVAC Energy in kWh we have saved 0.3% of energy consumption.

5.4.4 WWR results and discussions:

After conducting the simulations from case study one to three based on the base case, and changing the measurements to test out the results and explain them, we can summarize the process into the following table, table (18):

The summarized results of the simulated cases of WWR

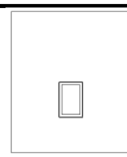
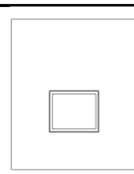
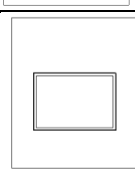
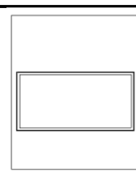
Cases	WWR %		Total %	Type	Width	Height	SDA	ASE
Base	North	3.5%	3.4%		0.700	0.900	5%	2%
	South	2.9 %						
	East	3.1%						
	West	4.2%						
WWR1	North	7%	5.6%		1.2000	1.0000	14%	4%
	East	3.5%						
	West	6.1%						
	South	5.6%						
WWR2	North	14%	12.4 %		2.000	1.400	20%	13%
	East	7.5%						
	West	15%						
	South	13%						
WWR3	North	19.5%	17.8 %		2.800	1.400	20%	14%
	East	12.5%						
	West	20.8%						
	South	18.3%						

Table (18) a table that summarizes the results of the simulated cases of WWR

The simulated study cases have resulted in the finding of that the best case study is (WWR 2) because in terms of SDA it achieves 20% of the total spatial daylight in the building and it reduces energy consumptions in term of lighting and utilities.

Although the ASE is 14% which is over the acquired limit and it will cause glare and probable thermal discomfort due to the direct sunlight, it will fixed through the addition of adding shading devices.

5.4.5 Shading study and comparison:

in this part, we will study several simulations in regards of shading by adding various types of it and test it out in order to achieve the idle type that will allow more daylight to reduce energy consumption.

<u>5.4.5.1 Shading case study num. 1:</u>

Based on the simulated base case a series of simulations is conducted to to find the idle shading, by trying various types of it, in this case study the type that was used: *Overhang shading device.*

a. Overhang shading device type 1:

   the reason why the over hang shading device was devided into two types is to test out to diffrenet measures to define which is better, in the Over hang shading device type 1 we used the following measures:

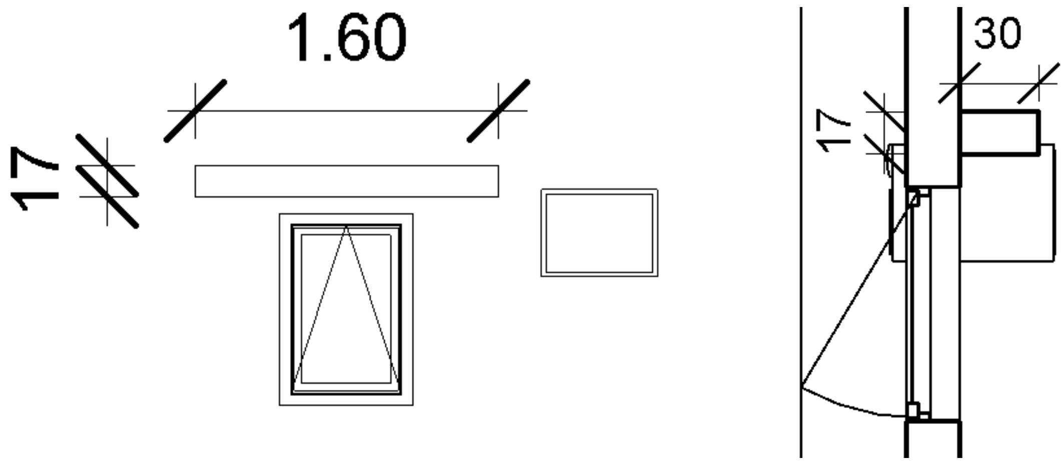


figure (82) Pictures that shows the measurements used to create an overhang shading device type 1

Throughout the first overhang shading device, we have designed a device with the width of 1.6 m, 17 cm in height and 30 c in depth.

By choosing said measures to design an overhang shading device it will affect the Annual energy consumptions depending on the width, height and diameter which is as explained in the following graph:

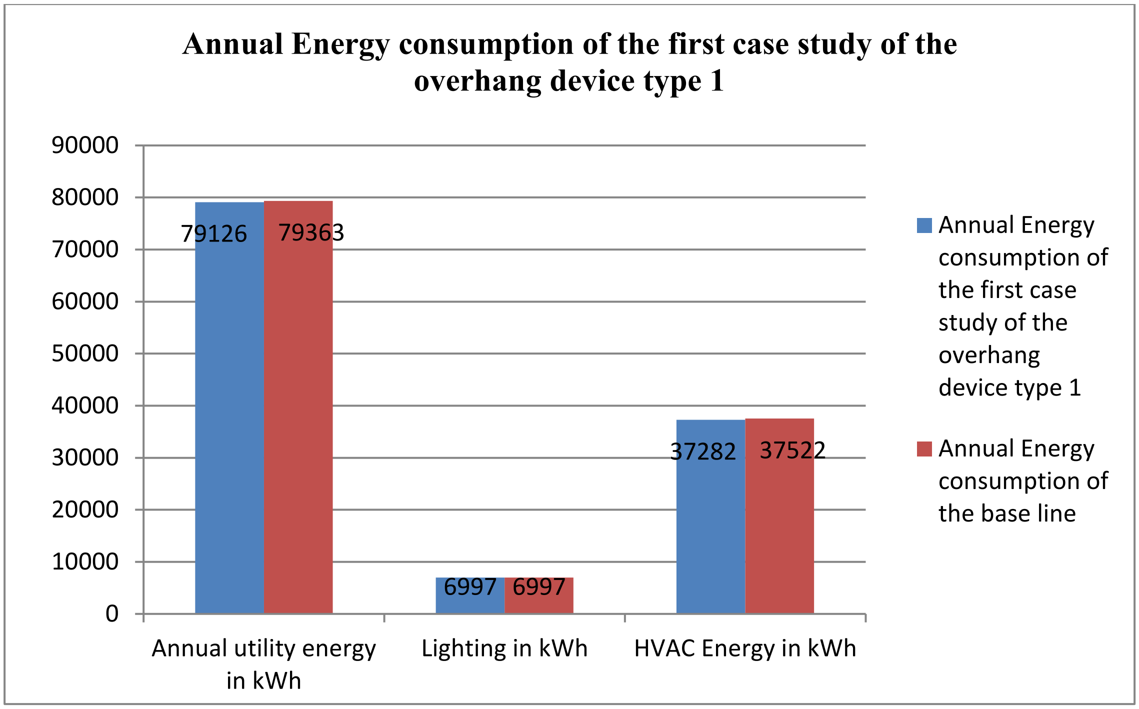


figure (83) a graph that explains the Annual energy consumption of the first case study of the overhang shading device type 1

The graph shows cases the results that were acquired through the implementation of the overhang shading device type 1, which is listed as the following:

1. In the annual utility energy in kWh we have saved 0.3% of energy consumption.
2. In the Lighting in kWh around -0% was lost.
3. In the HVAC Energy in kWh we have saved 1% of energy consumption.

b. *Overhang shading device type 2:*

in the following over hang shading device type 2 we used the following measures in contrast to type 1:

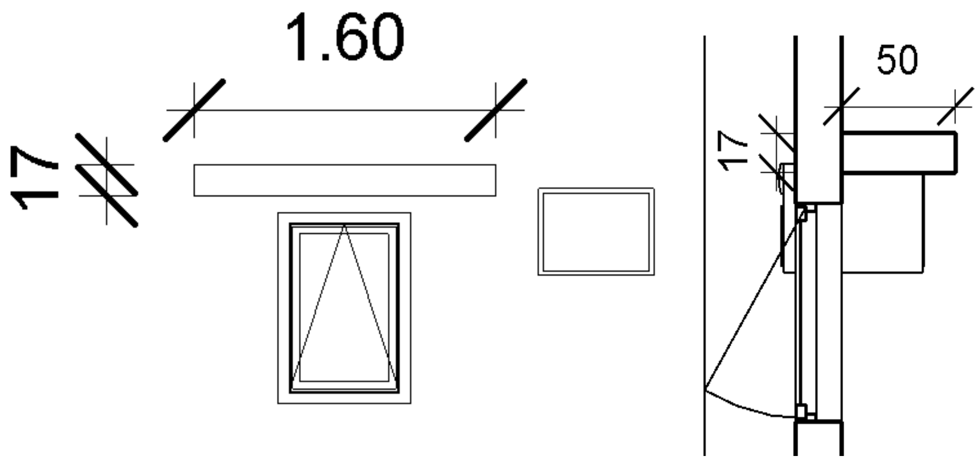


figure (84) Pictures that shows the measurements used to create an overhang shading device type 2

In the overhang shading device type 2, we have almost followed the same measuremnets in type 1 with a width of 1.6 m and 17 cm in height except we have changed the depth from 30 to 50.

By choosing said measures to design an overhang shading device it will affect the Annual energy consumptions depending on the width, height and diameter which is as explained in the following graph:

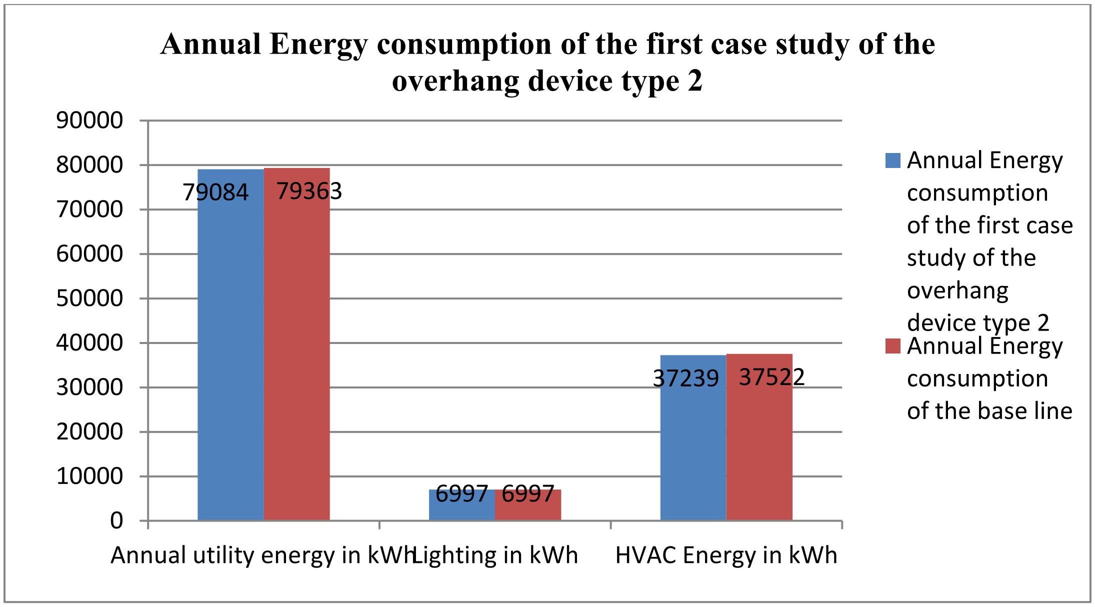


figure (85) a graph that explains the Annual energy consumption of the first case study of the overhang shading device type 2

The graph shows cases the results that were acquired through the implementation of the overhang shading device type 2, which is listed as the following:

1. In the annual utility energy in kWh we have saved 0.4% of energy consumption.
2. In the Lighting in kWh around -0% was lost.
3. In the HVAC Energy in kWh we have saved 0.1% of energy consumption.

5.4.5.2 Shading case study num. 2:

As previously mentioned,based on the simulated base case a series of simulations is conducted to to find the idle shading, by trying various types of it, in this case study the type that we used is: *overhang/fins shading device.*

a. Overhang/fins shading device type 1:

the reason why the over hang shading device was devided into two types is to test out to diffrenet measures to define which is better, in the Over hang/fins shading device type 1 we have combined two shading devices: fins and overhang to produce a vertical/horizantial shading device, which resulted into the following design and measure:

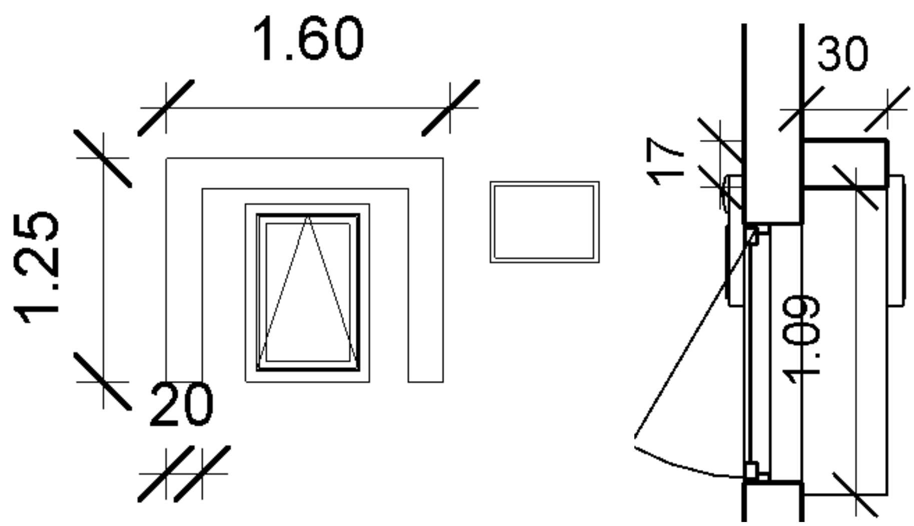


figure (86) Pictures that shows the measurements used to create an overhang/fins shading device type 1

Throughout the first overhang shading device, we have designed a device with the width of 1.6 m, 1.25 m in height, 30 in depth and 20 cm in frame.

By choosing said measures to design an overhang/fins shading device it will affect the Annual energy consumptions depending on the width, height and diameter which is as explained in the following graph:

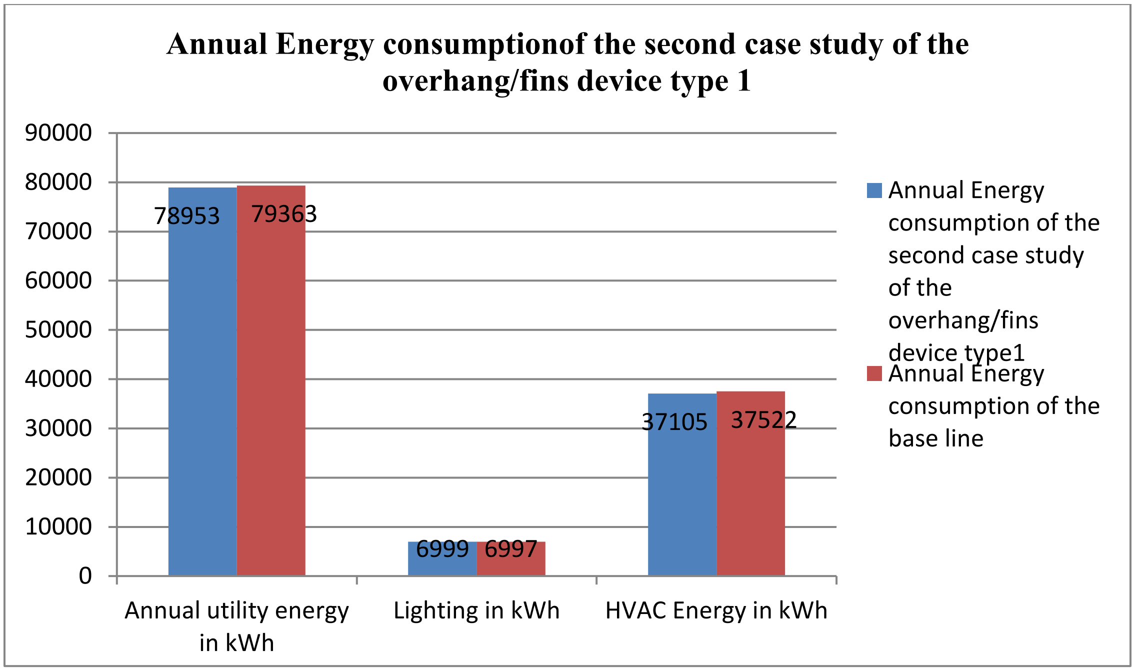


figure (87) a graph that explains the Annual energy consumption of the second case study of the overhang/fins shading device type 1

The graph shows cases the results that were acquired through the implementation of the overhang/fins shading device type 1, which is listed as the following:

1. In the annual utility energy in kWh we have saved 1% of energy consumption.
2. In the Lighting in kWh around -0% was lost.
3. In the HVAC Energy in kWh we have saved 1% of energy consumption.

b. Overhang/fins shading device type 2:

in the following overhang/fins shading device type 2 we used the following measures in contrast to type 1:

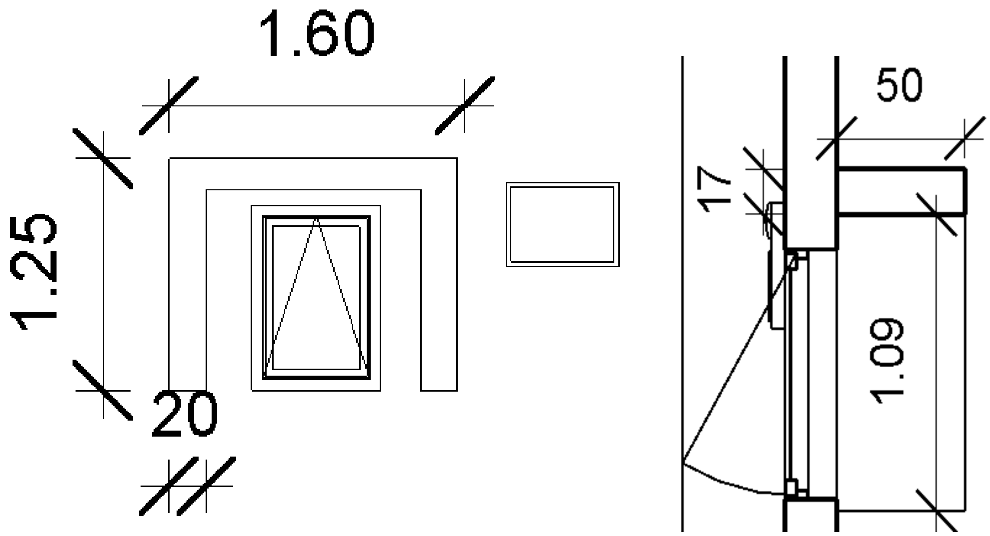


figure (88) Pictures that shows the measurements used to create an overhang/fins shading device type 2

In the overhang shading device type 2, we have almost followed the same measuremnets in type 1 with a width of 1.6 m, 20 cm in frame and 1.25 cm in height except we have changed the depth from 30 to 50.

By choosing said measures to design an overhang/fins shading device it will affect the Annual energy consumptions depending on the width, height and diameter which is as explained in the following graph:

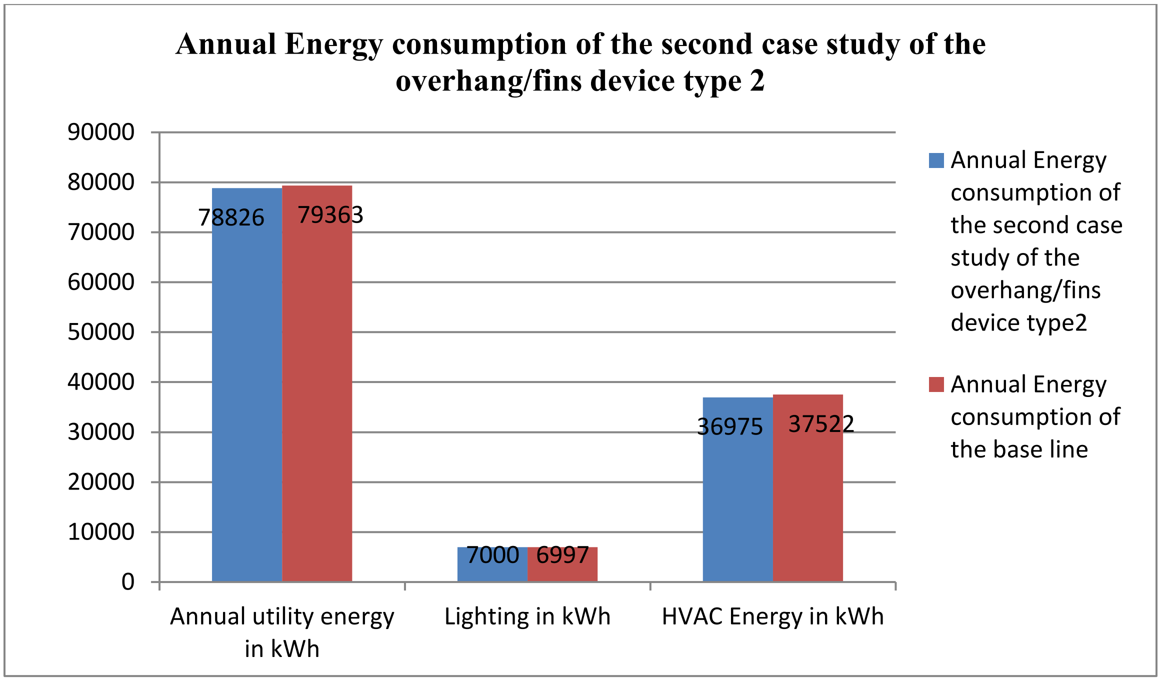


figure (89) a graph that explains the Annual energy consumption of the second case study of the overhang/fins shading device type 2

The graph shows cases the results that were acquired through the implementation of the overhang/fins shading device type 2, which is listed as the following:

1. In the annual utility energy in kWh we have saved 1% of energy consumption.
2. In the Lighting in kWh around -0% was lost.
3. In the HVAC Energy in kWh we have saved 1% of energy consumption.

5.4.5.3 Shading results and discussions:

After conducting the simulations from case study one to two based on the base case, and creating shading devices to solve energy issues we have acquired the following results:

The best option of a shading device is the overhang/fins shading device because it protects from direct sunlight throughout the duration of the day, hw ever the question arises which is: which type of overhang/fins shading device is better?

Due to both types having almost identical results we have looked in order aspects to choose which one is better, and we have decided to choose the overhang/fins shading device with the 30 cm of depth to conserve more material.

5.4.6 Glazing study and comparison:

in this part, a study on several simulations in regards of glaring by adding various types of it and test it out in order to achieve the idle type that will allow proper daylight to enter the area while keeping thermal comfort in check that will result in saving energy.

5.4.6.1 Single tint glazing:

In the first case study we choose single tint glazing that is tinted and 1/4 inch in size, By choosing the following measurements we will achieve these results:

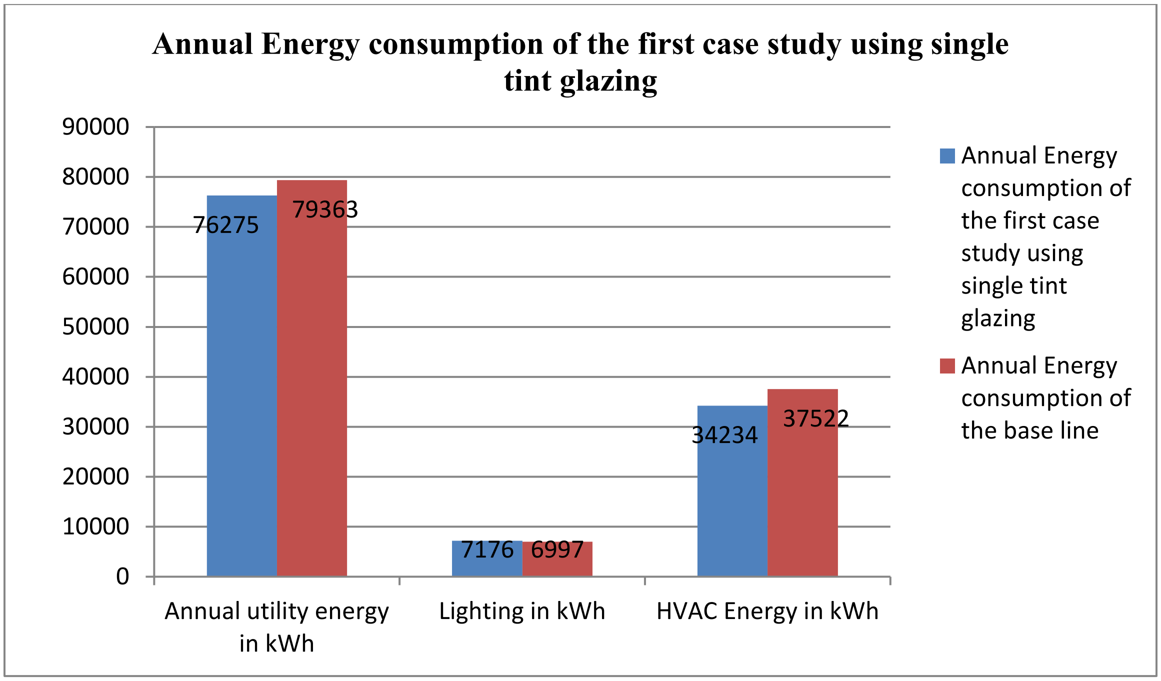


figure (90) a graph that explains the Annual energy consumption of the first case study using single tint glazing

The graph shows cases the results that were acquired by using single tint glazing, which is listed as the following:

1. In the annual utility energy in kWh we have saved 4% of energy consumption.
2. In the Lighting in kWh around -3% was lost.
3. In the HVAC Energy in kWh we have saved 9% of energy consumption.

5.4.6.2 Double - glaze, tinted glass:

In the second case study we choose Double - glaze, tinted glass that is bronze/ Low-E/thin air and 3 mm thickness, by choosing the following measurements we will achieve these results:

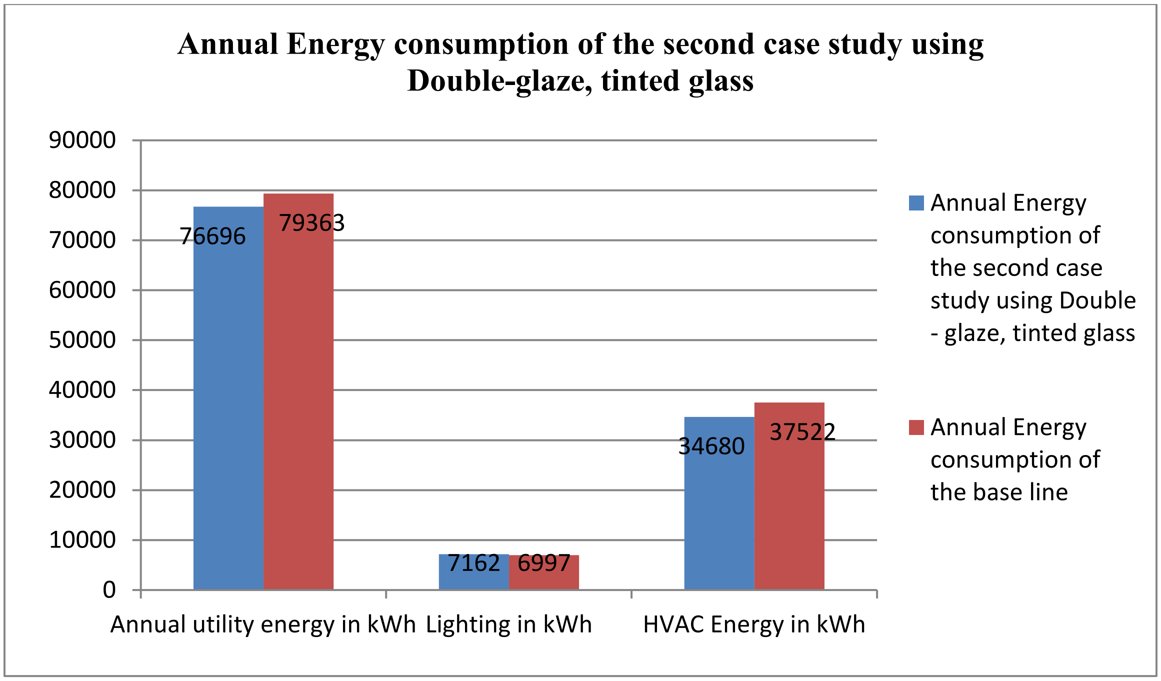


figure (91) a graph that explains the Annual energy consumption of the second case study using Double - glaze, tinted glass

The graph shows cases the results that were acquired by using Double - glaze, tinted glass, which is listed as the following:

1. In the annual utility energy in kWh around -1% was lost.
2. In the Lighting in kWh around -1% was lost.
3. In the HVAC Energy in kWh we have saved 0.2% of energy consumption.

5.4.6.3 Double - glaze, clear glass:

In the third case study we choose Double - glaze, clear glass that is sun-guard and 6 mm in thickness, by choosing the following measurements we will achieve these results:

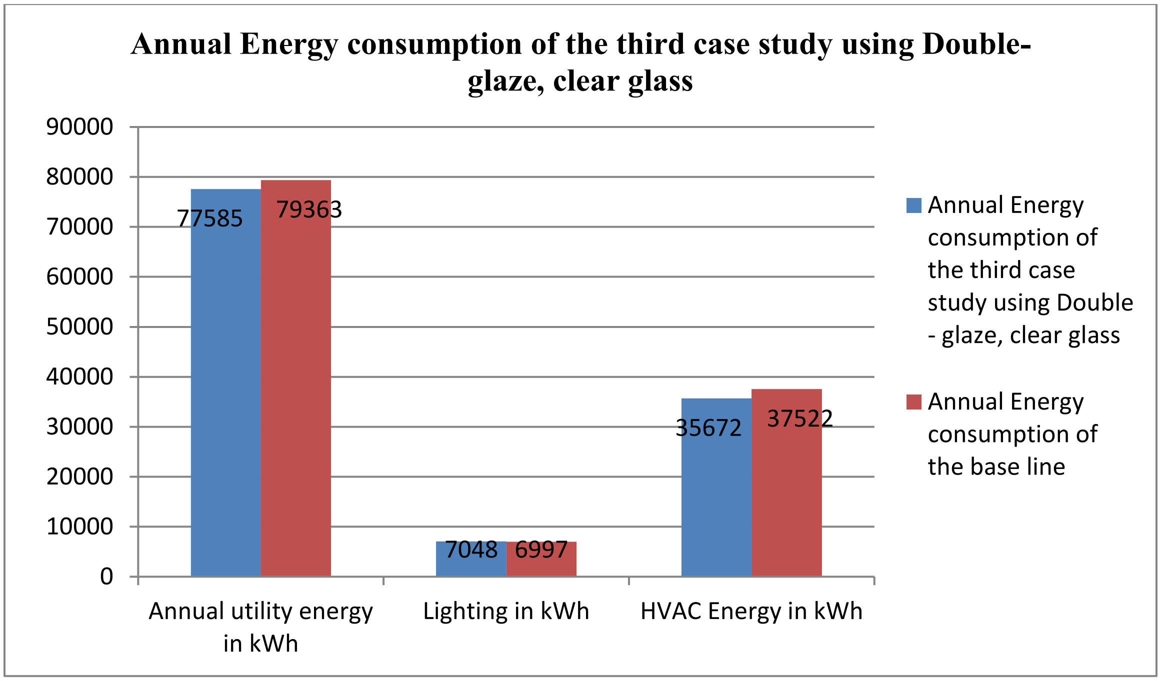


figure (92) a graph that explains the Annual energy consumption of the third case study using Double - glaze, clear glass

The graph shows cases the results that were acquired by using Double - glaze, clear glass, which is listed as the following:

1. In the annual utility energy in kWh we have saved 2% of energy consumption.
2. In the Lighting in kWh we have saved 2% of energy consumption.
3. In the HVAC Energy in kWh around -1% was lost.

5.4.6.4 Double-Glazed, Medium-solar-gain Low-E Glass:

In the fourth case study we choose Double-Glazed, Medium-solar-gain Low-E Glass that is clear glass with 1/8 inch and 1/4-inch air, by choosing the following measurements we will achieve these results:

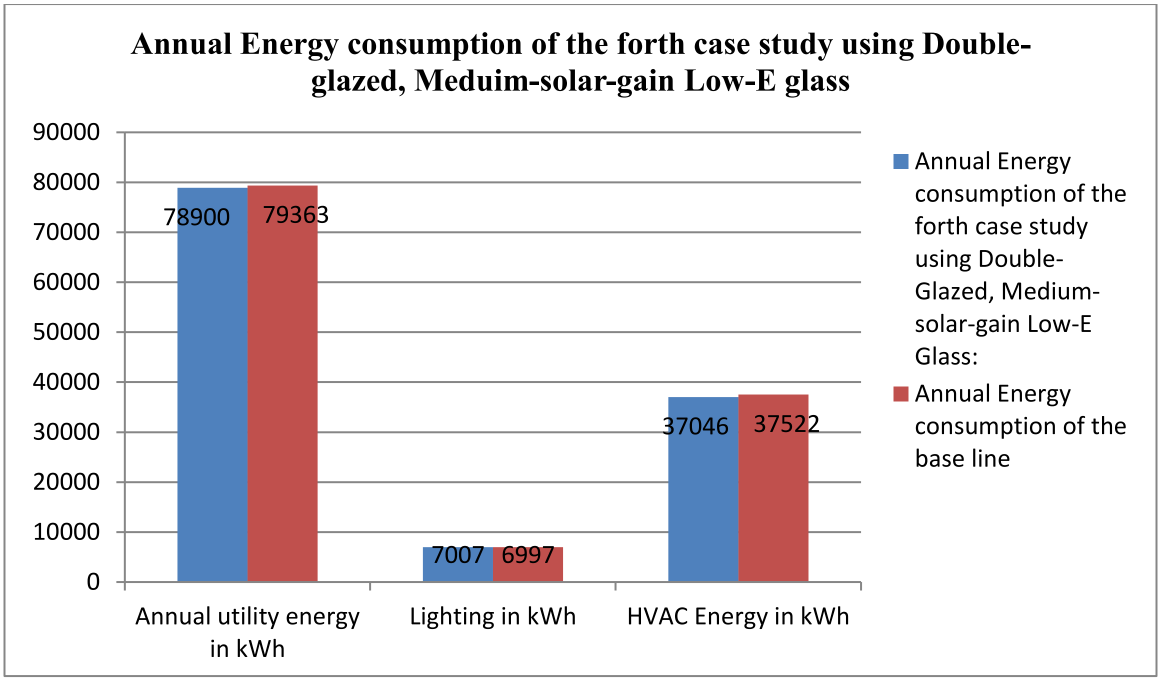


figure (93) a graph that explains the Annual energy consumption of the forth case study using Double-Glazed, Medium-solar-gain Low-E Glass

The graph shows cases the results that were acquired by using Double-Glazed, Medium-solar-gain Low-E Glass, which is listed as the following:

1. In the annual utility energy in kWh we have saved 1% of energy consumption.
2. In the Lighting in kWh we have saved 1% of energy consumption.
3. In the HVAC Energy in kWh around -0% was lost.

5.4.6.5 Double tint glazing:

In the fifth case study we choose Double tint glazing that is tinted with 1/4 inch and 1/4-inch air, by choosing the following measurements we will achieve these results:

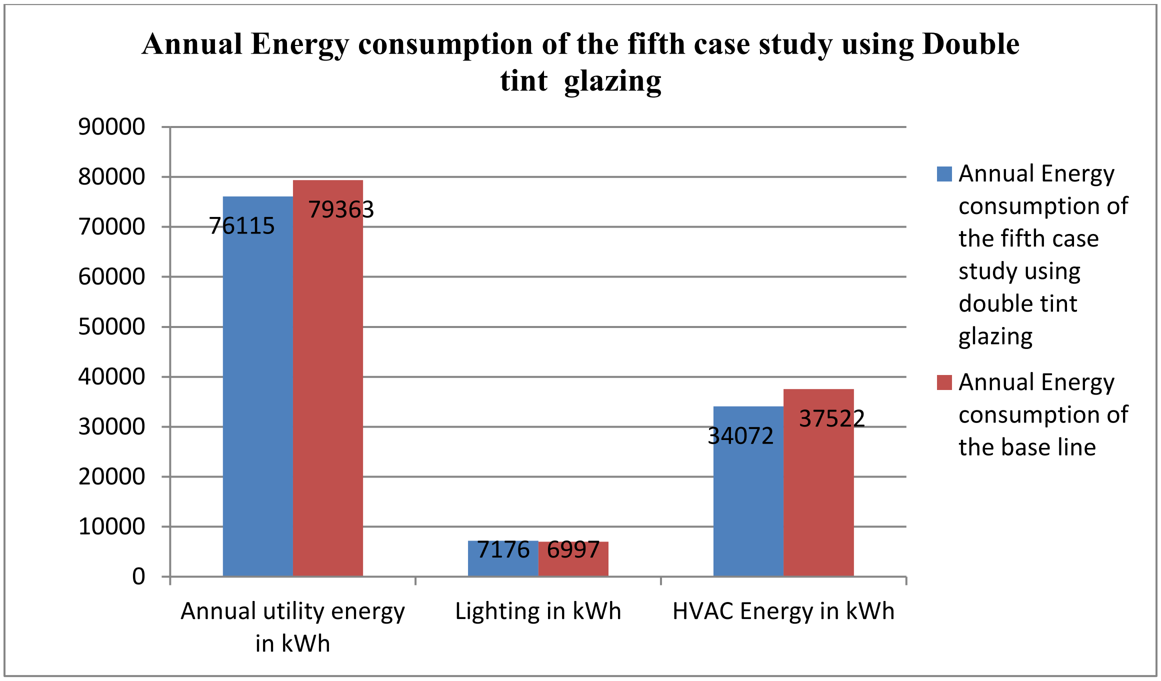


figure (94) a graph that explains the Annual energy consumption of the fifth case study using double tint glazing

The graph shows cases the results that were acquired by using double tint glazing, which is listed as the following:

1. In the annual utility energy in kWh we have saved 4% of energy consumption.
2. In the Lighting in kWh around -3% was lost.
3. In the HVAC Energy in kWh we have saved 9% of energy consumption.

5.4.6.6 glazing results and discussions:

After conducting the simulations from case study one to five based on the base case, and selecting a couple of glazed windows to test out on the simulated base case we have acquired the following results:

the idle type of glazing device is the Single tint glazing and double tint glazing, however the question arises: which is better? the single tint glazing or the double tint glazing?

Due to both glazing's having almost identical results we have looked at different aspects to choose which one is better, and we have decided to choose the single tint glazing because it costs less than the double tint glazing and it achieves almost the same results of it in this case study.

5.5 the ideal energy conservative and daylight approved residential building design based on study results:

After testing various parameters to find the best group of methods to implement into the ideal villa design, we have achieved the following:

1. *Window to wall ratio:*

   The best Window to wall ratio from the group of simulations we have done is the second one with the following measurements: 2 m in width and 1.4 m in height.

2. *Shading devices*:

   The best Shading devices from the simulated cases we have done is from the second case study type 1 by the name (Overhang/fins shading device), with the following measures: width of 1.6 m, 1.25 m in height, 30 in depth and 20 cm in frame.

3. Glazing:

   The best type of glazing that we have concluded from the series of simulations is Single tint glazing due to its perfect results and low cost.

5.6 Analysis of the idle residental building design:

In this section of the research, we will test out the results that were aquired throw the simulations to test out if its really befiting to the base case and that if it haves actual results and could work toghter to save energy and allow sufficent amount of daylight.

1. *Annual energy consumption:*

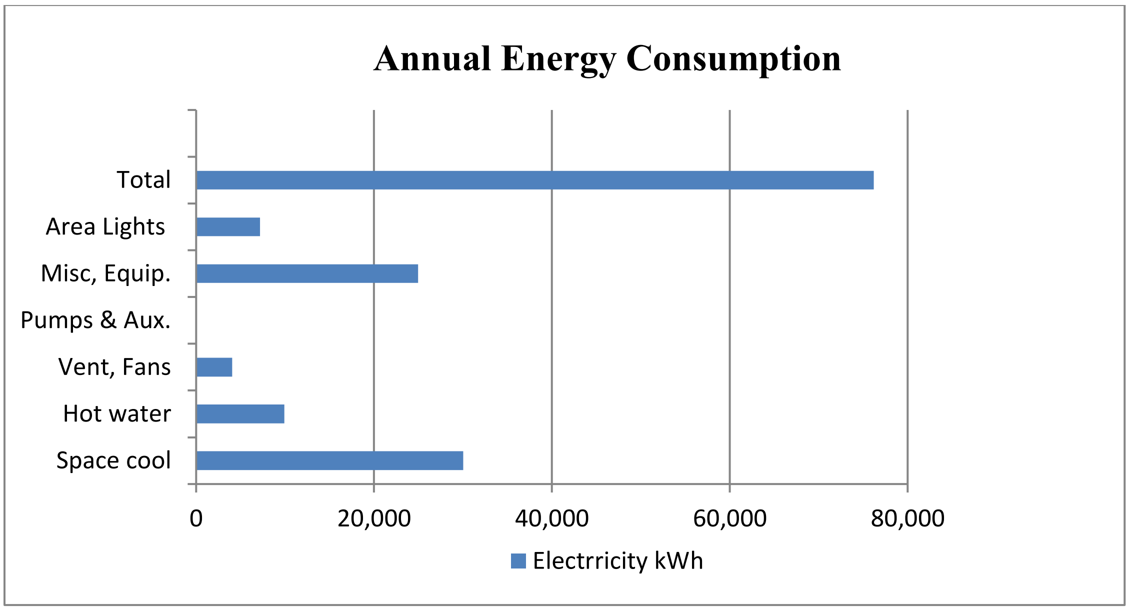


figure (95) A graph the shows the results of the Annual energy consumption

The following graph is the result of implementing the improved or added parameters into the base case villa located in Dammam city in KSA, which resulted in reducing the total energy use from 79,290 kWh to 76,176 kWh that lead to the reduction of the highest energy consuming device (space cooling) from 33,243 kWh to 30,016 kWh.

2. *Electric consumption kW:*

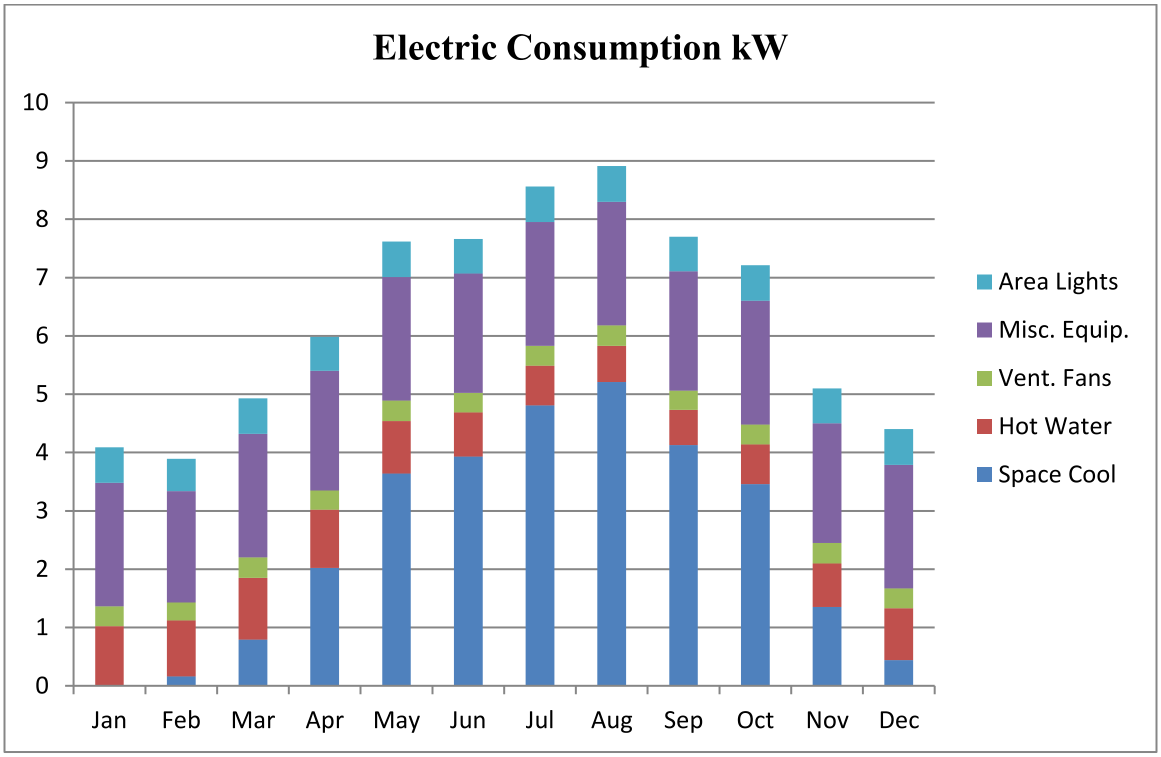


figure (96) A graph the shows the results of the electric consumption kW

The following graph is the result of implementing the improved or added parameters into the electric Consumption in kW of each month throughout the year to try to find ways in order to minimize use or waste of the highest electric consuming appliance, however after implementing the parameters we have improved the use of space cooling (AC) by reducing around 2.5% of its yearly consumption.

To summarized it more simply, the results were organized into the following pie chart:

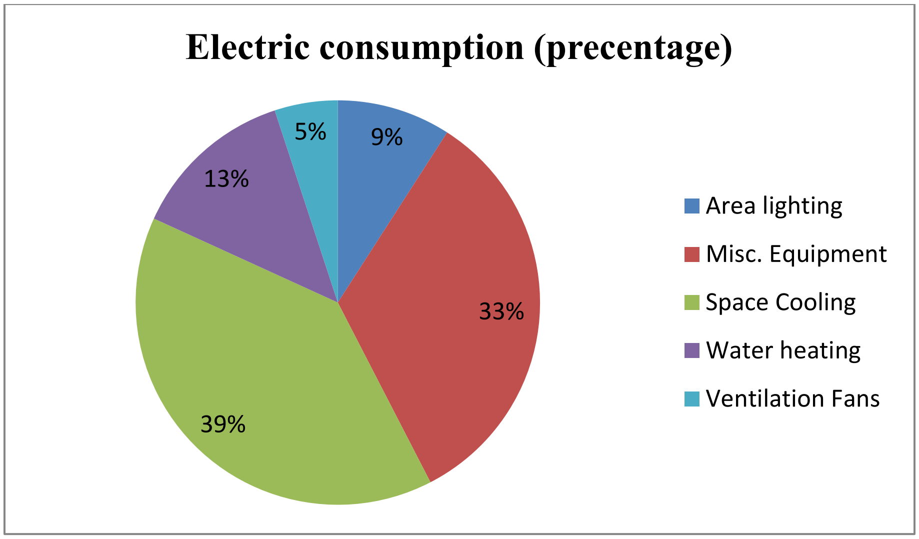


figure (97) A pie chart that shows the results of the electric consumption percentage

3. *Daylight improvement results:*

through the implementation of all previously mentioned and tested parameters such as shading and glazing, the base case building have improved as the following:

figure (98) A plan of the improved model ground floor ASE/SDA

figure (99) A plan of the improved model first floor ASE/SDA

In the improved residential building design, the total of the ASE (Annual Sunlight Exposure) have improved significantly from the original, though it still doesn't abide by the intended frame of 10% and less but it is still preferable than the chosen parameter result by 2%.

In the SDA method, 9 rooms out of 24 abide by the SDA (Spatial daylight Exposure) as they vary from 57% - 93% which aliens with the percentage frame of SDA that is 55% - 75% which leads to SDA law to a preferred availability of daylight and a good availability of daylight but if calculated in total it still doesn't abide by the intended frame but is better than the chosen parameter by increasing 11% more.

To summarized the results simply it could be explained in a general form as the following graph:

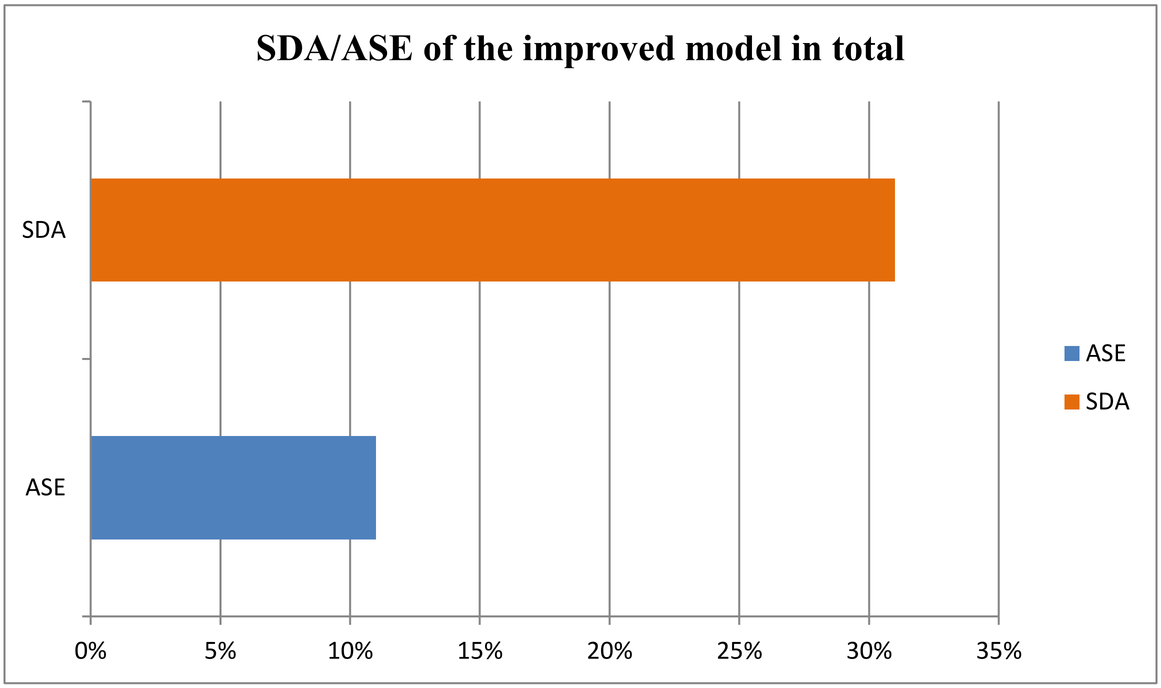


Figure (100) A graph of the SDA and ASE of the improved model

5.7 A comparison between the base case and the improved model:

In order to determine if the parameters really have affected the base case into an improved model, a comparison (before-after) was needed to determine said results which is as follows:

A comparison between the base case and the improved model				
Month	Base case results		Improved model results	
	Kwh	S. R	Kwh	S. R
Jan	4140	745.2	4130	745.2
Feb	4020	723.6	3910	703.8
Mar	5110	919.8	4930	887.4
Apr	6220	1146	5970	1074.6
May	7980	1674	7620	1566
Jun	8030	1689	7670	1581
Jul	9020	1986	8560	1848
Aug	9390	2097	8900	1950
Sep	8080	1704	7700	1590
Oct	7540	1542	7200	1440
Nov	5310	955.8	5100	918
Dec	4540	817.2	4410	793.8
Total	79360	15999.6	76110	13648.8

Table (19) A comparison table between the base case and improved model design

In order to explain the result and comparisons, a graph was made as the following:

3. A comparison based on cost (S.R):

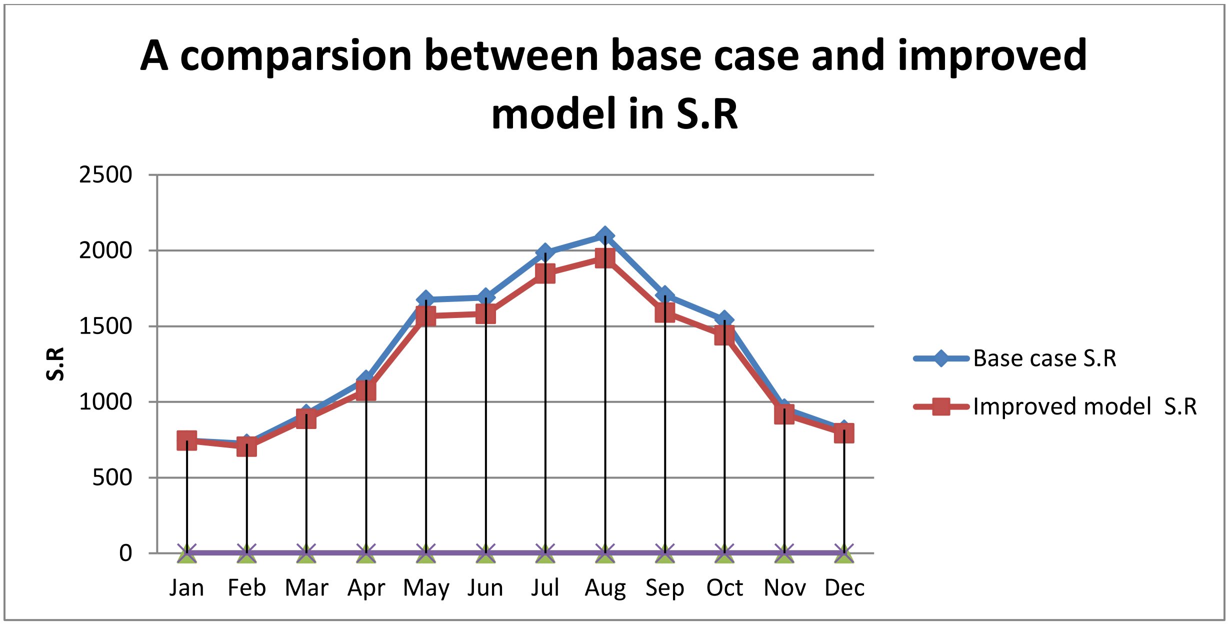


Figure (101) A comparison graph between the base case and improved model design in S.R

In the following graph we have compared the base case to the Improved model according to cost (S.R), which in the improved model is significantly less than the base case in the peak months of the year (between July to October) where the electricity demand is at its highest.

To sum up the results we can explain in a simpler manner by comparing the total cost of each the base case and the improved model as follows:

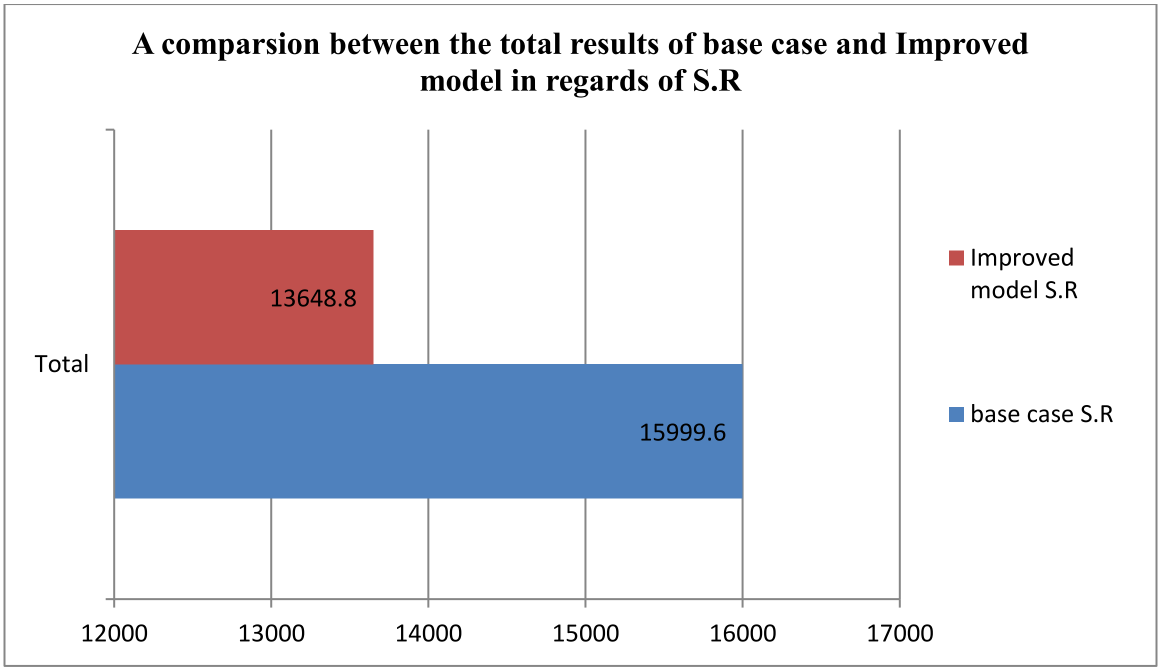


Figure (102) A comparison graph between the total of base case and total of improved model design in S.R

The total cost of the improved model is less than the base case cost, and to define such improvement we use the following equation:

$$\frac{13648.8 - 15999.6}{15999.6} * 100 = 14.692\%$$

the improved model is less than the base case by 14.7% in cost (S.R)

4. A comparison based on kWh:

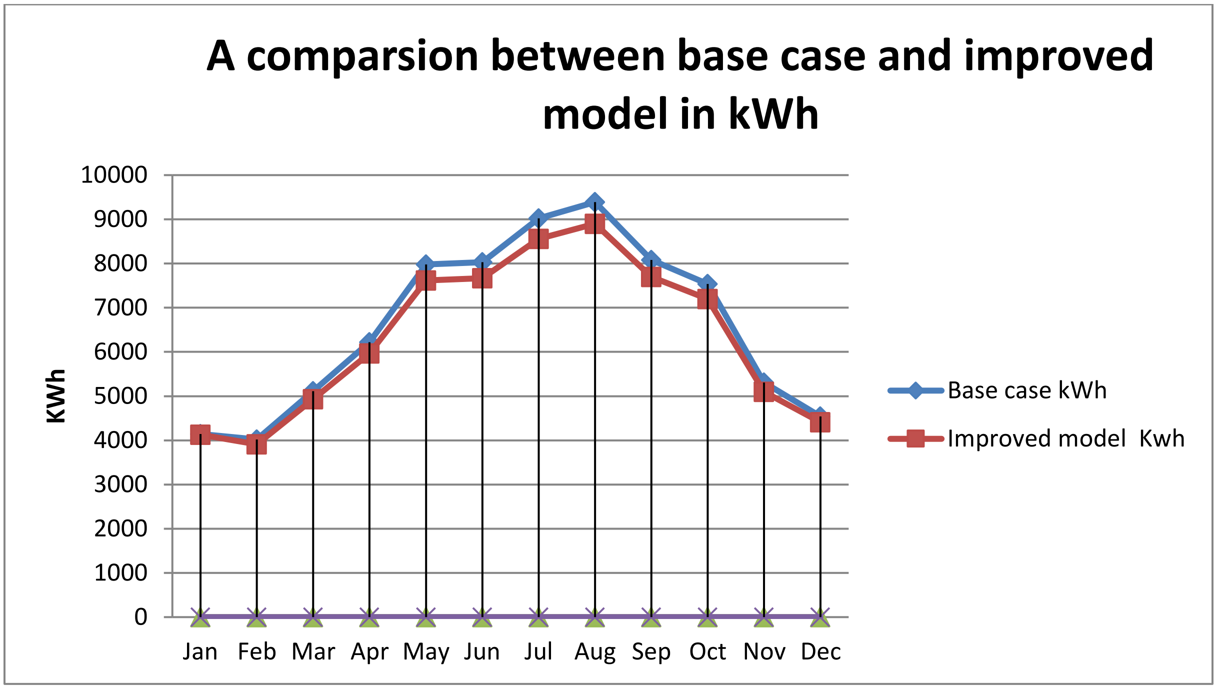


Figure (103) A comparison graph between the base case and improved model design in kWh

In the following graph we have compared the base case to the Improved model according to kWh, which in the improved model is less than the base case in the peak months of the year (between July to October) where the electricity demand is at its highest.

To sum up the results we can explain in a simpler manner by comparing the total cost of each the base case and the improved model as follows:

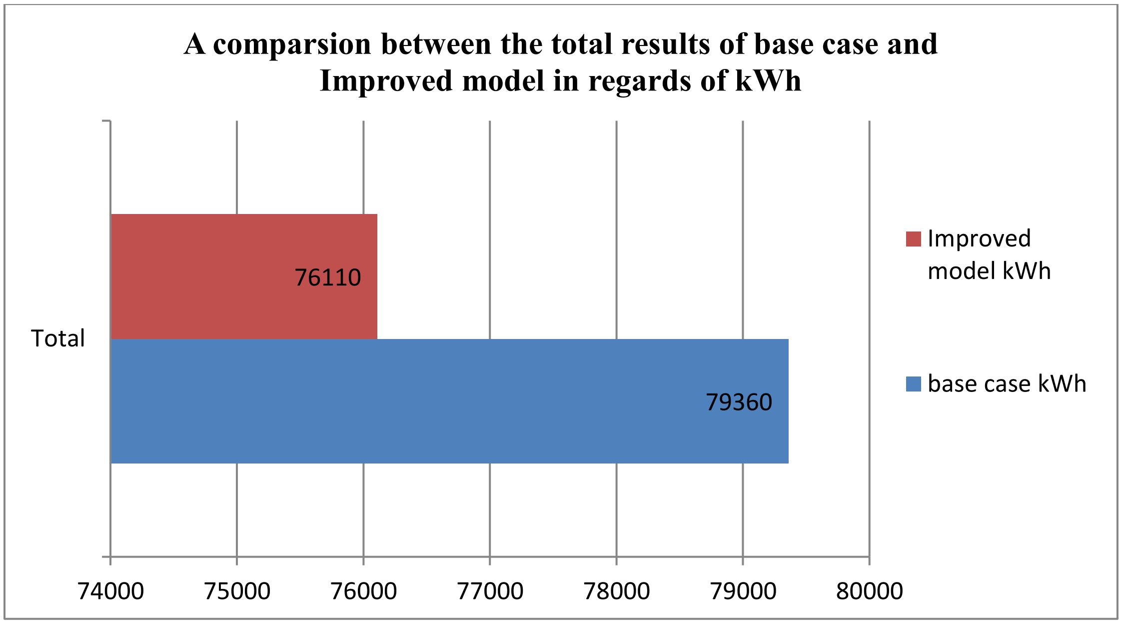


Figure (104) A comparison graph between the total of base case and total of improved model design in kWh

The total kWh of the improved model is less than the base case kWh, and to define such improvement we use the following equation:

$$\frac{76110 - 79360}{79360} * 100 = 4.094\ \%$$

the improved model is less than the base case by 4.1% in kWh.

Chapter 6

Conclusions and recommendations

6.1 Introduction:

In this chapter we will present the results that we have established throw the simulation and discus its benefits on the housing units (Villa's) in Kingdom of Saudi Arabia and present a couple of recommendations that could be considered beneficial in the future.

6.2 Summary and conclusions:

In Kingdom of Saudi Arabia, lighting systems and housing appliances consume a huge amount of artificial energy in Villa's which greatly affect the resident's financial states. Daylighting is a method can help residents greatly either in health or finance if applied correctly, there are many methods that include daylighting that can do so, for example: the combination of daylight and artificial light through lighting controls which can lead to low energy usage, low cooling energy and hopefully the integration of a smaller cooling unit.

Another example is window designs, this element is considered important in the combination method because depending on the window size, daylight amount can vary as well as heat acquisition or loss.

In the literature review, it was established that the topic of daylighting became a desirable topic in recent years with the modern energy friendly movements rise, with many foreign countries opting to find more energy conservative methods, with many studies being produced that exemplify that daylight is the best conservative option that include the following elements:

1. Daylight aids the resident's health.
2. Integrating daylight in any housing unit can greatly affect the resident's productivity.
3. Daylight in foreign countries is considered the go to method to conserve energy.

we have saved around 4% of wasted energy which is not enough if we wanted to achieve a higher percentage, we have to change other elements that effect the energy, such as: insulation width of a wall...etc.

However, the study focuses on providing daylight while making sure to provide energy at the same time while taking into consideration that daylight is one of the elements that effects energy using, since saving 4% is considered a positive result as well as taking in to consideration its effect on cost which is around 14%.

6.3 Recommendations:

Based on the results of our study, a series of recommendations were created to aid in future Daylighting friendly housing unit (Villa's) in Kingdom of Saudi Arabia, the following are a set of recommendations that are suggested to attain energy efficiency and improve daylighting in residential buildings in humid and hot climate, which are the following:

1. The implementation of daylight in early stages of residential buildings design is highly recommended while applying available tools and methods to estimate daylighting in residential buildings, to aid in resident's health and expand the housing unit (Villa) life cycle.
2. Resizing of windows located in the northern zone to a larger size is recommended, while windows located in other zones use shading devices to control the heat gain and loss.
3. Changing the type of glazing used is also recommended to maximize energy reduction and use of daylighting.
4. An integrated system of daylighting and artificial lighting is recommended to be included into the Saudi Energy Code.
5. developing an assistant design tool is recommended in order to aid energy efficient and daylighting friendly window designs.

6.4 Future recommendation for further studies:

This study emphasis certain findings that derive to potential future studies, Different variables in the common characteristics of housing units in KSA is important to be addressed and investigated more as well as expanding the study to several types of buildings, not only focusing on implementing daylight itself but in the unity of daylight and artificial light through the zone or area that will be served.

APPENDIX: SURVEY RESULTS

1- Distributed surveys:

Daylighting and Energy performance Questionnaire

The following questioner focuses about daylighting and energy and energy performance, Daylighting and energy performance is the method of using normal light sun as a substitute for artificial lighting in order to achieve optimum performance, to achieve that you are required to answer the following questions:

Section 1: General Information				
Age	25 and less	25-45	45-60	60 and above
Gender	Male		Female	
City	Dammam	Al-Khobar	Al-Ehsa	
Section 2: Materialistic Information *				
The size of your living room is? (Square meter)	5 and less	5-10	10-19	19-28
The direction of your living room ?	North	East	West	South
The size of your livingroom window? (Square meter)	5 and less	5-10	10-19	19-28
How much of the window sky view is obscured in your living room?	Nearly all of it	Frequently	Half	A little to none
The size of your bed room is? (Square meter)	5 and less	5-10	10-19	19-28
The direction of your bed room ?	North	East	West	South
The size of your bed room window? (Square meter)	5 and less	5-10	10-19	19-28
How much of the window sky view is obscured in your bed room?	Nearly all of it	Frequently	Half	A little to none
What type of lamps do you use in your home?	LED	Florescent	CFL	Halogen

Section 3: Sensation Towards Daylighting*					
How many hours does natural light last within the day without manmade light? (Electricity)	An hour and less	1-3 hours	3-5 hours	5 hours and more	
Whish room in your home haves a good lighting division?	Living room	Bed room	Bath room		
Which room in your home haves the most sunlight in summer?	Living room	Bed room	Bath room		
Which room in your home haves the most sunlight in winter?	Living room	Bed room	Bath room		
If you will grade the sunlight that is allowed inside your home yearly, what grade will you give it?	Excellent	Good	Neutral	Bad	
<u>Based on your living conditions, does Artificial lighting bring/allow ....?</u>					
Heat Discomfort	Always	Sometimes	Rarely	Never	
Glare	Always	Sometimes	Rarely	Never	
Poor eye sight	Always	Sometimes	Rarely	Never	
Full access to control its levels?	Fully available	Limited availability	Not available		
Do you think that the artificial light in your home is good?	Strongly agree	Agree	Perfect	Disagree	Strongly Disagree
Physiological discomfort?	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree

Section 4: Human Demeanor*					
What do you do in your living room within the day?	Watching TV	Eating	Chatting	Reading	
The indoor shading in your home is usually?	Fully drawn	More than half drawn	Half drawn	Less than a half drawn	Not drawn at all
How many hours do you turn on artificial lighting? (Electricity)	An hour and less	1-3 hours	3-5 hours	5 hours and more	
If you have the chance, what are the things that you will change in your home to allow more daylighting in?	______________________ ______________________ ______________________ ______________________				
Section 5: Illumination Comfort*					
Do you agree that daylighting in your home is satisfactory?	Strongly agree	Agree	Perfect	Disagree	Strongly Disagree

استبيان للاستفسار عن مؤثرات ضوء النهار والطاقة

الاستبيان التالي يركز على موضوع ضوء النهار وأداء الطاقة، ضوء النهار وأداء الطاقة هو طريقة استخدام ضوء الشمس الطبيعي كبديل للإضاءة الاصطناعية من أجل تحقيق الأداء الأمثل، ولتحقيق ذلك أنت مطالب بالإجابة على الأسئلة التالية:

القسم الأول: معلومات عامة				
العمر	**25 وأقل**	**45-25**	**60-45**	**60 وفوق**
الجنس	**ذكر**		**أنثى**	
المدينة	**الدمام**	**الخبر**	**الاحساء**	
القسم الثاني: المعلومات المادية				
المعيشة غرفة حجم بك الخاصة (متر مربع)	**5 وأقل**	**10-5**	**19-10**	**28-19**
اتجاه غرفة المعيشة الخاصة بك؟	**شمال**	**شرق**	**غرب**	**جنوب**
حجم نافذة غرفة المعيشة هو؟ (متر مربع)	**5 وأقل**	**10-5**	**19-10**	**28-19**
كم كمية المنظر الخارجي من نافذتك يتم حجبه بسبب غرفة معيشتك؟	**تقريباً أغلبه**	**معظمه**	**النصف**	**بعضاً منه**
حجم غرفة نومك؟ (متر مربع)	**5 وأقل**	**10-5**	**19-10**	**28-19**
اتجاه غرفة المعيشة الخاصة بك؟	**شمال**	**شرق**	**غرب**	**جنوب**
حجم نافذة غرفة النوم هو؟ (متر مربع)	**5 وأقل**	**10-5**	**19-10**	**28-19**
كم كمية المنظر الخارجي من نافذتك يتم حجبه بسبب غرفة معيشتك؟	**تقريباً أغلبه**	**معظمه**	**النصف**	**بعضاً منه**

ما هو نوع اللمبات التي تستخدمها في منزلك؟	LED	Florescent	CFL	Halogen

القسم الثالث: الإحساس نحو ضوء النهار

كم عدد الساعات التي يستمر فيها ضوء النهار الطبيعي في منزلك دون استخدام الكهرباء؟	**ساعة وأقل**	**1-3 ساعات**	**3-5 ساعات**	**5 ساعات وأكثر**

أي غرفة في الفيلا التي تسكن فيها تحتوي على تقسيم ضوئي ممتاز؟	**غرفة المعيشة**	**غرفة النوم**

أي غرفة في الفيلا التي تسكن فيها كثر عرضة لضوء الشمس في الصيف؟	**غرفة المعيشة**	**غرفة النوم**

أي غرفة في الفيلا التي تسكن فيها كثر عرضة لضوء الشمس في الصيف؟	**غرفة المعيشة**	**غرفة النوم**

إذا كنت ستقيم مقدار ضوء الشمس المسموح بدخوله سنوياً إلى منزلك، فما هو المعيار التي ستختاره؟	**ممتاز**	**جيد**	**محايد**	**سيء**

استناداً إلى ظروفك المعيشية، هل تسبب لك الإضاءة المشكلات التالية؟

عدم الشعور بالراحة من الناحية الحرارية (الشعور بالبرد أو الحر)	**دائما**	**بعض الأحيان**	**نادرا**	**أبدا**

الشعور بوهج؟ (ضوء شديد)	**دائما**	**بعض الأحيان**	**نادرا**	**أبدا**

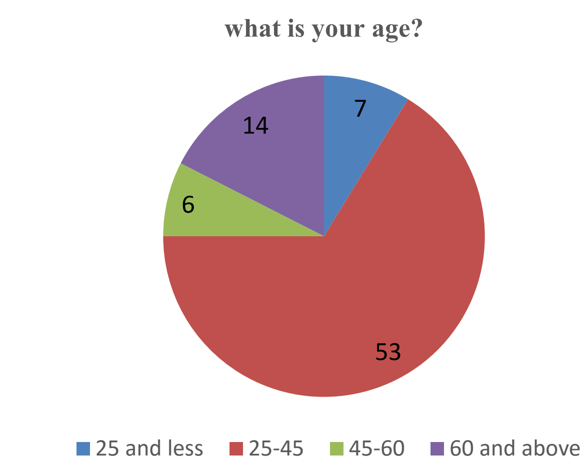
ضعف نظر؟	**دائماً**	**بعض الأحيان**	**نادرا**	**أبدا**

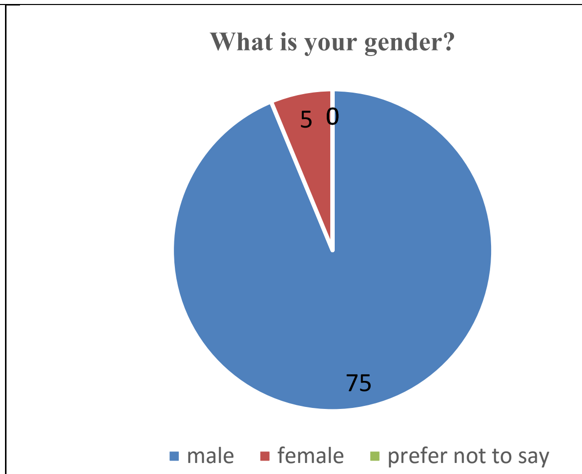
القدرة بالتحكم بمعايير الإضاءة؟ (تخفيض الإضاءة أو العكس؟)	**القدرة التامة**	**القدرة محدودة**	**عدم القدرة**

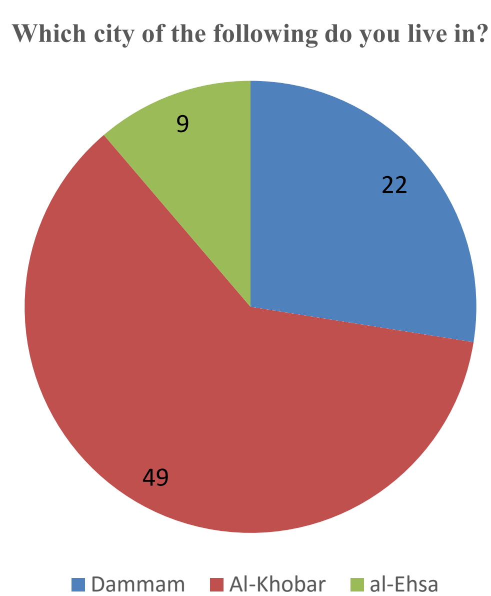
هل تعتقد أن الإضاءة ممتازة في منزلك؟	أؤيد بشدة	أؤيد	ممتاز	أعارض	أعارض بشدة
عدم الراحة النفسية؟	أؤيد بشدة	أؤيد	ممتاز	أعارض	أعارض بشدة
القسم الرابع: السلوك البشري					
ماذا تفعل في غرفة معيشتك خلال اليوم؟	أشاهد التلفاز	أكل	أتحدث مع أحد أفراد العائلة		أقرء
الستائر في فيلتك عادة ما تكون...؟	مغلقة	نصف مفتوحة	أقل من نصف مفتوحة		مفتوحة
كم عدد الساعات التي تستعمل فيها الإضاءة الكهربية؟	ساعة وأقل	1-3 ساعات	3-5 ساعات		5 ساعات وأكثر
إذا أتيحت لك الفرصة ماهي الأمور التي ستغيرها في منزلك لتسمح بضوء الشمس بالدخول أكثر إلى منزلك؟	______________________ ______________________ ______________________				
القسم الخامس: الراحة من ناحية الضوء					
هل تؤيد أنك راضي بشكل عام عن الإضاءة في الفيلا التي تسكن فيها؟	أؤيد بشدة	أؤيد	ممتاز	أعارض	أعارض بشدة

2- Survey results:

Section 1: general information:

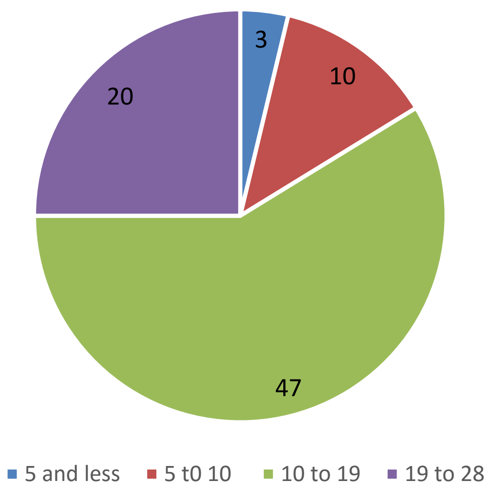




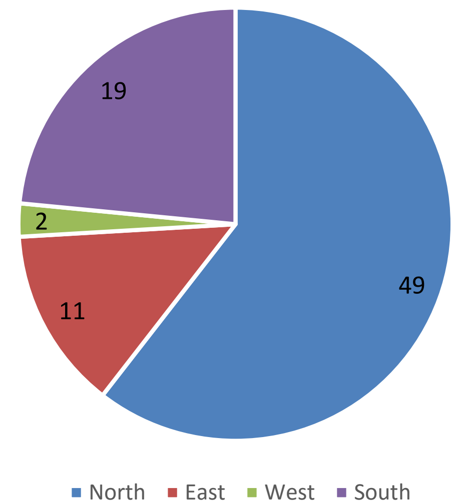


Section 2: Materialistic Information:

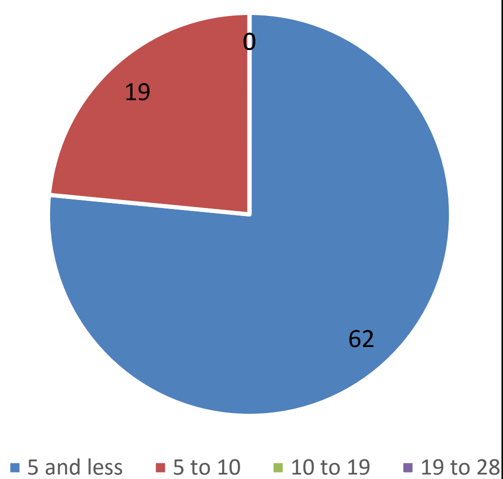
What is The size of your living room? (Square meter)



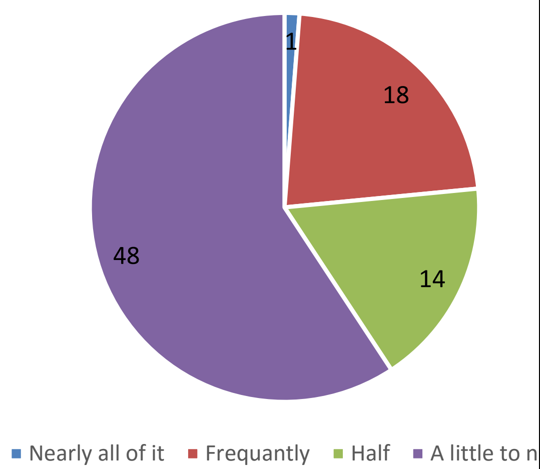
The direction of your living room ?



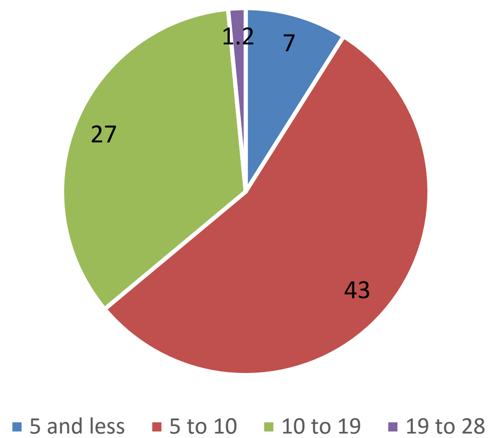
What is the size of your living room window? (Square meter)



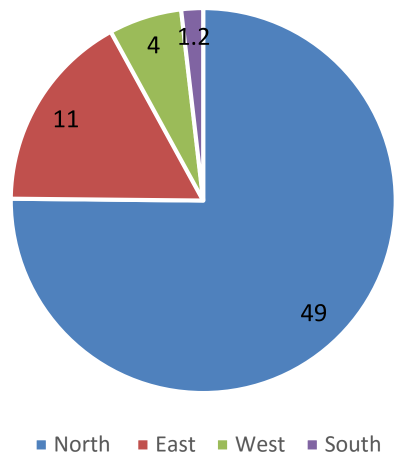
How much of the window sky view is obscured in your living room?



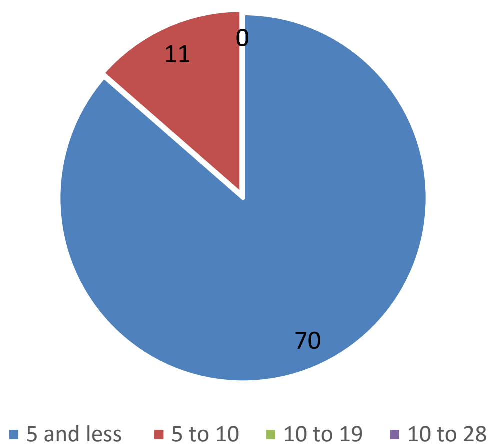
What is the size of your bed room? (Square meter)



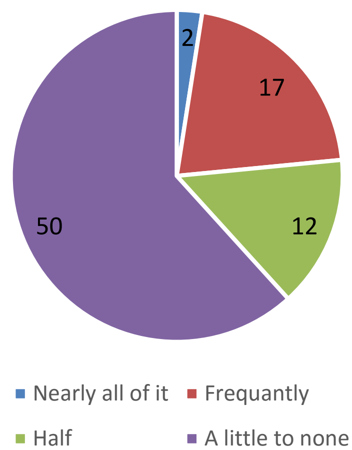
What is the direction of your bed room ?



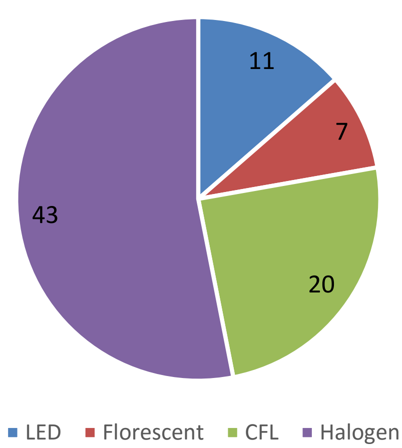
What is the size of your bed room window? (Square meter)



How much of the window sky view is obscured in your bed room?

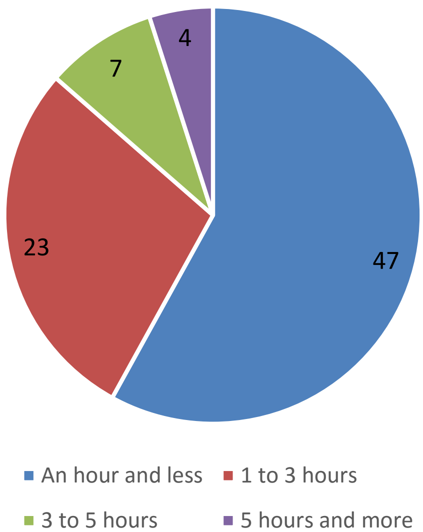


What type of lamps do you use in your home?

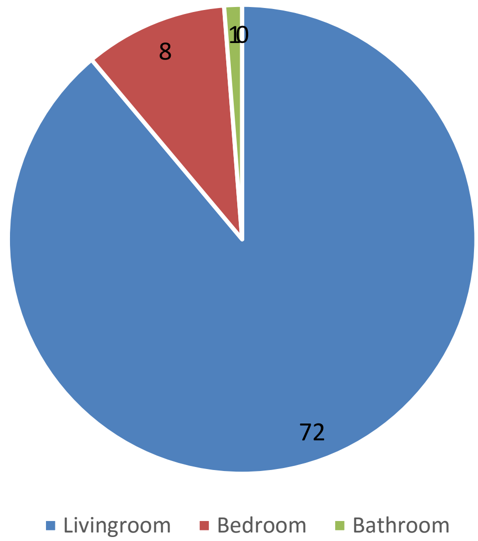


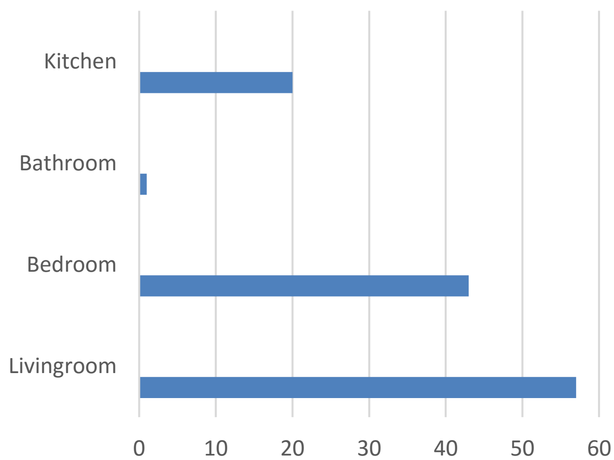
Section 3: Sensation Towards Day lighting:

How many hours does natural light last within the day without man made light? (Electricity)

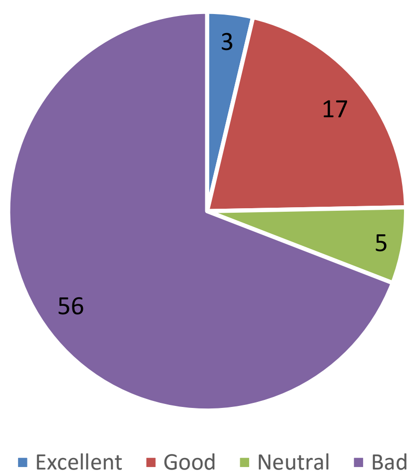


Which room in your home haves a good lighting division?



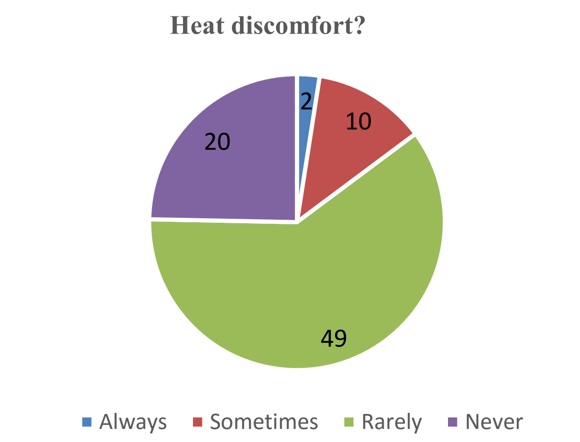


If you will grade the sunlight that is allowed inside your home yearly, what grade will you give it?

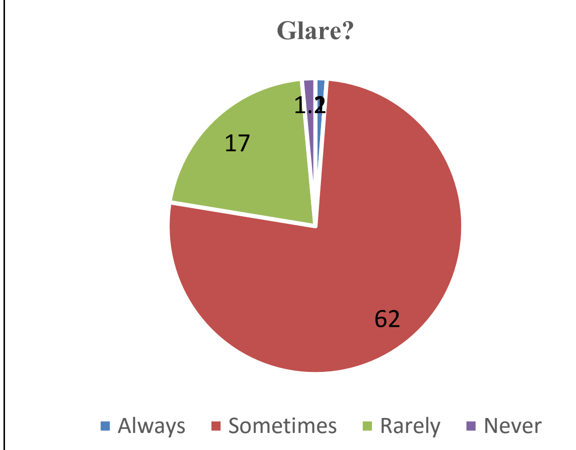


5- Based on your living conditions, does Artificial lighting bring/allow ....?

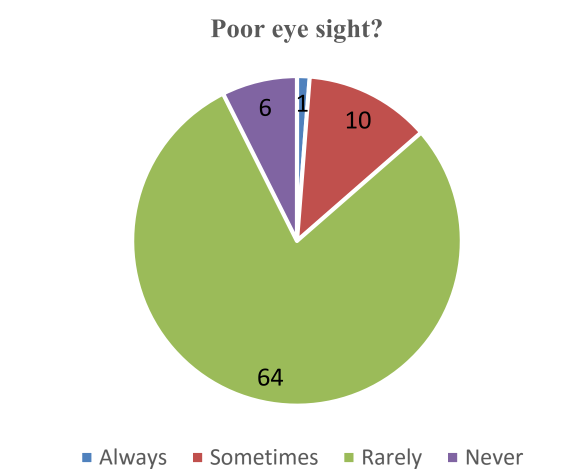
A- heat discomfort?



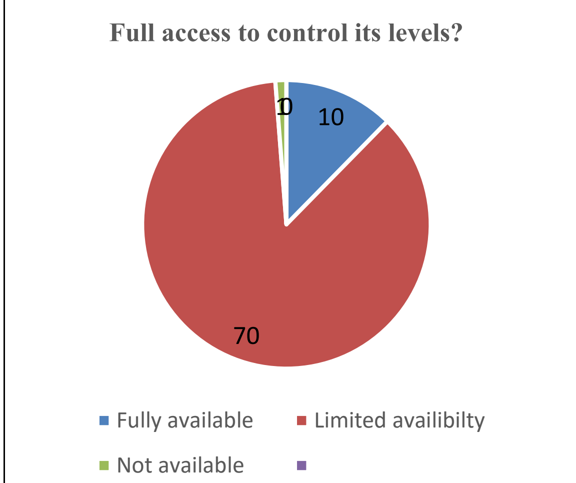
B- Glare?



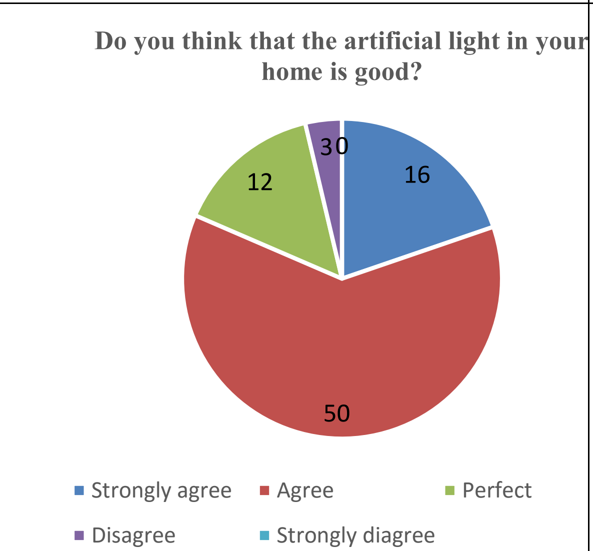
C- Poor eye sight?



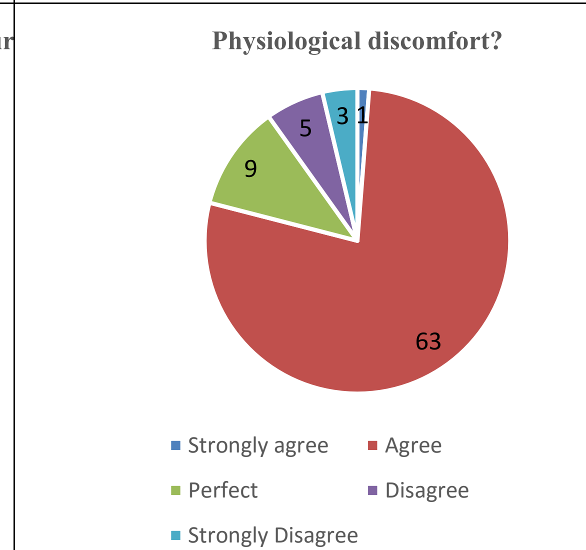
D- Full access to control its levels?



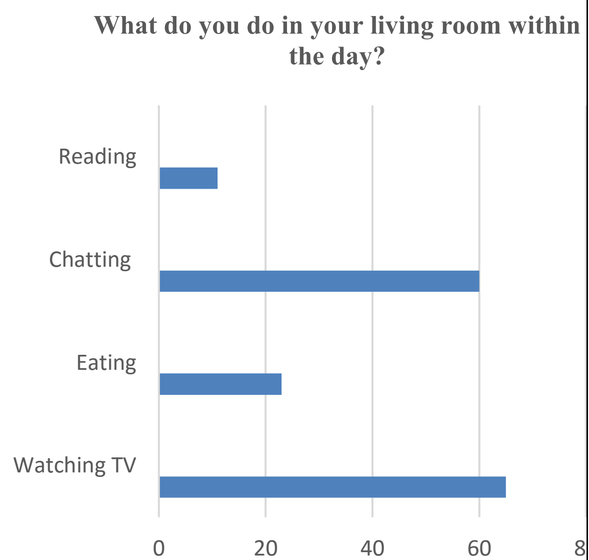
E- Do you think that the artificial light in your home is good?

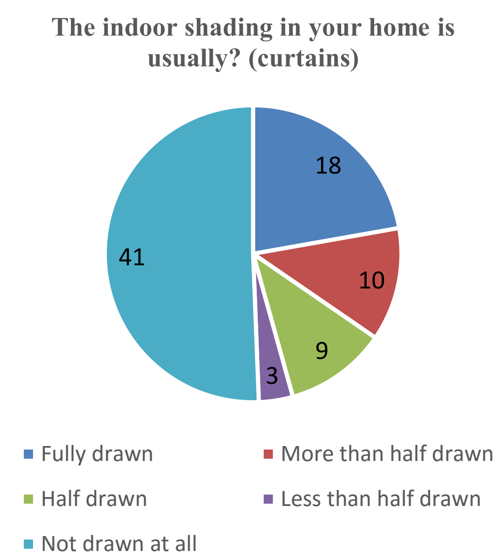


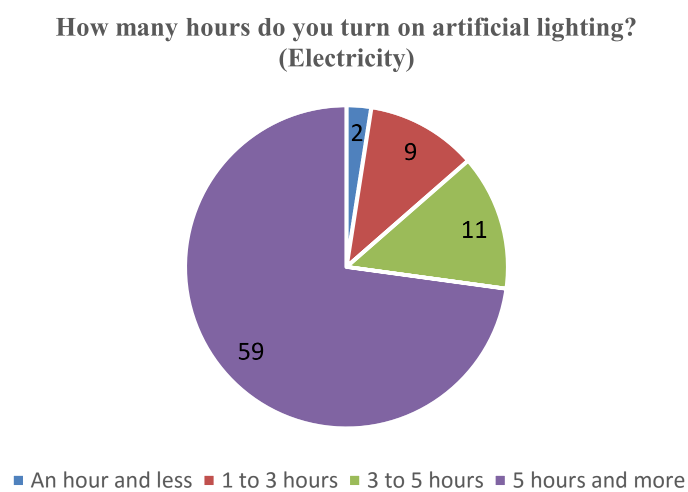
F- Physiological discomfort?



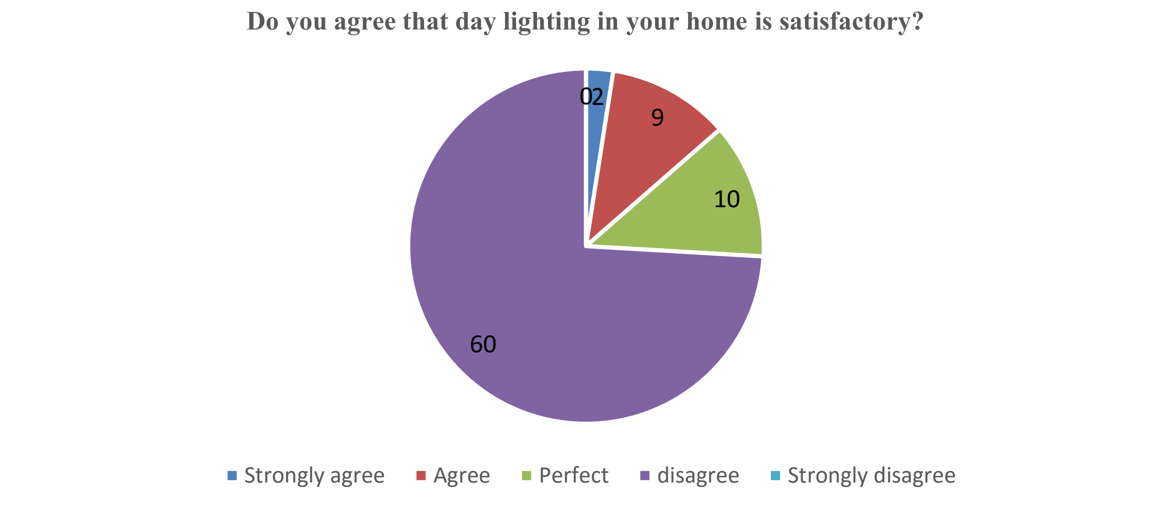
Section 4: Human Demeanor:







Section 5: Illumination Comfort:



3- Interview survey:

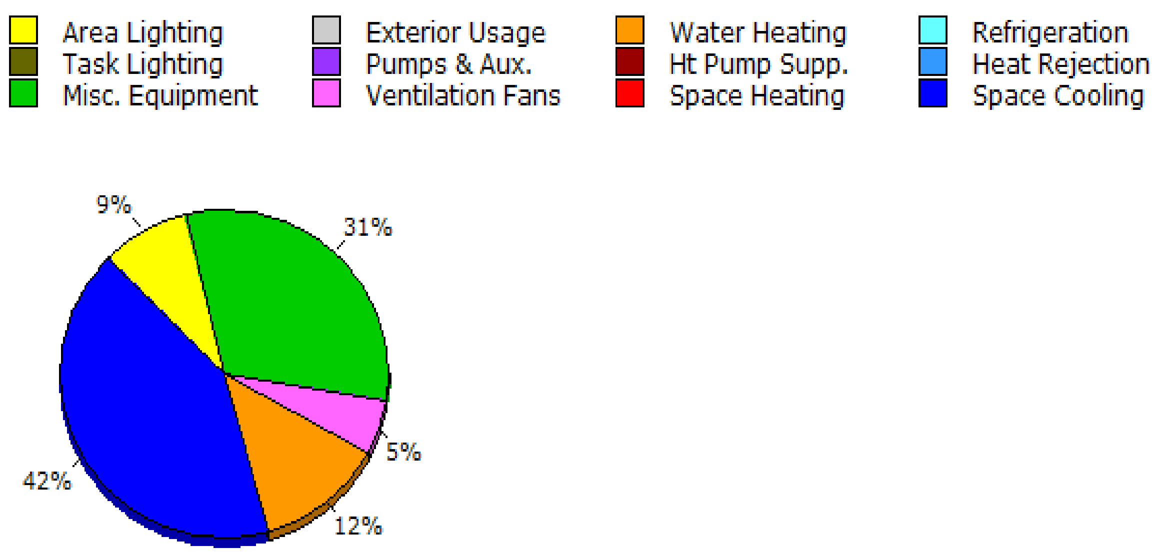
<table>
<tr><td colspan="5">Section 1: General Information (not mandatory)</td></tr>
<tr><td rowspan="2">Age</td><td>25 and less</td><td>25-45</td><td>45-60</td><td>60 and above</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Gender</td><td colspan="2">Male</td><td colspan="2">Female</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">City</td><td>Dammam</td><td>Al-Khobar</td><td colspan="2">Al-Ehsa</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="5">Section 2: Materialistic Information (mandatory) *</td></tr>
<tr><td>Question</td><td colspan="4">Answer</td></tr>
<tr><td>What type of window glass do you usually use when designing a window for a Villa?</td><td colspan="4"></td></tr>
<tr><td>What are the common dimensions do you usually use when designing a Villa floor?</td><td colspan="4"></td></tr>
<tr><td>What are the usual materials you use when building the Villa's external walls?</td><td colspan="4"></td></tr>
<tr><td>What are the usual materials you use when building the Villa's roof?</td><td colspan="4"></td></tr>
<tr><td>What are the common recommended lighting levels you recommend ?</td><td colspan="4"></td></tr>
</table>

4- Annual Energy consumption results of base case:

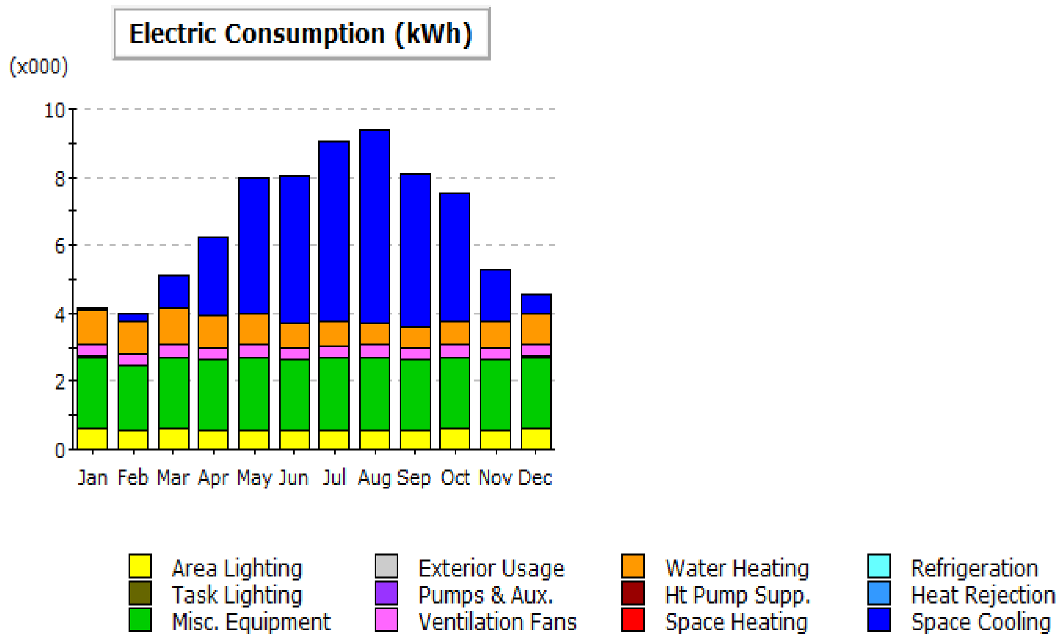
Annual Energy Consumption by Enduse

	Electricity kWh	Natural Gas Btu	Steam Btu	Chilled Water Btu
Space Cool	33,243	-	-	-
Heat Reject.	-	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	-	-	-
HP Supp.	-	-	-	-
Hot Water	9,898	-	-	-
Vent. Fans	4,197	-	-	-
Pumps & Aux.	53	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	24,947	-	-	-
Task Lights	-	-	-	-
Area Lights	6,952	-	-	-
Total	79,290	-	-	-

5- Electric consumption of base case:



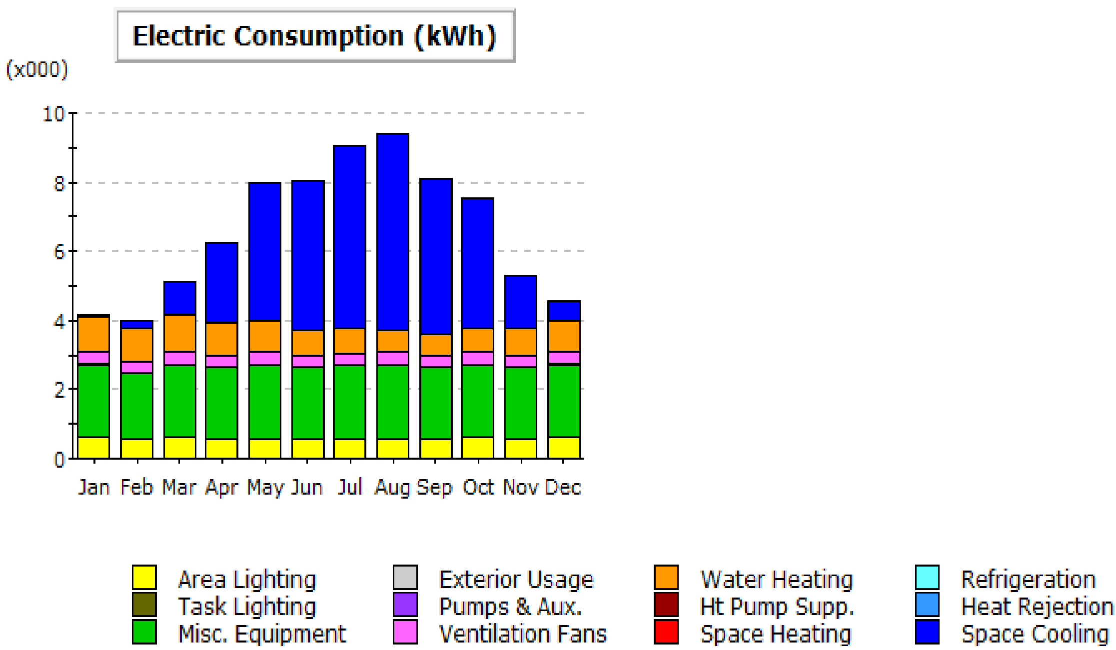
6- Electric Demand of base case:



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.02	0.27	0.97	2.27	4.01	4.30	5.28	5.70	4.51	3.80	1.56	0.57	33.26
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.01	0.96	1.06	1.00	0.90	0.76	0.68	0.62	0.60	0.68	0.75	0.89	9.90
Vent. Fans	0.36	0.32	0.36	0.34	0.36	0.35	0.35	0.36	0.34	0.35	0.36	0.35	4.21
Pumps & Aux.	0.03	0.01	-	-	-	-	-	-	-	-	-	0.01	0.05
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	2.12	1.91	2.12	2.05	2.12	2.05	2.12	2.12	2.05	2.12	2.05	2.12	24.95
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.60	0.54	0.60	0.57	0.59	0.57	0.58	0.59	0.58	0.60	0.58	0.60	7.00
Total	4.14	4.02	5.11	6.22	7.98	8.03	9.02	9.39	8.08	7.54	5.31	4.54	79.36

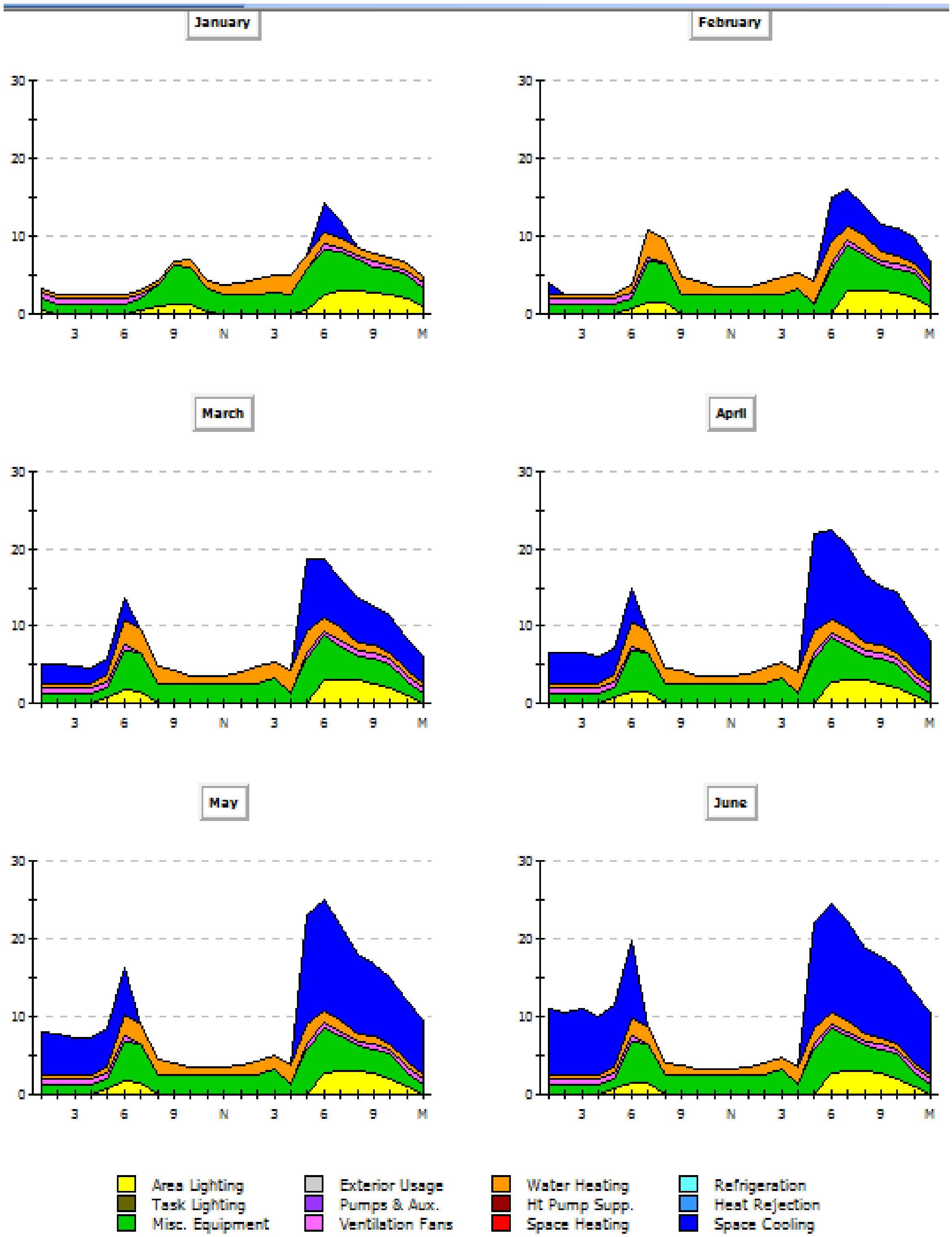
7- Electric Consumption of base case:

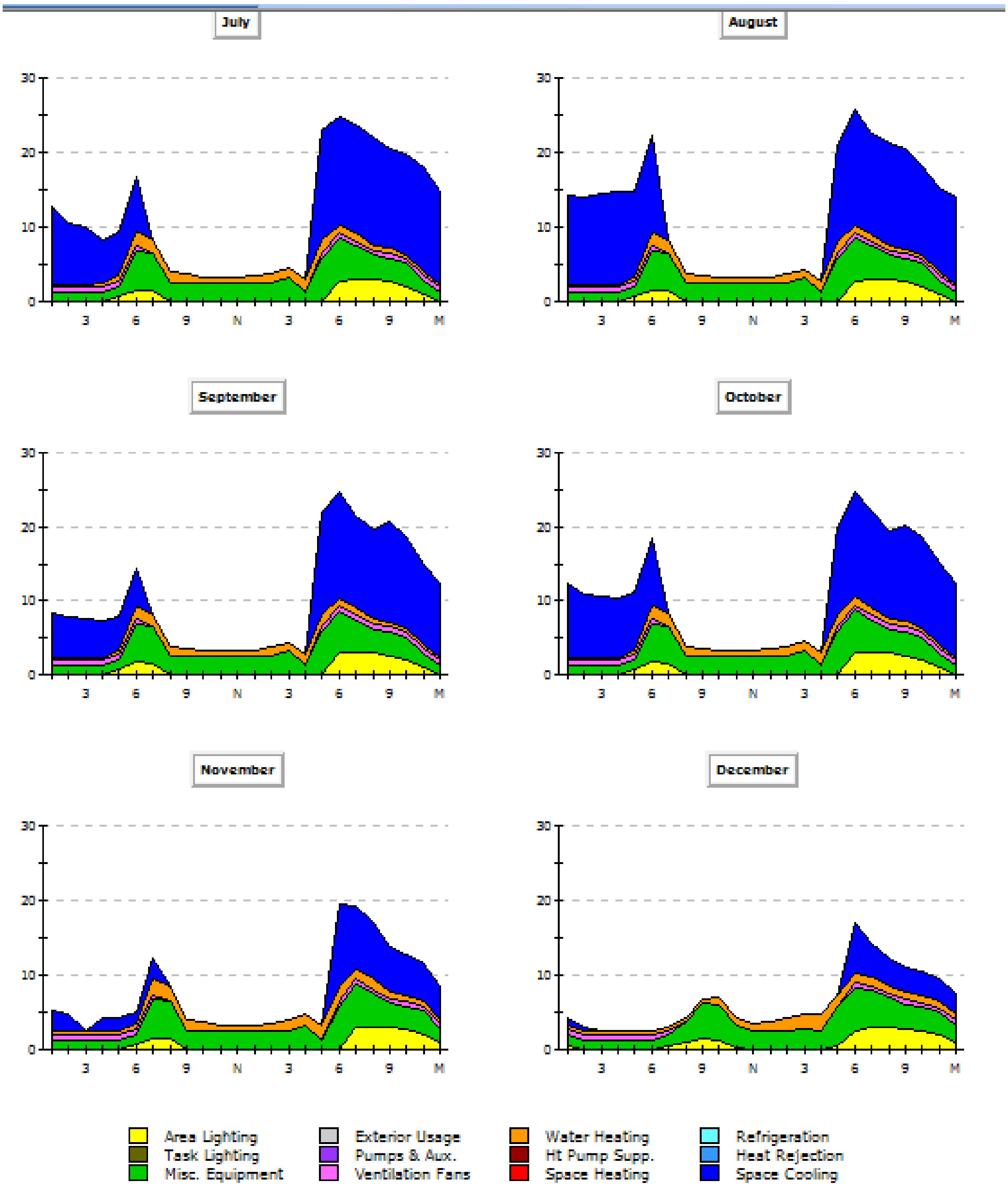


Electric Consumption (kWh x000)

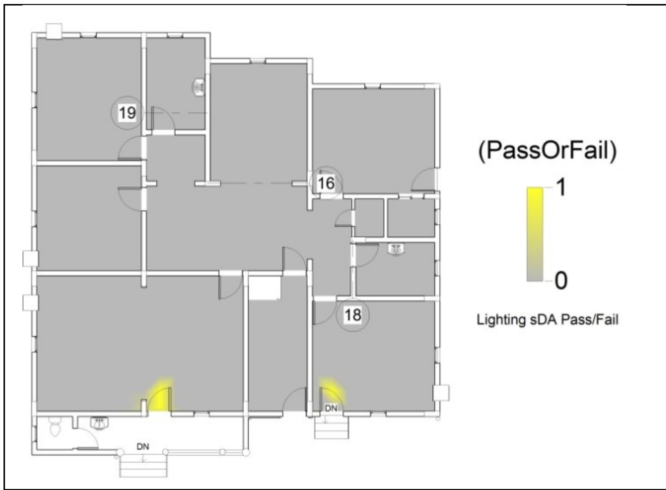
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.02	0.27	0.97	2.27	4.01	4.30	5.28	5.70	4.51	3.80	1.56	0.57	33.26
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.01	0.96	1.06	1.00	0.90	0.76	0.68	0.62	0.60	0.68	0.75	0.89	9.90
Vent. Fans	0.36	0.32	0.36	0.34	0.36	0.35	0.35	0.36	0.34	0.35	0.36	0.35	4.21
Pumps & Aux.	0.03	0.01	-	-	-	-	-	-	-	-	-	0.01	0.05
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	2.12	1.91	2.12	2.05	2.12	2.05	2.12	2.12	2.05	2.12	2.05	2.12	24.95
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.60	0.54	0.60	0.57	0.59	0.57	0.58	0.59	0.58	0.60	0.58	0.60	7.00
Total	4.14	4.02	5.11	6.22	7.98	8.03	9.02	9.39	8.08	7.54	5.31	4.54	79.36

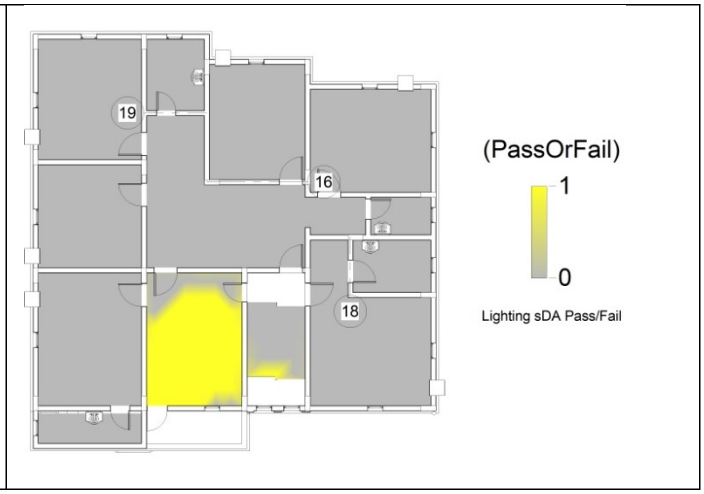
8- Monthly Energy consumption throughout a duration of a year for the base case:





9- WWR of the base case:





Daylight Autonomy (sDA preview)
For all Rooms Included in Daylighting

Jan 1 to Dec 31, 8:00 am to 6:00 pm
(Both sDA and ASE must be met for Room area to qualify)

$sDA_{300/50}$ + $ASE_{1000/250}$ 0 Points

5% of Building area meets sDA % hours
in Rooms with <20% area above ASE

Detailed Summary:

5% of Building area meets sDA % hours
0% of sDA Building area fails for Rooms >ASE

2% of Building area >ASE hours threshold

5% of Rooms meet sDA >55% Room area
5% of Rooms meet sDA 75% Room area
0% of Rooms >ASE hours >20% Room area

At least 55% must exceed sDA300/50 in Rooms with ASE1000/250 < 20% of Room area

A	B	C	D	E	F	G	H	I	J	K
				Include In	sDA 300/50		ASE 1000/250		sDA/ASE	
Level	Name	Number	Area	Daylighting	%	Points	%	Pass	%	Points
Ground Floor	Room	1	20 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	2	49 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	3	20 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	4	3 m²	☑	0	none	11	Yes	0	none
Ground Floor	Room	5	2 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	6	7 m²	☑	0	none	7	Yes	0	none
Ground Floor	Room	7	21 m²	☑	2	none	0	Yes	2	none
Ground Floor	Room	8	12 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	9	43 m²	☑	2	none	3	Yes	2	none
Ground Floor	Room	10	17 m²	☑	0	none	7	Yes	0	none
Ground Floor	Room	11	8 m²	☑	0	none	0	Yes	0	none
First Floor	Room	12	20 m²	☑	0	none	0	Yes	0	none
First Floor	Room	13	7 m²	☑	0	none	0	Yes	0	none
First Floor	Room	14	17 m²	☑	0	none	0	Yes	0	none
First Floor	Room	15	20 m²	☑	0	none	0	Yes	0	none
First Floor	Room	16	31 m²	☑	0	none	0	Yes	0	none
First Floor	Room	17	17 m²	☑	0	none	6	Yes	0	none
First Floor	Room	18	22 m²	☑	0	none	5	Yes	0	none
First Floor	Room	19	20 m²	☑	78	3 pt	7	Yes	78	3 pt
First Floor	Room	20	24 m²	☑	0	none	0	Yes	0	none
First Floor	Room	21	12 m²	☑	23	none	5	Yes	23	none
First Floor	Room	22	7 m²	☑	0	none	7	Yes	0	none
First Floor	Room	23	4 m²	☑	0	none	0	Yes	0	none
First Floor	Room	24	5 m²	☑	0	none	0	Yes	0	none

10- WWR of case study one:

Daylight Autonomy (sDA preview)
For all Rooms Included in Daylighting

Jan 1 to Dec 31, 8:00 am to 6:00 pm
(Both sDA and ASE must be met for Room area to qualify)

$sDA_{300/50}$ + $ASE_{1000/250}$ 0 Points
16% of Building area meets sDA % hours
in Rooms with <20% area above ASE

Detailed Summary:
16% of Building area meets sDA % hours
0% of sDA Building area fails for Rooms >ASE

4% of Building area >ASE hours threshold

11% of Rooms meet sDA >55% Room area
5% of Rooms meet sDA 75% Room area
0% of Rooms >ASE hours >20% Room area

At least 55% must exceed sDA300/50 in Rooms with ASE1000/250 < 20% of Room area

A	B	C	D	E	F	G	H	I	J	K
				Include In	sDA 300/50		ASE 1000/250		sDA/ASE	
Level	Name	Number	Area	Daylighting	%	Points	%	Pass	%	Points
Ground Floor	Room	1	20 m²	☑	7	none	8	Yes	7	none
Ground Floor	Room	2	49 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	3	20 m²	☑	1	none	0	Yes	1	none
Ground Floor	Room	4	3 m²	☑	0	none	7	Yes	0	none
Ground Floor	Room	5	2 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	6	7 m²	☑	0	none	3	Yes	0	none
Ground Floor	Room	7	21 m²	☑	7	none	2	Yes	7	none
Ground Floor	Room	8	12 m²	☑	9	none	4	Yes	9	none
Ground Floor	Room	9	43 m²	☑	13	none	4	Yes	13	none
Ground Floor	Room	10	17 m²	☑	4	none	11	Yes	4	none
Ground Floor	Room	11	8 m²	☑	0	none	0	Yes	0	none
First Floor	Room	12	20 m²	☑	39	none	11	Yes	39	none
First Floor	Room	13	7 m²	☑	0	none	0	Yes	0	none
First Floor	Room	14	17 m²	☑	4	none	0	Yes	4	none
First Floor	Room	15	20 m²	☑	45	none	6	Yes	45	none
First Floor	Room	16	31 m²	☑	0	none	0	Yes	0	none
First Floor	Room	17	17 m²	☑	6	none	6	Yes	6	none
First Floor	Room	18	22 m²	☑	6	none	5	Yes	6	none
First Floor	Room	19	20 m²	☑	89	3 pt	7	Yes	89	3 pt
First Floor	Room	20	24 m²	☑	61	2 pt	14	Yes	61	2 pt
First Floor	Room	21	12 m²	☑	23	none	5	Yes	23	none
First Floor	Room	22	7 m²	☑	0	none	7	Yes	0	none
First Floor	Room	23	4 m²	☑	0	none	0	Yes	0	none
First Floor	Room	24	5 m²	☑	0	none	0	Yes	0	none

11- WWR of case study two:

Daylight Autonomy (sDA preview)
For all Rooms Included in Daylighting

Jan 1 to Dec 31, 8:00 am to 6:00 pm
(Both sDA and ASE must be met for Room area to qualify)

$sDA_{300/50}$ + $ASE_{1000/250}$ * 0 Points
20% of Building area meets sDA % hours
in Rooms with <20% area above ASE

Detailed Summary:
45% of Building area meets sDA % hours
26% of sDA Building area fails for Rooms >ASE

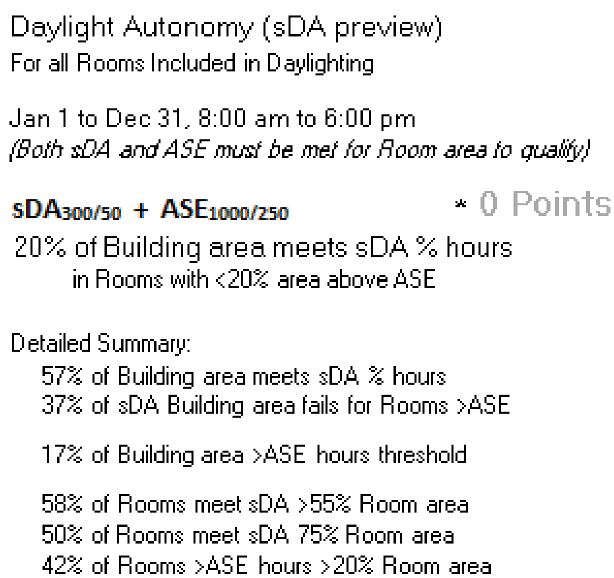
13% of Building area >ASE hours threshold

52% of Rooms meet sDA >55% Room area
21% of Rooms meet sDA 75% Room area
34% of Rooms >ASE hours >20% Room area

At least 55% must exceed sDA300/50 in Rooms with ASE1000/250 < 20% of Room area

A	B	C	D	E	F	G	H	I	J	K
				Include In	sDA 300/50		ASE 1000/250		sDA/ASE	
Level	Name	Number	Area	Daylighting	%	Points	%	Pass	%	Points
Ground Floor	Room	1	20 m²	☑	69	2 pt	21	No	0	none
Ground Floor	Room	2	49 m²	☑	12	none	0	Yes	12	none
Ground Floor	Room	3	20 m²	☑	12	none	0	Yes	12	none
Ground Floor	Room	4	3 m²	☑	0	none	11	Yes	0	none
Ground Floor	Room	5	2 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	6	7 m²	☑	0	none	7	Yes	0	none
Ground Floor	Room	7	21 m²	☑	39	none	5	Yes	39	none
Ground Floor	Room	8	12 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	9	43 m²	☑	63	2 pt	13	Yes	63	2 pt
Ground Floor	Room	10	17 m²	☑	26	none	29	No	0	none
Ground Floor	Room	11	8 m²	☑	0	none	0	Yes	0	none
First Floor	Room	12	20 m²	☑	96	3 pt	20	Yes	96	3 pt
First Floor	Room	13	7 m²	☑	0	none	0	Yes	0	none
First Floor	Room	14	17 m²	☑	58	2 pt	0	Yes	58	2 pt
First Floor	Room	15	20 m²	☑	100	3 pt	27	No	0	none
First Floor	Room	16	31 m²	☑	0	none	0	Yes	0	none
First Floor	Room	17	17 m²	☑	61	2 pt	31	No	0	none
First Floor	Room	18	22 m²	☑	62	2 pt	24	No	0	none
First Floor	Room	19	20 m²	☑	100	3 pt	24	No	0	none
First Floor	Room	20	24 m²	☑	93	3 pt	39	No	0	none
First Floor	Room	21	12 m²	☑	21	none	5	Yes	21	none
First Floor	Room	22	7 m²	☑	60	2 pt	20	Yes	60	2 pt
First Floor	Room	23	4 m²	☑	22	none	0	Yes	22	none
First Floor	Room	24	5 m²	☑	0	none	0	Yes	0	none

12- WWR of case study number three:



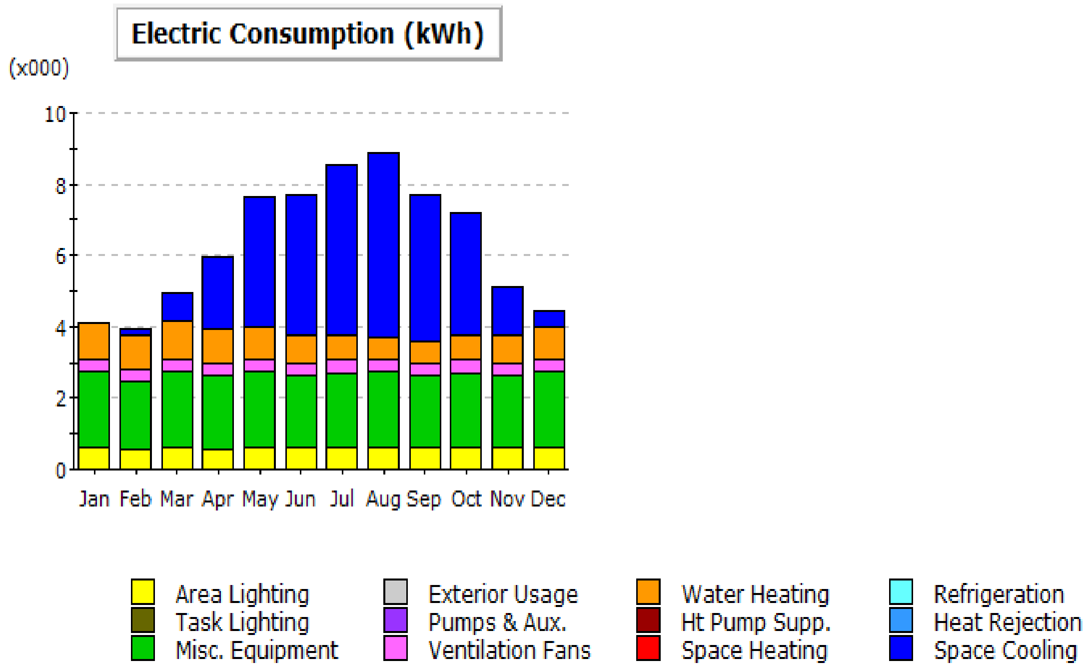
At least 55% must exceed sDA300/50 in Rooms with ASE1000/250 < 20% of Room area

A	B	C	D	E	F	G	H	I	J	K
Level	Name	Number	Area	Include In Daylighting	sDA 300/50		ASE 1000/250		sDA/ASE	
					%	Points	%	Pass	%	Points
Ground Floor	Room	1	20 m²	☑	69	2 pt	21	No	0	none
Ground Floor	Room	2	49 m²	☑	12	none	0	Yes	12	none
Ground Floor	Room	3	20 m²	☑	12	none	0	Yes	12	none
Ground Floor	Room	4	3 m²	☑	0	none	11	Yes	0	none
Ground Floor	Room	5	2 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	6	7 m²	☑	0	none	7	Yes	0	none
Ground Floor	Room	7	21 m²	☑	39	none	5	Yes	39	none
Ground Floor	Room	8	12 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	9	43 m²	☑	63	2 pt	13	Yes	63	2 pt
Ground Floor	Room	10	17 m²	☑	26	none	29	No	0	none
Ground Floor	Room	11	8 m²	☑	0	none	0	Yes	0	none
First Floor	Room	12	20 m²	☑	96	3 pt	20	Yes	96	3 pt
First Floor	Room	13	7 m²	☑	0	none	0	Yes	0	none
First Floor	Room	14	17 m²	☑	58	2 pt	0	Yes	58	2 pt
First Floor	Room	15	20 m²	☑	100	3 pt	27	No	0	none
First Floor	Room	16	31 m²	☑	0	none	0	Yes	0	none
First Floor	Room	17	17 m²	☑	61	2 pt	31	No	0	none
First Floor	Room	18	22 m²	☑	62	2 pt	24	No	0	none
First Floor	Room	19	20 m²	☑	100	3 pt	24	No	0	none
First Floor	Room	20	24 m²	☑	93	3 pt	39	No	0	none
First Floor	Room	21	12 m²	☑	21	none	5	Yes	21	none
First Floor	Room	22	7 m²	☑	60	2 pt	20	Yes	60	2 pt
First Floor	Room	23	4 m²	☑	22	none	0	Yes	22	none
First Floor	Room	24	5 m²	☑	0	none	0	Yes	0	none

13- Annual energy and consumption of the case studies:

		Ambient Lights	Task Lights	Misc Equip	Space Heating	Space Cooling	Heat Reject	Pumps & Aux	Vent Fans	Dom Ht Wtr	Exterior Usage	Total
Annual Energy USE (kWh)												
0	Base Design	6.997	0	24.947	0	33.261	0	53	4.207	9.898	0	79.363
1	0+Window Ext Shading EEM	6.997	0	24.947	0	33.049	0	53	4.180	9.901	0	79.126
2	1+Window Ext Shading EEM 2	6.997	0	24.947	0	33.010	0	53	4.175	9.901	0	79.084
3	0+Window Ext Shading EEM 3	6.999	0	24.947	0	32.889	0	53	4.163	9.903	0	78.953
4	0+Window Ext Shading EEM 4	7.000	0	24.947	0	32.772	0	53	4.149	9.904	0	78.826
5	0+Window Area EEM	6.975	0	24.947	0	33.254	0	53	4.203	9.898	0	79.330
6	0+Window Area EEM 2	6.959	0	24.947	0	33.246	0	53	4.199	9.898	0	79.301
7	0+Window Area EEM 3	6.952	0	24.947	0	33.243	0	53	4.197	9.898	0	79.290
8	0+Window Glass Type EEM	7.176	0	24.947	0	30.116	0	53	4.065	9.918	0	76.275
9	8+Window Glass Type EEM 2	7.162	0	24.947	0	30.564	0	53	4.063	9.906	0	76.696
10	0+Window Glass Type EEM 3	7.048	0	24.947	0	31.559	0	53	4.060	9.919	0	77.585
11	0+Window Glass Type EEM 4	7.007	0	24.947	0	32.862	0	53	4.130	9.900	0	78.900
12	0+Window Glass Type EEM 5	7.176	0	24.947	0	29.959	0	53	4.060	9.920	0	76.115
Incremental SAVINGS (MWh)	(values are relative to previous measure (% savings are relative to base case use), negative entries indicate increased use)											
1	0+Window Ext Shading EEM	-0.00 (-0%)	--	0.00 (0%)	--	0.21 (1%)	--	0.00 (0%)	0.03 (1%)	-0.00 (-0%)	--	0.24 (0%)
2	1+Window Ext Shading EEM 2	-0.00 (-0%)	--	0.00 (0%)	--	0.04 (0%)	--	0.00 (0%)	0.00 (0%)	-0.00 (-0%)	--	0.04 (0%)
3	0+Window Ext Shading EEM 3	-0.00 (-0%)	--	0.00 (0%)	--	0.37 (1%)	--	0.00 (0%)	0.04 (1%)	-0.01 (-0%)	--	0.41 (1%)
4	0+Window Ext Shading EEM 4	-0.00 (-0%)	--	0.00 (0%)	--	0.49 (1%)	--	0.00 (0%)	0.06 (1%)	-0.01 (-0%)	--	0.54 (1%)
5	0+Window Area EEM	0.02 (0%)	--	0.00 (0%)	--	0.01 (0%)	--	0.00 (0%)	0.00 (0%)	-0.00 (-0%)	--	0.03 (0%)
6	0+Window Area EEM 2	0.04 (1%)	--	0.00 (0%)	--	0.02 (0%)	--	0.00 (0%)	0.01 (0%)	-0.00 (-0%)	--	0.06 (0%)
7	0+Window Area EEM 3	0.04 (1%)	--	0.00 (0%)	--	0.02 (0%)	--	0.00 (0%)	0.01 (0%)	-0.00 (-0%)	--	0.07 (0%)
8	0+Window Glass Type EEM	-0.18 (-3%)	--	0.00 (0%)	--	3.15 (9%)	--	0.00 (0%)	0.14 (3%)	-0.02 (-0%)	--	3.09 (4%)
9	8+Window Glass Type EEM 2	0.01 (0%)	--	0.00 (0%)	--	-0.45 (-1%)	--	0.00 (0%)	0.00 (0%)	0.01 (0%)	--	-0.42 (-1%)
10	0+Window Glass Type EEM 3	-0.05 (-1%)	--	0.00 (0%)	--	1.70 (5%)	--	0.00 (0%)	0.15 (3%)	-0.02 (-0%)	--	1.78 (2%)
11	0+Window Glass Type EEM 4	-0.01 (-0%)	--	0.00 (0%)	--	0.40 (1%)	--	0.00 (0%)	0.08 (2%)	-0.00 (-0%)	--	0.46 (1%)
12	0+Window Glass Type EEM 5	-0.18 (-3%)	--	0.00 (0%)	--	3.30 (10%)	--	0.00 (0%)	0.15 (3%)	-0.02 (-0%)	--	3.25 (4%)
Cumulative SAVINGS (MWh)	(values (and % savings) are relative to the Base Case, negative entries indicate increased use)											
1	0+Window Ext Shading EEM	-0.00 (-0%)	--	0.00 (0%)	--	0.21 (1%)	--	0.00 (0%)	0.03 (1%)	-0.00 (-0%)	--	0.24 (0%)
2	1+Window Ext Shading EEM 2	-0.00 (-0%)	--	0.00 (0%)	--	0.25 (1%)	--	0.00 (0%)	0.03 (1%)	-0.00 (-0%)	--	0.28 (0%)
3	0+Window Ext Shading EEM 3	-0.00 (-0%)	--	0.00 (0%)	--	0.37 (1%)	--	0.00 (0%)	0.04 (1%)	-0.01 (-0%)	--	0.41 (1%)
4	0+Window Ext Shading EEM 4	-0.00 (-0%)	--	0.00 (0%)	--	0.49 (1%)	--	0.00 (0%)	0.06 (1%)	-0.01 (-0%)	--	0.54 (1%)
5	0+Window Area EEM	0.02 (0%)	--	0.00 (0%)	--	0.01 (0%)	--	0.00 (0%)	0.00 (0%)	-0.00 (-0%)	--	0.03 (0%)
6	0+Window Area EEM 2	0.04 (1%)	--	0.00 (0%)	--	0.02 (0%)	--	0.00 (0%)	0.01 (0%)	-0.00 (-0%)	--	0.06 (0%)
7	0+Window Area EEM 3	0.04 (1%)	--	0.00 (0%)	--	0.02 (0%)	--	0.00 (0%)	0.01 (0%)	-0.00 (-0%)	--	0.07 (0%)
8	0+Window Glass Type EEM	-0.18 (-3%)	--	0.00 (0%)	--	3.15 (9%)	--	0.00 (0%)	0.14 (3%)	-0.02 (-0%)	--	3.09 (4%)
9	8+Window Glass Type EEM 2	-0.16 (-2%)	--	0.00 (0%)	--	2.70 (8%)	--	0.00 (0%)	0.14 (3%)	-0.01 (-0%)	--	2.67 (3%)
10	0+Window Glass Type EEM 3	-0.05 (-1%)	--	0.00 (0%)	--	1.70 (5%)	--	0.00 (0%)	0.15 (3%)	-0.02 (-0%)	--	1.78 (2%)
11	0+Window Glass Type EEM 4	-0.01 (-0%)	--	0.00 (0%)	--	0.40 (1%)	--	0.00 (0%)	0.08 (2%)	-0.00 (-0%)	--	0.46 (1%)
12	0+Window Glass Type EEM 5	-0.18 (-3%)	--	0.00 (0%)	--	3.30 (10%)	--	0.00 (0%)	0.15 (3%)	-0.02 (-0%)	--	3.25 (4%)

14- Electric consumption of the base case:



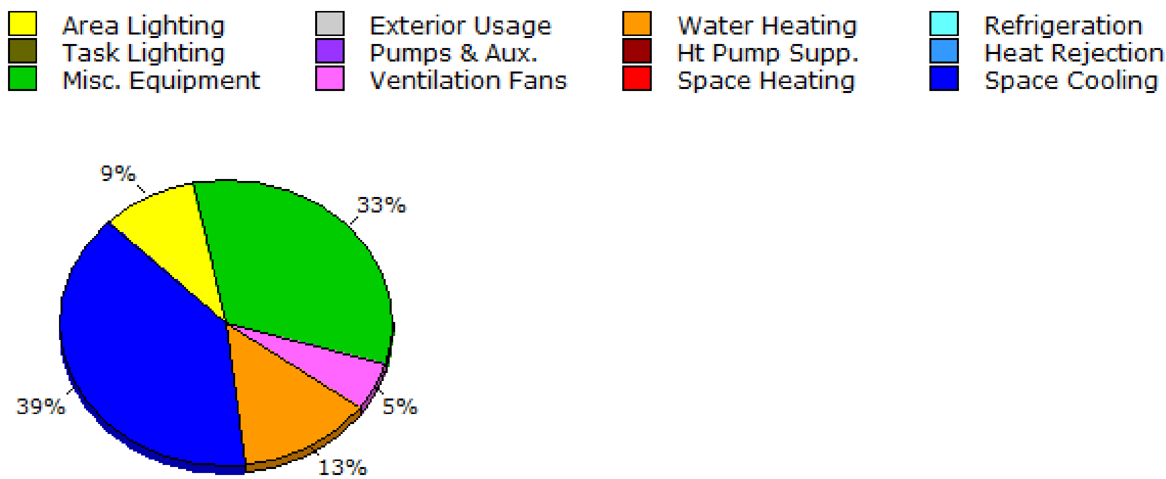
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.00	0.16	0.79	2.02	3.64	3.93	4.81	5.21	4.13	3.46	1.35	0.44	29.96
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.02	0.96	1.06	1.00	0.90	0.76	0.68	0.62	0.60	0.68	0.75	0.89	9.92
Vent. Fans	0.34	0.31	0.35	0.33	0.35	0.33	0.34	0.35	0.33	0.34	0.35	0.34	4.06
Pumps & Aux.	0.03	0.01	-	-	-	-	-	-	-	-	-	0.01	0.05
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	2.12	1.91	2.12	2.05	2.12	2.05	2.12	2.12	2.05	2.12	2.05	2.12	24.95
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.61	0.55	0.61	0.58	0.61	0.59	0.61	0.61	0.59	0.61	0.60	0.61	7.18
Total	4.13	3.91	4.93	5.97	7.62	7.67	8.56	8.90	7.70	7.20	5.10	4.41	76.11

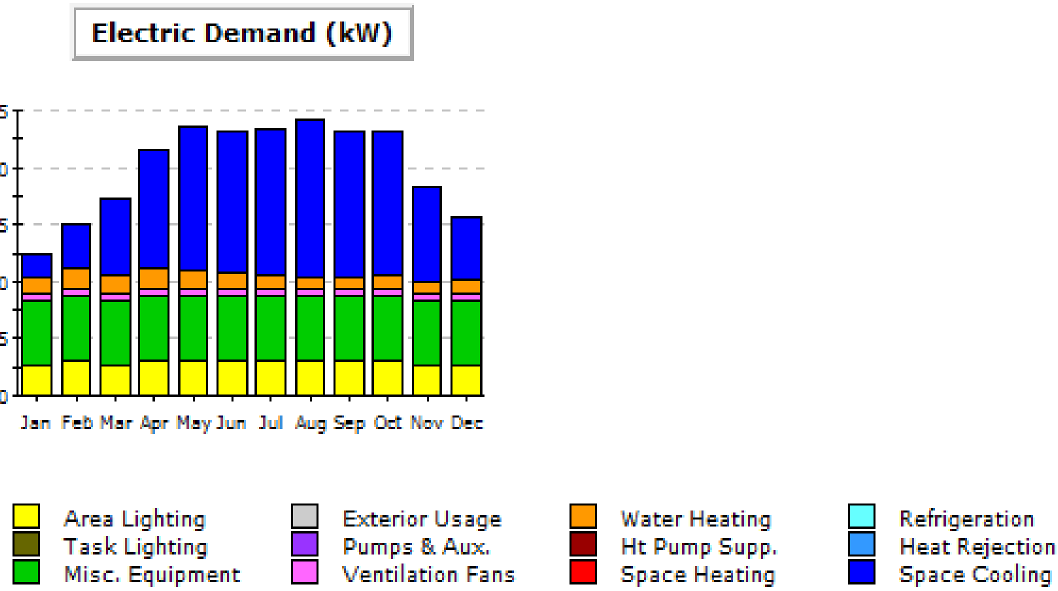
15- Annual energy consumption for the run model:

Annual Energy Consumption by Enduse

	Electricity kWh	Natural Gas Btu	Steam Btu	Chilled Water Btu
Space Cool	30,016	-	-	-
Heat Reject.	-	-	-	-
Refrigeration	-	-	-	-
Space Heat	-	-	-	-
HP Supp.	-	-	-	-
Hot Water	9,920	-	-	-
Vent. Fans	4,064	-	-	-
Pumps & Aux.	53	-	-	-
Ext. Usage	-	-	-	-
Misc. Equip.	24,947	-	-	-
Task Lights	-	-	-	-
Area Lights	7,176	-	-	-
Total	76,176	-	-	-



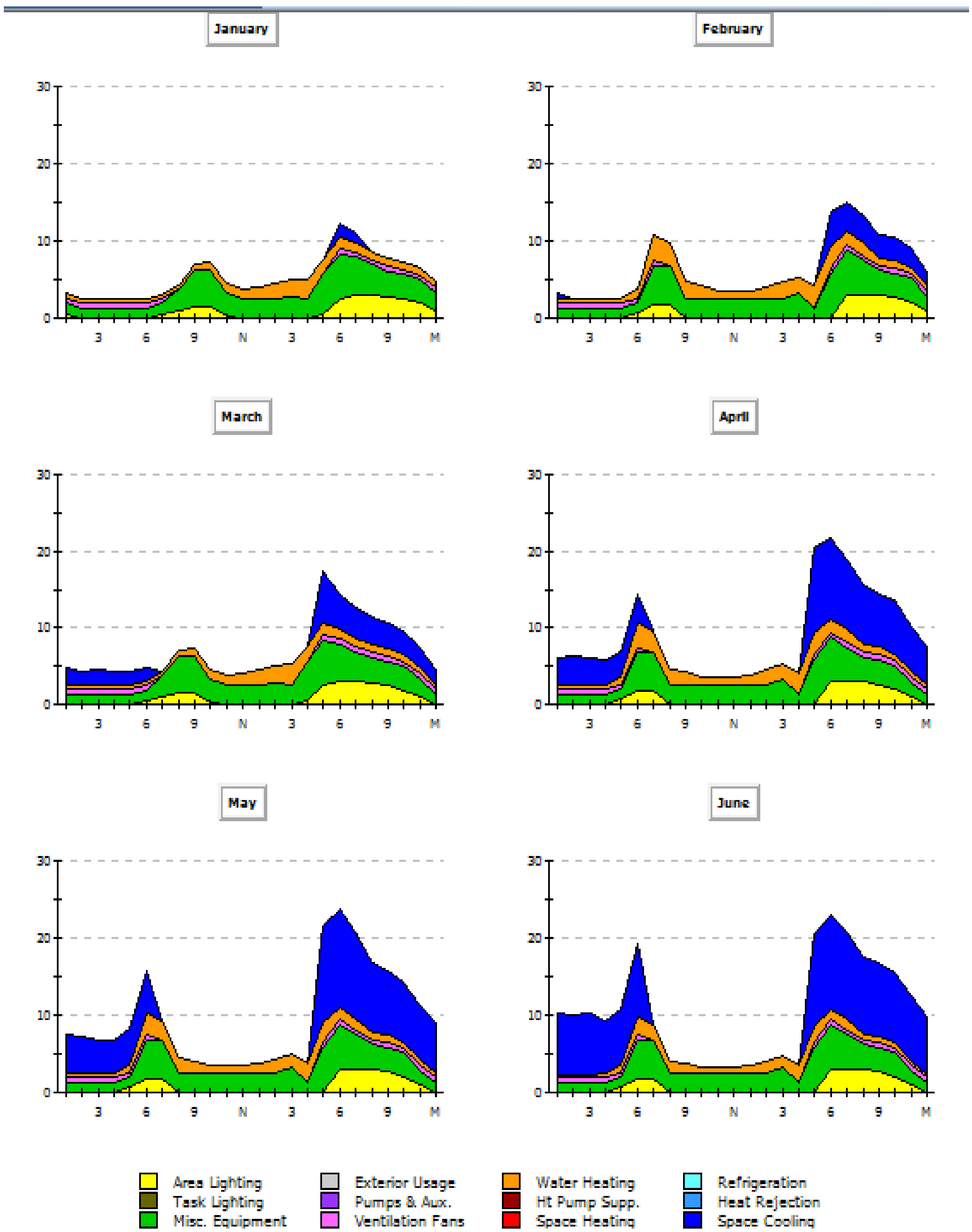
16- Electric demand kW of the run case model:

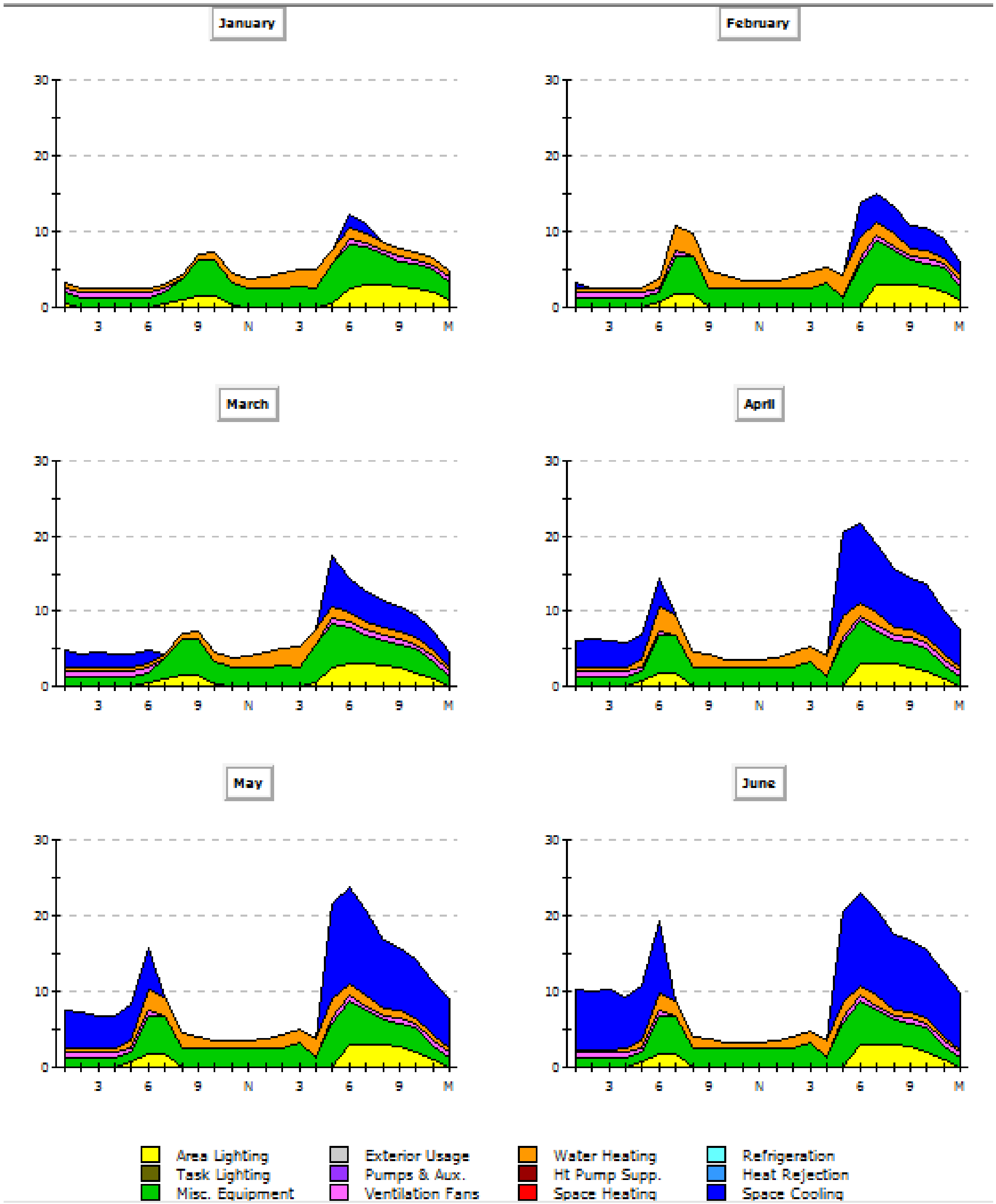


Electric Demand (kW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.93	3.94	6.88	10.48	12.71	12.41	12.80	13.88	12.80	12.70	8.27	5.44	114.24
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.46	1.79	1.52	1.74	1.52	1.31	1.13	0.98	1.01	1.10	1.10	1.28	15.93
Vent. Fans	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	7.85
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	5.76	5.78	5.76	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.76	5.76	69.25
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	2.54	2.97	2.54	2.97	2.97	2.97	2.97	2.97	2.97	2.97	2.54	2.54	33.90
Total	12.34	15.12	17.36	21.61	23.63	23.12	23.32	24.26	23.20	23.19	18.33	15.68	241.18

17- Monthly Energy consumption throughout a duration of a year for the run case model:




January
February
March
April
May
June
30
20
10
0
3
6
9
N
3
6
9
M
Area Lighting
Task Lighting
Misc. Equipment
Exterior Usage
Pumps & Aux.
Ventilation Fans
Water Heating
Ht Pump Supp.
Space Heating
Refrigeration
Heat Rejection
Space Cooling

18- WWR and daylight for the run case model:

Daylight Autonomy (sDA preview)
For all Rooms Included in Daylighting

Jan 1 to Dec 31, 8:00 am to 6:00 pm
(Both sDA and ASE must be met for Room area to qualify)

$sDA_{300/50}$ + $ASE_{1000/250}$ 0 Points

31% of Building area meets sDA % hours
in Rooms with <20% area above ASE

Detailed Summary:
43% of Building area meets sDA % hours
12% of sDA Building area fails for Rooms >ASE

11% of Building area >ASE hours threshold

47% of Rooms meet sDA >55% Room area
21% of Rooms meet sDA 75% Room area
20% of Rooms >ASE hours >20% Room area

At least 55% must exceed sDA300/50 in Rooms with ASE1000/250 < 20% of Room area										
A	B	C	D	E	F	G	H	I	J	K
				Include In	sDA 300/50		ASE 1000/250		sDA/ASE	
Level	Name	Number	Area	Daylighting	%	Points	%	Pass	%	Points
Ground Floor	Room	1	20 m²	☑	60	2 pt	17	Yes	60	2 pt
Ground Floor	Room	2	49 m²	☑	11	none	0	Yes	11	none
Ground Floor	Room	3	20 m²	☑	11	none	0	Yes	11	none
Ground Floor	Room	4	3 m²	☑	0	none	11	Yes	0	none
Ground Floor	Room	5	2 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	6	7 m²	☑	0	none	7	Yes	0	none
Ground Floor	Room	7	21 m²	☑	38	none	5	Yes	38	none
Ground Floor	Room	8	12 m²	☑	0	none	0	Yes	0	none
Ground Floor	Room	9	43 m²	☑	57	2 pt	10	Yes	57	2 pt
Ground Floor	Room	10	17 m²	☑	29	none	24	No	0	none
Ground Floor	Room	11	8 m²	☑	0	none	0	Yes	0	none
First Floor	Room	12	20 m²	☑	96	3 pt	18	Yes	96	3 pt
First Floor	Room	13	6 m²	☑	0	none	0	Yes	0	none
First Floor	Room	14	17 m²	☑	50	none	0	Yes	50	none
First Floor	Room	15	20 m²	☑	100	3 pt	20	Yes	100	3 pt
First Floor	Room	16	31 m²	☑	0	none	0	Yes	0	none
First Floor	Room	17	17 m²	☑	59	2 pt	27	No	0	none
First Floor	Room	18	22 m²	☑	62	2 pt	21	No	0	none
First Floor	Room	19	20 m²	☑	100	3 pt	15	Yes	100	3 pt
First Floor	Room	20	24 m²	☑	89	3 pt	32	No	0	none
First Floor	Room	21	12 m²	☑	19	none	5	Yes	19	none
First Floor	Room	22	7 m²	☑	60	2 pt	20	Yes	60	2 pt
First Floor	Room	23	4 m²	☑	22	none	0	Yes	22	none
First Floor	Room	24	5 m²	☑	0	none	0	Yes	0	none

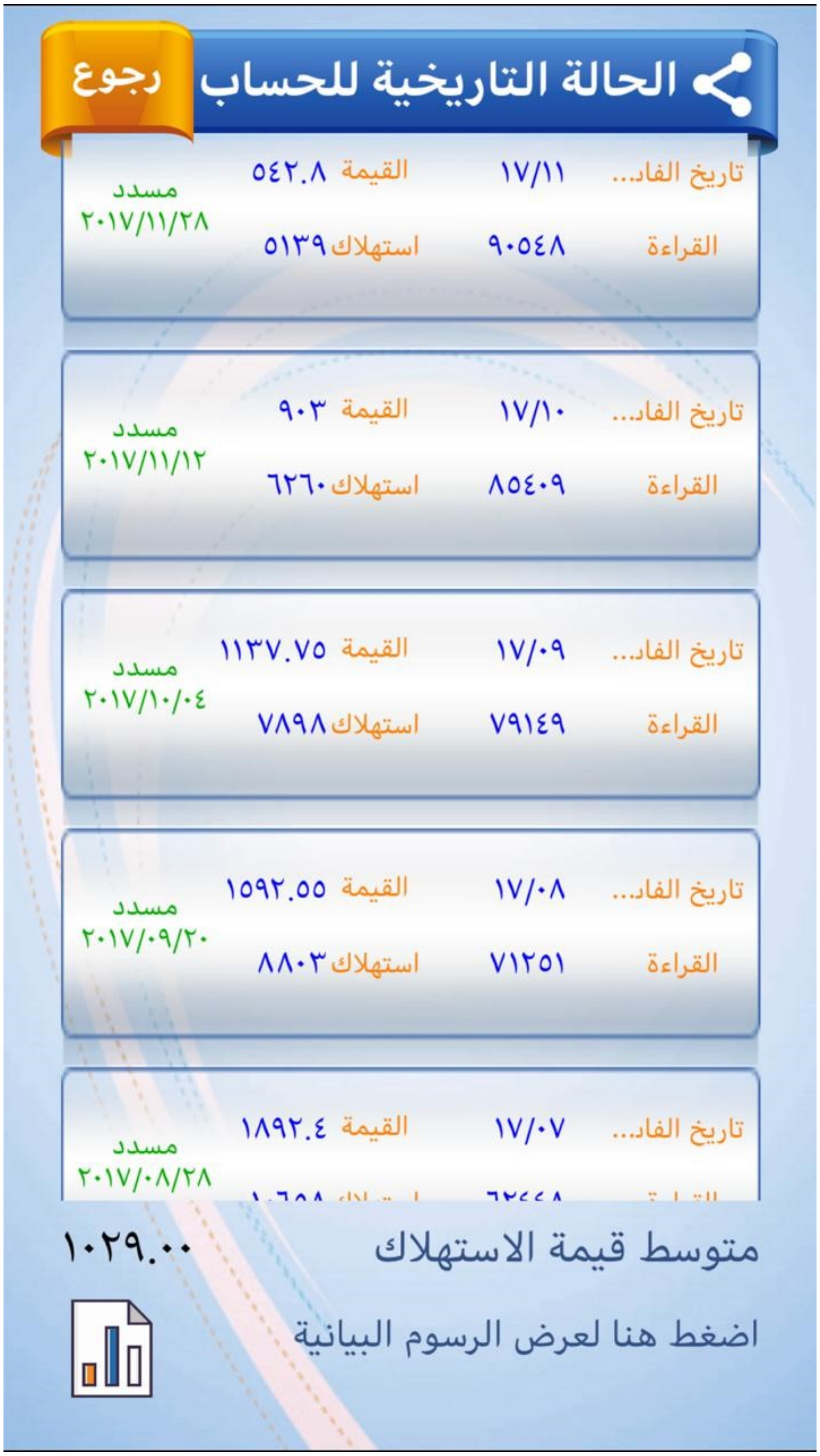
19- Electricity rate in KSA:

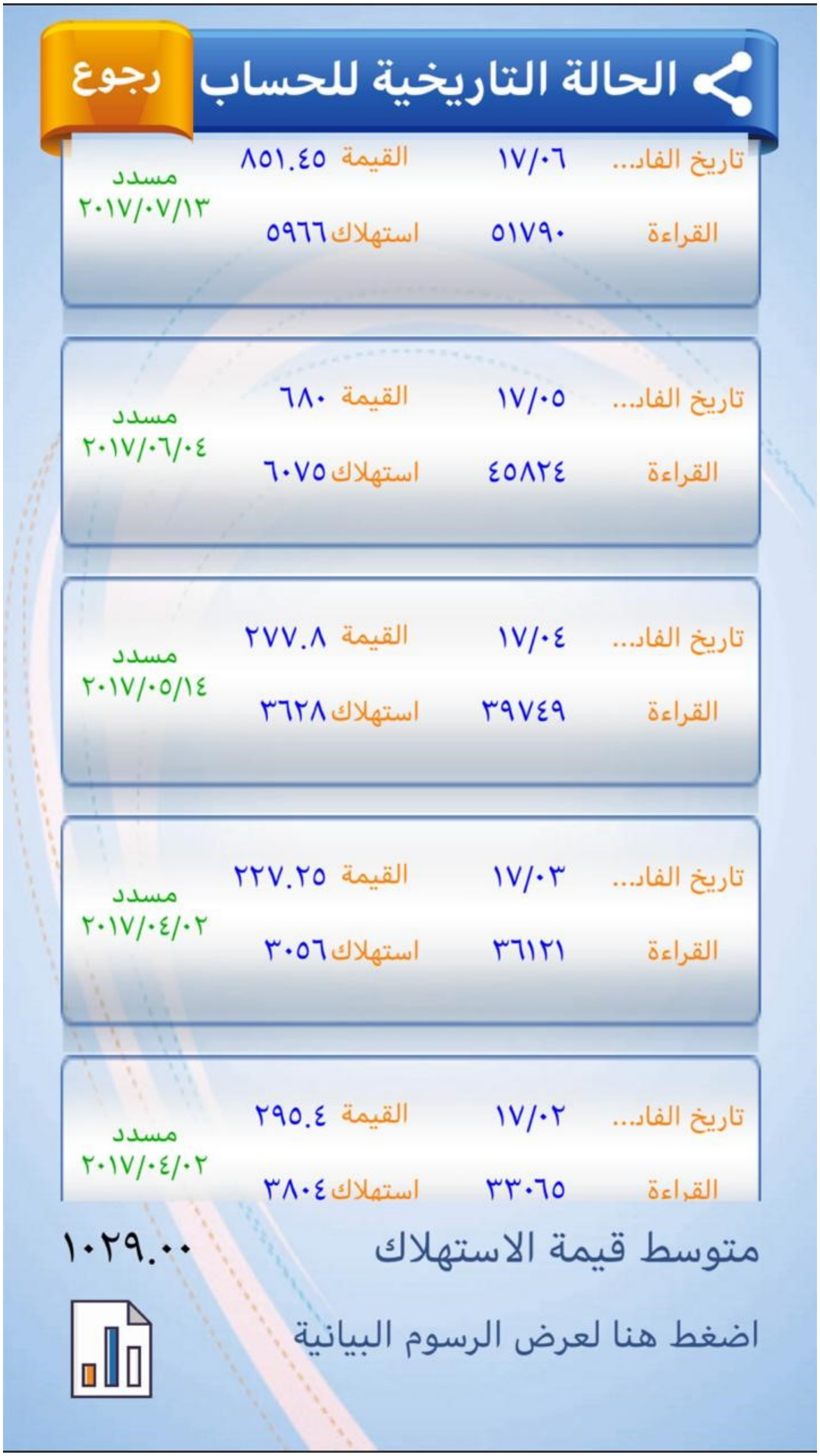
تعريفة الاستهلاك

صدر قرار مجلس الوزراء الموقر بتاريخ ٢٠١٧/١٢/١٢م بخصوص تطبيق تعريفة استهلاك جديدة لكافة فئات المشتركين والتي ستطبق ابتداءً من ٢٠١٨/١/١م حسب الجدول التالي :

شرائح الاستهلاك (ك.و.س/ شهر)	السكني (هللة/ ك.و.س)	التجاري (هللة/ ك.و.س)	الزراعي والجمعيات الخيرية ومافي حكم ذلك (هللة/ ك.و.س)	الحكومي (هللة/ ك.و.س)	المصانع (هللة/ ك.و.س)	المنشآت الصحية الخاصة والمؤسسات والمعاهد والمدارس الأهلية (هللة/ ك.و.س)
١ - ٦٠٠٠	١٨	٢٠	١٦	٣٢	١٨	١٨
أكثر من ٦٠٠٠	٣٠	٣٠	٢٠			

20- electric bills:





الحالة التاريخية للحساب
رجوع
تاريخ الفاد... ١٧/٠٦ القيمة ٨٥١.٤٥
مسدد ٢٠١٧/٠٧/١٣
القراءة ٥١٧٩٠ استهلاك ٥٩٦٦
تاريخ الفاد... ١٧/٠٥ القيمة ٦٨٠
مسدد ٢٠١٧/٠٦/٠٤
القراءة ٤٥٨٢٤ استهلاك ٦٠٧٥
تاريخ الفاد... ١٧/٠٤ القيمة ٢٧٧.٨
مسدد ٢٠١٧/٠٥/١٤
القراءة ٣٩٧٤٩ استهلاك ٣٦٢٨
تاريخ الفاد... ١٧/٠٣ القيمة ٢٢٧.٢٥
مسدد ٢٠١٧/٠٤/٠٢
القراءة ٣٦١٢١ استهلاك ٣٠٥٦
تاريخ الفاد... ١٧/٠٢ القيمة ٢٩٥.٤
مسدد ٢٠١٧/٠٤/٠٢
القراءة ٣٣٠٦٥ استهلاك ٣٨٠٤
متوسط قيمة الاستهلاك ١٠٢٩.٠٠
اضغط هنا لعرض الرسوم البيانية

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