A COMPARATIVE STUDY ON THERMAL PERFORMANCES OF A HOUSE IN SEMI ARID CLIMATE CONDITIONS WITH BREEAM REQUIRMENTS

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I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any reward. Where other sources of information have been used, they have been acknowledged.

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ABSTRACT

Fossil fuel is the main environmental source of energy. In the last four decades, the global consumption of fossil fuels has doubled, especially in Tehran which has encountered a pollution crisis. As a consequence there has been a rapid increase in carbon dioxide levels in the atmosphere, leading to climate change. It is imperative that overall energy consumption is reduced. This can be achieved mainly by reducing energy consumption within domestic buildings, through low-carbon houses. The latter can be attained through sustainable design, which consists of low impact on environment with a durable design and energy efficiency on passive heating and cooling. These processes are influenced by various factors. These are thermal mass, air tightness of the building envelope, the transfer rate of heat and orientation. A research over the variables affecting the thermal properties of a building like insulation and shading can be a good help to reduce energy consumption.

Keywords: Sustainability, energy efficiency, thermal performance, insulation, shading

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CHAPTER I

INTRODUCTION

The application of concepts such as sustainability and sustainable development has opened a new field in architecture which is known as sustainable architecture. It is possible to incorporate sustainable architecture into the important movements of our time since the climate change is the greatest challenge faced by the modern humanity. About 45 percent of the worldwide energy consumption and most of the carbonic gas emission belong to the buildings. Finding a technique for decreasing this energy consumption and using various types of renewable energy sources can inhibit an environmental disaster. So the necessity and urgency of developing the concept of sustainable architecture is inevitable, especially in Tehran which is affected by an environmental crisis. Each state, according to its own conditions, has sought solutions for this matter. This study aims to undertake a study, stimulation and analyze of a contemporary building in Tehran and then the orientation of that building to attain a sustainable design according to BREEAM requirements.

To decrease the consumption of energy, thermal variables in a building must be studied which they are affecting the cooling and heating process. Those variables are such as: geographic and climate, orientation of the building, ventilation, glazing and insulation, shading, building materials and building form.

The first chapter gives information about the area which is IRAN/TEHRAN, where the building is situated. The information is about geographical and climate properties of this region, an important factor which it has to be focused on.

The second chapter is about thermal comfort, in that part will be explained the circumstances and situations that the human body is feeling relax, the main goal that in each building has to reach.

The third chapter explains how different variables are affecting the thermal properties of a building.

The fourth chapter is about a simulation and analyzes of the case study building of the insulation and shading and shows how those factors are affecting the thermal properties.

The fifth chapter introduces BREEAM and its thermal requirements, and then the case study building is rated by BREEAM assessment.

The sixth chapter includes the conclusion of the subject. In this part the importance of this research is explained.

1.1. Aim and Scope of the Study

The aim of this study was to analyze the consequences of design elements on thermal conditions in a building situated in IRAN/TEHRAN and to compare it with BREEAM standards. In according to perform this study heating and cooling process has been stimulated in different situation (shading and insulation) with a software (design builder) and some analyzes has been done and then the actual building has been rated by BREEAM assessment method.

The study shows that factors such as insulation and shading are very important and has to be considered while constructing a building, these factors affects directly over the energy consumption of a building. In a sustainable purpose without these elements a building is incomplete.

In this study some questions are essential to pass through to reach some goals: 1- what is the main feature of sustainability in Iran’s conventional architecture? 2- What sorts of sustainability related considerations according to BREEAM criteria have been taken into account by the architects and building designers? 3- How would be a perfect sustainable architectural design for Iran environmental situation?

1.2. Research Methodology

The present study investigates and compares the contemporary work of architecture in Tehran through a selection of a case study. To this end, the compound methodologies and the library research were respectively employed for acquiring the result and collecting the necessary data. One specific house with contemporary architecture (which the plans and photos were collected from an architect Mr. Amir Bazuvarz in Tehran) is stimulated with the software design builder and energy plus which they are approved by BREEAM and analyzed due to obtain a comparison of the thermal mass transfer and energy consumption in different cases.

In the final stage of the study, all data were collected from the stimulations and were arranged in graphics and tables. According to those data analyzes, evaluation and conclusion were made.

1.3. Summary

This thesis is about a study over a subject house in Tehran, which in different situation it has been simulated (according to insulation and shading) by design builder software which is approved by BREEAM, then the result has been compared and to finish the building has been rated with BREEAM. The purpose of this study was to have an idea how to evaluate and develop buildings in Tehran and to decrease energy consumption and CO_2 emission of buildings to face the actual environmental crisis and pollution problems.

CHAPTER II

ENVIRONMENTAL CONDITIONS OF TEHRAN/IRAN

Iran is situated in a high plateau which is situated at latitudes in between of 25-40 degrees in the northern hemisphere of the Earth with an arid climate. The dry and hot deserts of Saudi Arabia and northern Africa extend from the Atlantic Ocean in western Africa across Iran and to finish it ends in Turkmenistan and Afghanistan.

After lots of researches, Iranian environmental professors (like Dr. Hassan Ganji) have announced four different climatic regions from an architectural view (Lang and Rajabi, 2003):

- Hot-dry climate (central plateau of Iran)
- Mountainous cold climate (mountainous parts of western Iran)
- Humid and moderate climate (southern borders of the Caspian Sea)
- Hot-humid climate (northern borders of the Persian Gulf and the Oman Sea)

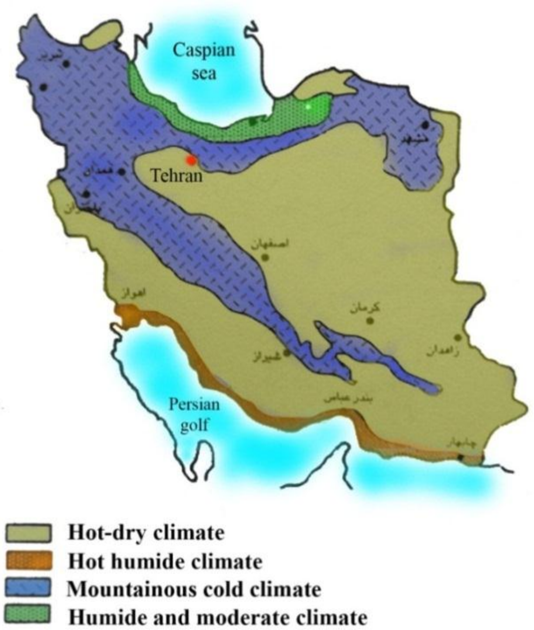


Figure 1: Iran climatic divisions (Akhtar Kavan, 2010)

To be more precise, Iran climatic characteristics can be divided in two different seasons summer and winter, which it was analyze and measured in twenty years of research with 170 different weather stations in Iran. These researches reached to a conclusion with 4 different climates in summer time and five different climates in winter time as shown in the following images and table:

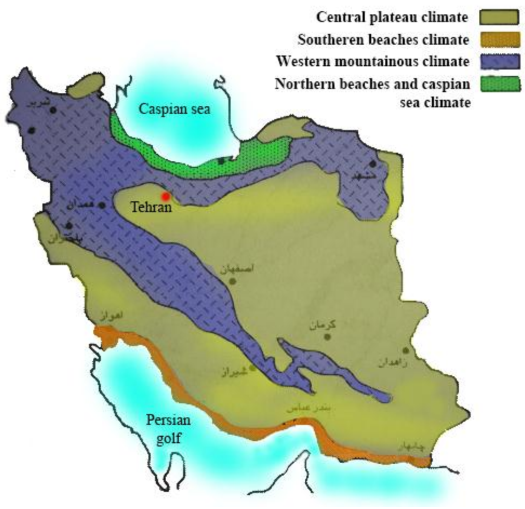


Figure 2: Summer climate division (Akhtar Kavan, 2010)

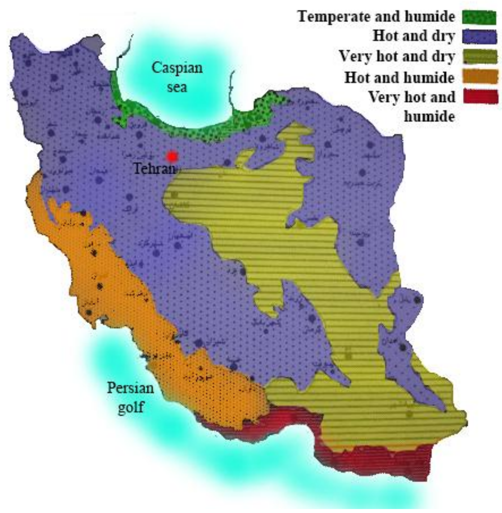


Figure 3: Winter climate division

Table 1: The 9 different types of Iran climate (Akhtar Kavan, 2010)

Type of climate	Characteristics	Average temperature in summer	Average temperature in winter	Examples
1	hot summer and very humide, without winter season	35 to 40	10 to 15	Jask, Chabahar, Bandar lengeh, Bandar abbas,
2	Very hot summer and humide, without winter season	45 to 50	5 to 10	Abadan, Ahvaz
3	Hot and humide summer, moderate winter	35 to 40	0 to 5	Kazerun
4	Very hot summer, without winter season	40 to 45	5 to 10	Iranshahr
5	Very hot and dry summer, moderate winter	40 to 45	0 to 5	Tabas, Kashan
6	Humide and moderate summer, with moderate winter	25 to 30	0 to 5	Babolsar, Bandar anzali, Rasht, Gorgan
7	Hot and dry summer, with moderate winter	35 to 40	0 to 5	Zabol, Zahedan, Fesa, Bam
8	Hot and dry summer, with cold winter	35 to 40	0 to -5	Teharan, Shiraz, Mashad
9	Hot and dry summer, very cold winter	35 to 40	-10 to -5	Arak, Hamedan, Zanjan, Tabriz

After the table 1, it can be considered that Tehran is situated in a hot dry climate with cold winter which its temperature in summer can reach 40 degrees and in winter -5 degrees.

The various properties of the four categories of Iran climate have had helpful effects on the building materials and the architectural designs used in regional cities. Generally, the persons living in these areas had the possibility to devise acceptable approaches for dealing with the adverse weather conditions. They have used and developed useful manners over many years in the goal to obtain an architectural design compatible with the climate in each area. These solutions get under control the annoying situations of the extreme climatic conditions and even obtained some useful and comfortable environmental situations that the people enjoy.

Mostly, logical structures in this area have been mixed with the environment and as a result, the traditional buildings in Iran, different as usual modern buildings, are favorable with and have a favorable connection to the natural environment. (Akhtar Kavan, 2010)

1.1. The Geographical Situation of Tehran

Tehran is the biggest city in scale of population and area and it is the capital of Iran, which is one the biggest city of western Asia and the 21st biggest city in the world, the province of Tehran covers 18,956 square kilometers. Tehran is situated in the north central part of the country and in the southern part of the Elburz Chain Mountains and 115 kilometers far from the Caspian Sea at longitude 51,23 E and latitude 35,41 N.

The borders of Tehran stretch south to the city of Share ray and the flatlands of the city of Varamin, and north to the Elburz Mountains. Damavand, the highest summit of the Alborz Mountains is located northeast of Tehran. On a clear and sunny day, the snowy peak of Damavand (the highest mountain of Iran) can be seen from almost everywhere in Tehran. The east and west borders of Tehran stretch up to the city of Damavand and to the city of Karaj, respectively.

Tehran building style can be divided in two parts, European and modern style in the north of Tehran then the old type buildings and mud houses which it has kept the historical style in the southern section of Tehran.

The density of population in Tehran province after the census of October 1996 was nearly 11.176 million that makes about 84.15% are resident in urban areas and 15.85% are resident in the rural area (Shahram Khosravi, 2008).

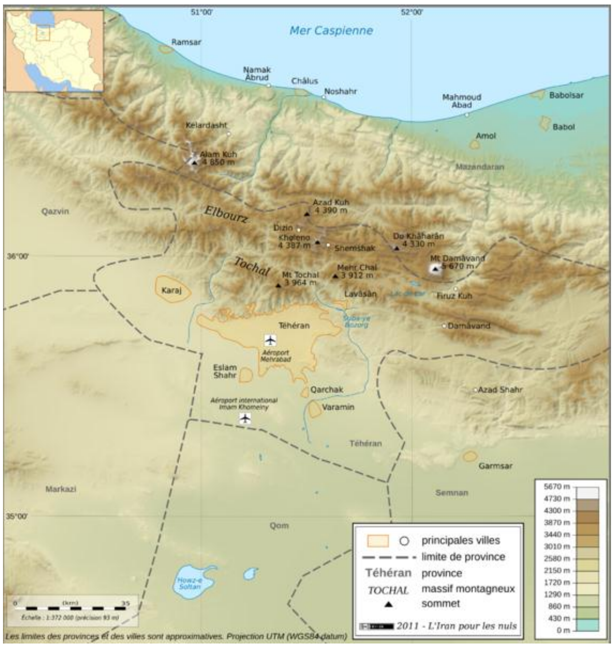


Figure 4. Tehran topographic map (http://en.wikipedia.org/wiki/File:Carte_Topo_Region_Teheran.png)

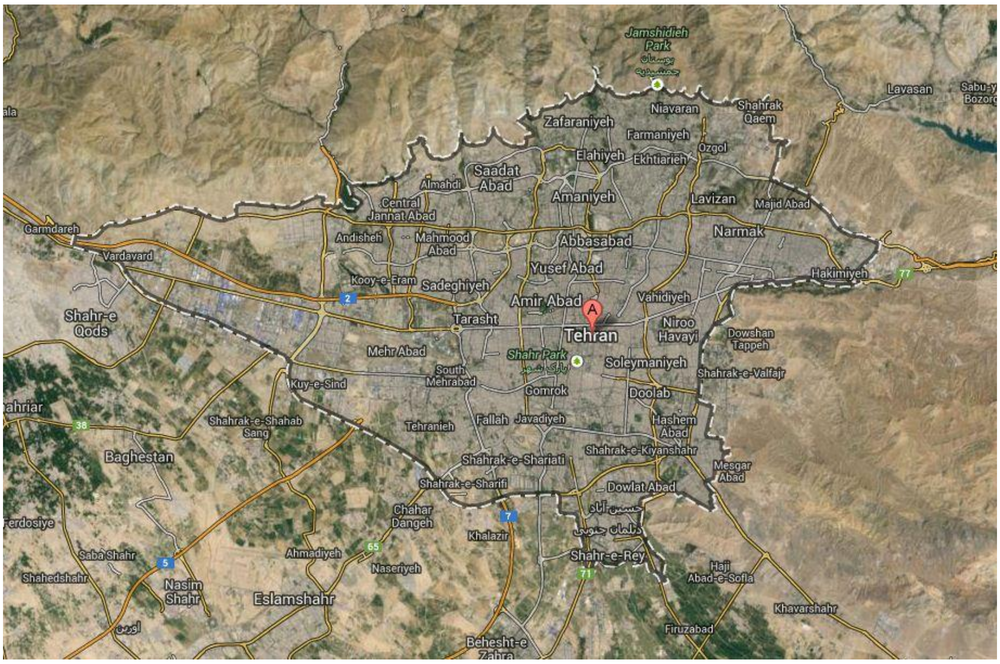


Figure 5. Tehran borders (https://maps.google.com/maps)

1.2. Climate

Tehran appropriates a semi-arid, continental climate. The northern regions can be defined as a Mediterranean climate near to humid continental. Tehran's climate is mostly known with its geographical situation, by the high rise Alborz Mountains situated in the north side and the central desert situated in the south. It can be normally defined as favorable weather in the spring and autumn, dry and warm in the summer, and cold in winter is cold.

The city is waste with various differentiations in height in between different neighborhoods; the climate is generally cooler in the northern part than in the flat southern part of Tehran. The remarkable 17.3 km Valie asr street begins from the Tehran's train station with, 1,117 m height up of the sea level, in the south part of the city to the Tajrish square, 1,612 m height up of sea level, in the north. Generally, the height can also reach up to 1,900 m at the ending of the Velenjak Street in the northern part of Tehran.

The summer time normally is dry and warm with a small amount of raining, but relative humidity is usually low and night times are cold. General sunlight annual precipitation happens from the end of autumn to middle of spring, but no particular month is humid. The warmest month is July, with a mean minimum temperature 26 °C and mean maximum temperature 36 °C, and the coldest month is January, with a mean minimum temperature −1 °C and mean maximum temperature 8 °C.

Tehran's weather is influenced by the monsoon so it is very dry in summer time, and the fall and spring time are generally lush, with the main precipitation happening at this time. (http://en.wikipedia.org/wiki/Tehran)

Table 2: Climate data for Tehran, Mehrabad station
(http://en.wikipedia.org/wiki/Tehran#cite_note-chaharmahalmet.ir-22)

Climate data for Tehran-MEHRABAD AIRPORT, Altitude: 1190.8 M - from 1988-2005													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	19.6 (67.3)	23.0 (73.4)	28.0 (82.4)	32.4 (90.3)	37.0 (98.6)	41.0 (105.8)	43.0 (109.4)	42.0 (107.6)	38.0 (100.4)	33.4 (92.1)	26.0 (78.8)	21.0 (69.8)	43 (109.4)
Average high °C (°F)	7.9 (46.2)	10.4 (50.7)	15.4 (59.7)	22.1 (71.8)	27.9 (82.2)	33.9 (93)	36.6 (97.9)	35.6 (96.1)	31.6 (88.9)	24.4 (75.9)	16.2 (61.2)	10.0 (50)	22.67 (72.8)
Average low °C (°F)	−0.4 (31.3)	1.2 (34.2)	5.4 (41.7)	11.2 (52.2)	16.1 (61)	20.9 (69.6)	23.9 (75)	23.3 (73.9)	19.3 (66.7)	13.3 (55.9)	6.7 (44.1)	1.7 (35.1)	11.88 (53.39)
Record low °C (°F)	−15.0 (5)	−13.0 (8.6)	−8.0 (17.6)	−4.0 (24.8)	2.4 (36.3)	5.0 (41)	14.0 (57.2)	13.0 (55.4)	9.0 (48.2)	2.8 (37)	−7.0 (19.4)	−13.0 (8.6)	−15 (5)
Precipitation mm (inches)	34.6 (1.362)	32.2 (1.268)	40.8 (1.606)	30.7 (1.209)	15.4 (0.606)	3.0 (0.118)	2.3 (0.091)	1.8 (0.071)	1.1 (0.043)	10.9 (0.429)	26.0 (1.024)	34.0 (1.339)	232.8 (9.166)
Avg. rainy days	9.1	8.4	10.9	10.7	8.8	3.0	2.1	1.3	1.0	5.2	7.1	8.8	76.4
Avg. snowy days	5.1	2.9	1.1	0.1	0	0	0	0	0	0	0.4	2.7	12.3
% humidity	64	56	48	41	33	25	26	26	27	36	49	62	41.1
Mean monthly sunshine hours	173.6	182.8	205.5	222.8	289.5	345.1	349.5	340.3	304.0	256.1	194.9	166.1	3,030.2

Table 3: Climate data for Tehran, Tehran-Shomal station
(http://en.wikipedia.org/wiki/Tehran#cite_note-chaharmahalmet.ir-22)

Climate data for Tehran-shomal (north of tehran), Altitude: 1548.2 M from: 1988-2005													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	16.4 (61.5)	19.0 (66.2)	23.8 (74.8)	33.6 (92.5)	33.6 (92.5)	37.8 (100)	39.8 (103.6)	39.4 (102.9)	35.6 (96.1)	31.2 (88.2)	23.0 (73.4)	19.0 (66.2)	39.8 (103.6)
Average high °C (°F)	6.1 (43)	8.1 (46.6)	12.9 (55.2)	19.8 (67.6)	25.0 (77)	31.2 (88.2)	33.9 (93)	33.5 (92.3)	29.3 (84.7)	22.4 (72.3)	14.3 (57.7)	8.6 (47.5)	20.43 (68.76)
Average low °C (°F)	−1.5 (29.3)	−0.2 (31.6)	4.0 (39.2)	9.8 (49.6)	14 (57)	19.6 (67.3)	22.6 (72.7)	21.9 (71.4)	17.5 (63.5)	11.6 (52.9)	5.4 (41.7)	1.0 (33.8)	10.48 (50.83)
Record low °C (°F)	−11.4 (11.5)	−11.0 (12.2)	−8.0 (17.6)	−1.6 (29.1)	3.0 (37.4)	12.0 (53.6)	15.4 (59.7)	13.5 (56.3)	8.8 (47.8)	2.6 (36.7)	−5.2 (22.6)	−9.6 (14.7)	−11.4 (11.5)
Precipitation mm (inches)	63.1 (2.484)	66.5 (2.618)	83.3 (3.28)	50.1 (1.972)	27.1 (1.067)	4.0 (0.157)	4.2 (0.165)	3.2 (0.126)	3.4 (0.134)	16.5 (0.65)	41.3 (1.626)	66.3 (2.61)	429 (16.889)
Avg. rainy days	12.3	10.9	12.3	10.0	8.9	3.3	3.4	1.6	1.3	5.8	8.6	10.7	89.1
Avg. snowy days	8.9	6.6	2.5	0.1	0.1	0	0	0	0	0	0.6	4.9	23.7
% humidity	67	59	53	44	39	30	31	31	33	44	57	66	46.2
Mean monthly sunshine hours	137.2	151.1	186.0	219.1	279.8	328.7	336.6	336.8	300.5	246.8	169.4	134.1	2,826.1

Generally, Tehran is mostly hot and dry in summer time and cold and dry in winter time, the rain and humidity is very low because vegetation is less abundant in this area. In this climate in effect of water efficiency and being far from water storages trees, wood and any kind of vegetation is rare. The differences between day and night temperature is high and the lake of clouds, rain, humidity and being far from the sea in this region are the main cause of this variation of temperature. The straight radiation of sun in summer time can reach the ground temperature to 70 degrees and in night time the temperature can decrease to 15 degrees or less. The air temperature in summer time can reach 45 to 50 degrees and in night time 15 to 25 degrees. The straight radiation of sun is high; it is equivalent to 700 till 800 kilo calories per hour in each meter square (Akhtar Kavan, 2010).

1.3. History of Agglomeration and Pollution Issues in Tehran

Tehran was discovered in the 12th century, but it was until 1785 still a small village, when Agha Mohammed Khan, first ruler of the Ghajar dynasty, names it for the capital of Iran. The Ghajars constructed well done gardens and palaces and the Imperial Mosque. The city began its modernization in 1925, when Reza Khan Pahlavi unseat the Ghajars and managed the plan of citywide development. Shah Mohammed Reza Pahlavi, who got the power in 1941, used Iran's oil incomes to support most of building construction in Tehran during the 1970's.

“In some Middle Persian texts, Ray (Ragha) is given as the birthplace of Zoroaster *although modern historians generally place the birth of Zoroaster in Khorasan. In one Persian tradition, the legendary king Manūčehr was born in Damavand.*

During the Sassanid era, Yazdegerd III in 641 issued from Ray his last appeal to the nation before fleeing to Khorasan. The sanctuary of Bibi Shahr-Banu situated in modern Tehran spur and accessible only to women is associated with the memory of the daughter of Yazdagird who, according to tradition, became the wife of al-Husayn b. Ali, the thirdShi'ite Imam. Ray was the fief of the Persian Mihran family and Siyawakhsh the son of Mihran the son of Bahram Chubin resisted the Arab invasion. Because of this resistance, when the Arabs captured Ray, they ordered the town to be destroyed and ordered Farrukhan b. Zaynabi b. Kula to rebuild the town.

The Turkamen laid Ray to waste in 1035 and in 1042, but the city recovered during the Saljuqid and Khwarazmian era. The Mongols laid Ray to complete waste and according to Islamic historians of the era, virtually all of its inhabitants were massacared. The city is mentioned in later Safavid chronicles as an unimportant city.

The origin of the name Tehran is unknown. Tehran was well known as a village in the 9th century, but was less well-known than the city of Rhages (Ray) which was flourishing nearby in the early era. Najm al-Din Razi known as Dayya gives the population of Ray as 500,000 before the Mongol invasion. In the 13th century, following the destruction of Ray by Mongols, many of its inhabitants escaped to Tehran. In some sources of the early era, the city is mentioned as "Rhages's Tehran". The city is later mentioned in Hamdollah Mostowfi's Nuz'hat al-Qulub (written in 1961) as a famous village.

In the 20th century, Tehran faced a large migration of people from all around Iran. Today, the city contains a mix of various ethnic and religious minorities, and is filled with many historic mosques, churches, synagogues and Zoroastrian fire temples. Most Iranian industries are headquartered in Tehran. The industries include the manufacturing of automobiles, electrical equipment, military weaponry, textiles, sugar and chemical products. It is also a leading center for the sale of carpets” (Hamidpour, 2010).

Figure 6: Tehran bazaar (http://en.tehran.ir/Default.aspx?tabid=96)

The Tehran agglomeration is growing rapidly northward. As well as west and southeast, to the north, residential development overwhelms former villages on the foothills of the Elburz Mountains. The large houses and apartment blocks of the new suburbs are home to many of Tehran's wealthier citizens. Commuters drive from the suburbs into the city center to work, adding to the capital's chronic traffic problems. To the west of the capital, cheaper housing and industrial development has spread toward Mehrabad Airport and beyond, effectively linking Tehran with its large satellite city, Karaj. South and east of Tehran the urban growth of the city has absorbed several towns.

At the 1996 census, 6.7 million people lived within the boundaries of Tehran city and the population of the metropolitan area exceeded 8.5 million. Later estimates suggest a population of more than 10 million for the urban area. To stem the city's rapid growth, the Iranian government plans to decentralize some government facilities to major regional centers. The city had only 1 million inhabitants in 1950 when a building boom began, fueled in part by the nation's oil wealth. People from country districts gathered to Tehran in search of employment. Rapid urban expansion in the 1980s created many problems. Development has been uneven and provision of affordable housing, water supplies and leisure and transportation facilities in the metropolis has underdeveloped (Cavendish, 2007).

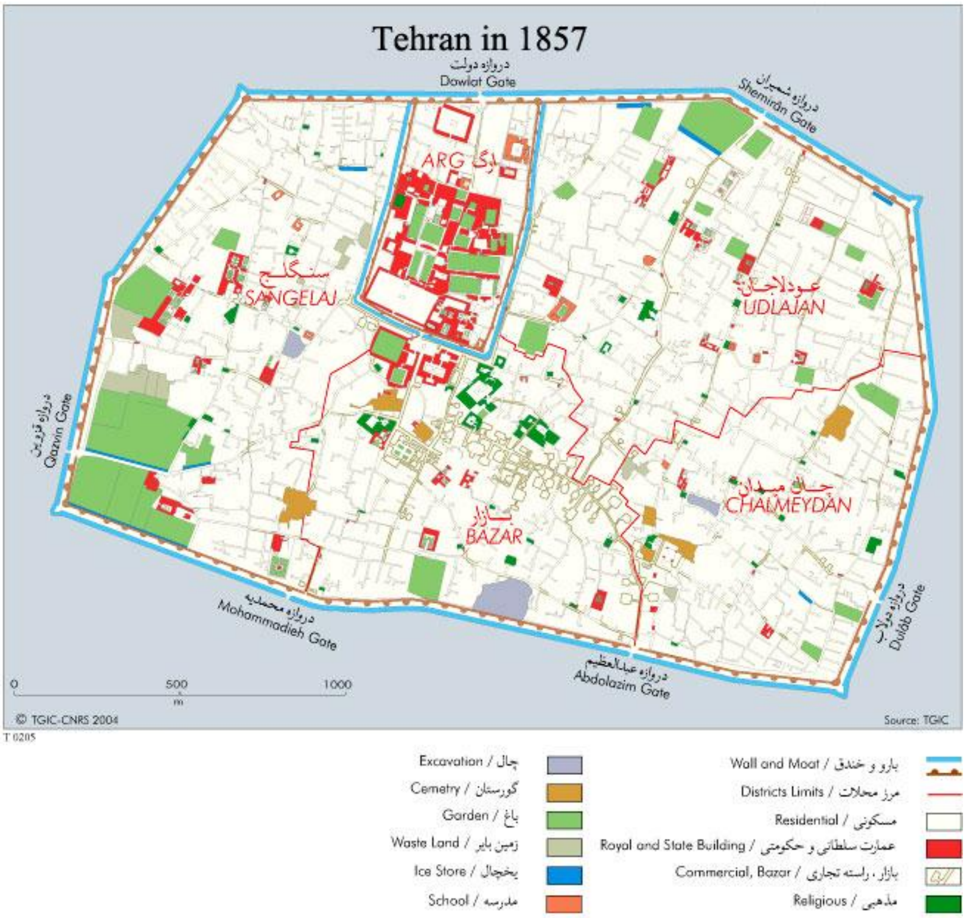


Figure 7: Tehran map in 1857 (http://en.tehran.ir/Default.aspx?tabid=96)

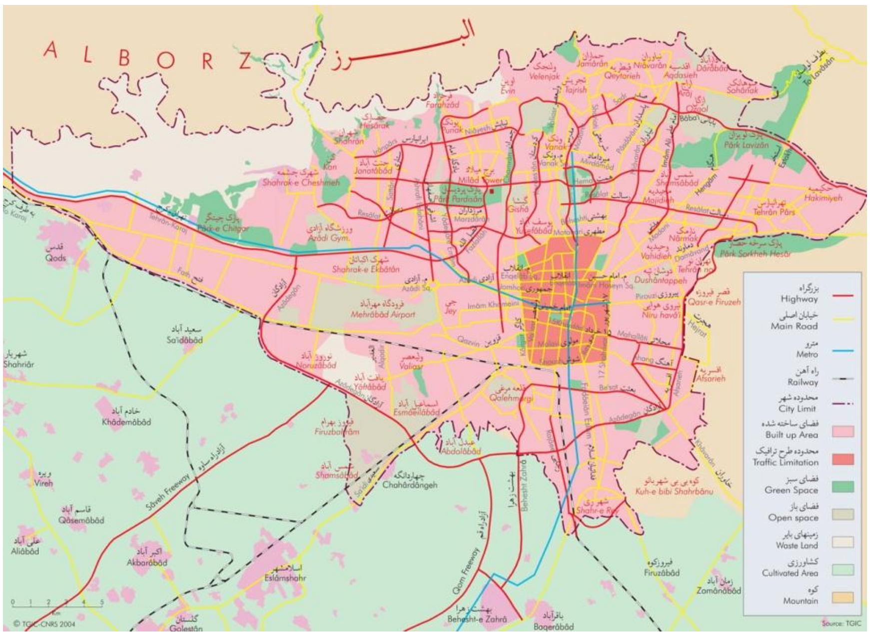


Figure 8: Tehran map today (http://en.tehran.ir/Default.aspx?tabid=99)

1.4 Environmental Crisis in Iran

Iran environmental issues include, mostly in urban areas, vehicle pollutions, industrial effluents and refinery operations that caused the actual bad air quality. Mostly cars are using gas containing lead and bad quality equipment with high emission. Tehran is known as one cities with high pollution in the world. Generally, cars and buses working on natural gas are managed to take the place of the actual public transportation fleet in the future. However, the price of energy is kept unreasonable low in Iran by the government heavy subsidies, as result highly irresponsible and polluting energy use patterns. Vehicle inspection, traffic management, electronic government and general use of electric bicycles are planned to be known as kind of the solution for the pollution problem.

The growing phenomena of breathing illnesses affected the city community of Arak and Tehran, southwest of the capital of Iran, to organize air pollution control plans. These plans goals are to manage and decrease the high level of dangerous chemicals emission into the environment.

Figure 9: Iranian fire altar (http://en.wikipedia.org/wiki/File:Iranian_Fire_altar.jpg)

Much of Iran's regions suffer from overgrazing, deforestation and desertification. Urban and industrial wastewater runoff has polluted coastal waters and rivers and contaminated potable water provisions. Animals and wetlands of fresh water are highly getting infected as agriculture and industry expand, and chemical and oil pollutions had already touched the sea life in the Caspian Sea and Persian Gulf. Iran claims that the world hurry to improve gas and oil supply in the Caspian Sea introduces that area with an original program for environmental approaches. However an organization of Environment has lunched since 1971, Iran could not still approach goals of sustainable development in the aim of some short term economic purposes which have taken the priority.

The World Bank assessed losses imposed on Iran's economy caused the deaths made by air pollution at $640 million or 0.57 percent of GDP (Gross domestic product). Illnesses due to air pollution are resulting losses considered at $260 million per year or 0.23 percent of the GDP on Iran's economy. A research made by the United Nations Environment program rated Iran at 117th place between 133 countries in terms of environmental indexes. (http://en.wikipedia.org/wiki/Environmental_issues_in_Iran)

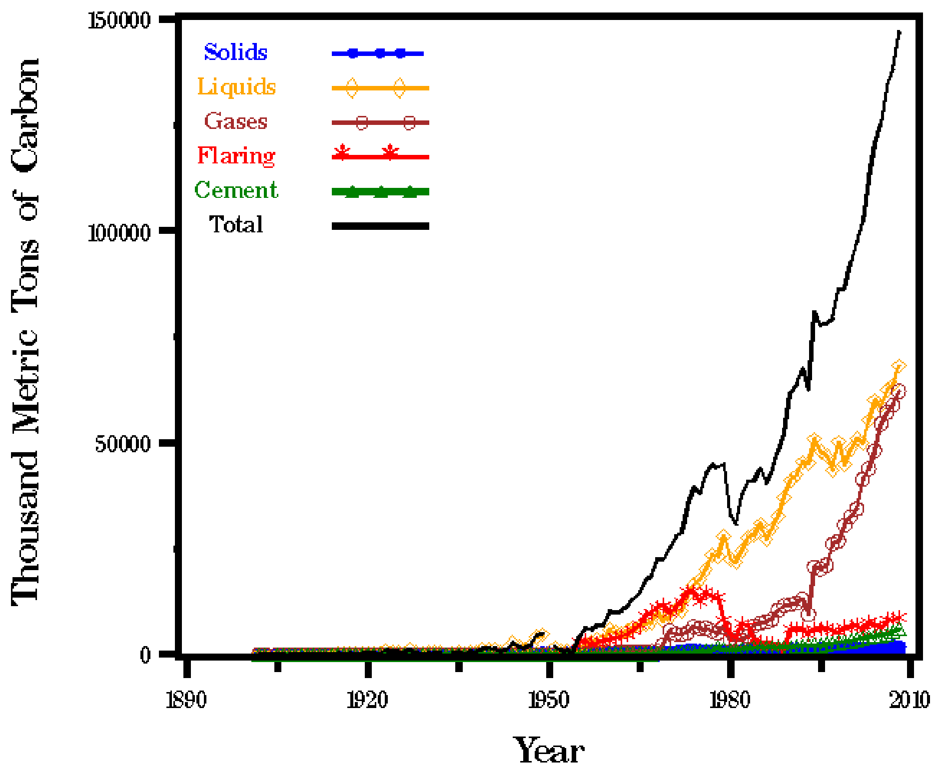


Figure 10: Iran CO2 emission (http://cdiac.ornl.gov/trends/emis/ira.html)

1.4.1 Tehran Pollution

Tehran has serve air pollution problems, primarily due to its 280 percent increase in energy consumption between 1980 and 1998 (EIA 2000). Most energy consumed has been gasoline, which inexpensive because oil is domestic product of Iran. Vehicles are estimated to cause 75 to 80 percent of air pollution in Tehran. About one quarter of Tehran's 2 million vehicles are at least 20 years old and do not have catalytic converters. Many vehicles run on leaded gasoline, others have leaky engines, and still others emit clouds of smoke. The road infrastructure in Tehran was not designed for the number of vehicles currently in the city. Pollution is exacerbated by the fact that the city is bounded by the mountains in the north, which slow the winds, particularly when a large scale subsidence inversion is present.

Smog events in Tehran have forced closures of elementary school and the city center. They have also forced residents to wear face masks when walking outside. Longer term measures taken in Tehran include the requirement that only vehicles with odd or even license plates can enter the city on a given day. In December 1999, the mayor of Tehran announced plans to phase out old automobiles, a measure that was expected to reduce pollution by 16 percent (Jacobson, 2002).

Figure 11: Tehran smog pollution (http://www.presstv.ir/detail/154105.html)

CHAPTER III

THERMAL COMFORT

Thermal comfort is the feeling and condition in which the human body appears to be satisfied by its thermal environment and this is assessed by a subjective evaluation. The goal is to obtain a standard of thermal comfort for a people living inside a building or in some close areas; this important goal can be achieved by the design of an engineer in heating, ventilation and air conditioning.

The application of the notion energy efficient building is possible when the persons living in the close areas are comfortable, if they are not in a such situation then the use of other systems to heat and cool the area will be necessary, systems such as window-mounted air conditioners or heaters that are actually much less energy efficient than usual ventilation, heating and air conditioning mechanisms. Thermal neutrality is obtained when the heat generated by a person body system is allowed to dissipate, reserving thermal maintenance with the inner environment. It is hard to measure the thermal comfort because it is very subjective. It is in dependence on the air temperature, air speeds, radiant temperature, humidity, activity rates, and clothing levels. Also, human body characteristic and physiology state are different from each other so a precise thermal comfort value can't be defined.

A colder situation will be nice when the human body is warmer than normal situation, but unwell when the corps is colder than usual. Another property of the human skin is that the temperature of it is not the same in the whole body. A variation is seen in different places of the body which is in relation with the differentiation in blood flow and the amount of fat containing in different parts. The quality of clothing insulation has also a special effect on the degree and distribution of skin temperature. The time is in a relation with the sensation of any special part of the skin and also location and clothing and the temperature of inner environment is important. (Martinez, 1995)

Thermal comfort is defined too by ASHARE standard, according as "*That condition of mind which expresses satisfaction with the thermal environment*". Also, the situation in which the majority of persons body is in a rang that climatic conditions of that area is in a way that nobody is in a thermal discomfort or is not feeling hot or cold can be defined as the thermal zone. In that situation favorable thermal comfort is brought (Gallo et al, 1998).

2.1. Metabolic Activity

The human body has different metabolic rates that can be affected by environment conditions and the activity level. The ASHRAE definition of metabolic rate is the range of chemical energy which transforms into mechanical activity and heat by metabolic activities inside the human body; it is normally written in notions of unit area of the total organism surface. Metabolic rate is known with met unit that is expressed as follows:

1 met = 58.2 W/m^2 (18.4 $Btu/h{\cdot}ft^2$), which is same as the production of energy per unit surface area of a normal body resting. The surface area of a normal body is 1.8 m^2.

ASHRAE Standard has produced a table that met rates are corresponding to different activities. The values which are used mostly, are 0.7 met for complete rest, 1.0 met for a normal resting position, 1.2 to 1.4 met for light activities standing, 2.0 met or upper for activities that need activity, walking, carrying heavy loads or working mechanism. For alternative activities, the standard states that are allowed to use a time weighted average metabolic rate while persons are performing activities that are various on a specific part of time equal to one hour or lower. If more time is needed then other metabolic rates must be calculated.

Considering metabolic rates is hard, and for ranges more than 2 or 3 met, the accuracy is low especially if there are different methods of performing those activities. That’s the reason that the Standard can’t be provided for activities with a general range more than 2 met. The amount of Met used to be defined much precisely than the ones in the tables, by the use of an experimental equation that is taking into account the level of carbon dioxide emission and respiratory oxygen consumption. Another physiological even less precise way is to measure the heart rate, until there is a relation with the heart rate and the production of oxygen.

The use of drinks and food can have an effect over the metabolic rates, in an indirectly effect thermal preferences. These effects are in relation with the amount and type of food and drink that has been used. The shape of the body is one of the factors which affecting the thermal comfort. Heat dissipation is in depending of the surface of human body area. A skinny and tall human has more surface-to-volume ratio, so it can dissipate easier the heat, and higher temperatures could also be tolerated more than a human with a curvy shape of body (Szokolay, 2010).

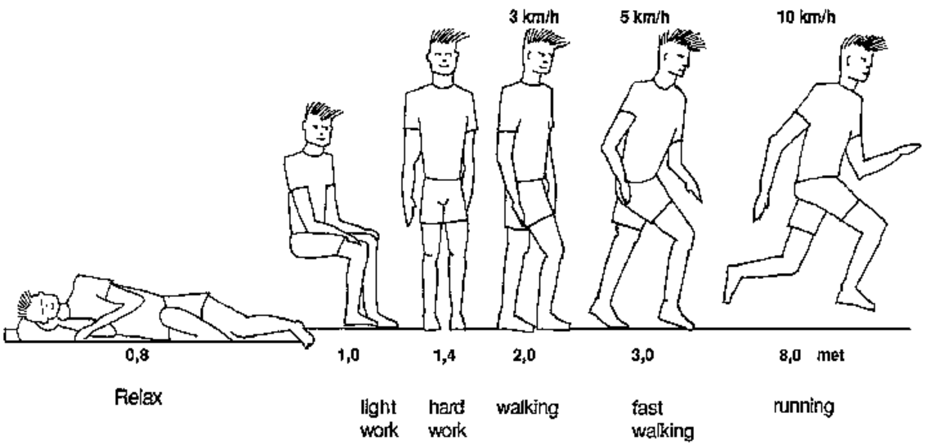


Figure 12: Metabolic rate of different activities (Gut and Ackerknecht, 1993)

Table 4: Metabolic rate at different typical activities (Bradshaw, 1993)

Activity	Metabolic Rate in Met Units[a]	Activity	Metabolic Rate in Met Units[a]
Resting		Miscellaneous Work	
Sleeping	0.7	Watch-repairing, seated	1.1
Reclining	0.8	Lifting/packing	1.2 to 2.4
Seated, reading	0.9	Garage work (e.g., replacing tires, raising cars by jack)	2.2 to 3.0
Office Work		Vehicle Driving	
Seated, writing	1.0	Car	1.5
Seated, typing or talking	1.2 to 1.4	Motorcycle	2.0
Seated, filing	1.2	Heavy vehicle	3.2
Standing, talking	1.2	Aircraft flying, routine	1.4
Drafting	1.1 to 1.3	Instrument landing	1.8
Miscellaneous office work	1.1 to 1.3	Combat flying	2.4
Standing, filing	1.4	Leisure Activities	
Walking (on Level Ground)		Stream fishing	1.2 to 2.0
2 mph (0.89 m/s)	2.0	Golf, swinging and walking	1.4 to 2.6
3 mph (1.34 m/s)	2.6	Golf, swinging and with golf cart	1.4 to 1.8
4 mph (1.79 m/s)	3.8	Dancing	2.4 to 4.4
Domestic Work		Calisthenics exercise	3.0 to 4.0
Shopping	1.4 to 1.8	Tennis, singles	3.6 to 4.6
Cooking	1.6 to 2.0	Squash, singles	5.0 to 7.2
House cleaning	2.0 to 3.4	Basketball, half court	5.0 to 7.6
Washing by hand and ironing	2.0 to 3.6	Wrestling, competitive or intensive	7.0 to 8.7
Carpentry			
Machine sawing, table	1.8 to 2.2		
Sawing by hand	4.0 to 4.8		
Planing by hand	5.6 to 6.4		

2.2. Clothing

The quantity of layers worn by a human acting as thermal insulation can have a fundamental effect on thermal comfort, with its affects over the thermal balance and also the heat loss. These different layers which are acting as insulation clothing is prohibiting the loss of heat and it is helping to let a person being warm or even keep him overheated. Normally, as much as the layers get thicker, the insulation ability gets higher. It is in depend of the material used in the clothing and the ability of clothing insulation can decrease according to relative humidity and air flow.

1 clo is equal to 0.155 $m^2 \cdot K/W$ (0.88 $°F \cdot ft^2 \cdot h/Btu$) which corresponds to trousers, a long sleeved shirt, and a jacket.

Table 5: Clo values for individual items of clothing (Bradshaw, 1993)

Men		Women	
Clothing	clo	Clothing	clo
Underwear		Underwear	
Sleeveless	0.06	Girdle	0.04
T-shirt	0.09	Bra and panties	0.05
Briefs	0.05	Half slip	0.13
Long underwear, upper	0.10	Full slip	0.19
Long underwear, lower	0.10	Long underwear, upper	0.10
		Long underwear, lower	0.10
Shirt		Blouse	
Light, short sleeve	0.14	Light, long sleeve	0.20
long sleeve	0.22	Heavy, long sleeve	0.29
Heavy, short sleeve	0.25	Dress, light	0.22
long sleeve	0.29	Dress, heavy	0.70
(Plus 5% for tie or turtleneck)			
Vest, light	0.15	Skirt, light	0.10
Vest, heavy	0.29	Skirt, heavy	0.22
Trousers, light	0.26	Slacks, light	0.10
Trousers, heavy	0.32	Slacks, heavy	0.44
		Sweater	
Sweater, light	0.20	Light, sleeveless	0.17
Sweater, heavy	0.37	Heavy, long sleeve	0.37
Jacket, light	0.22	Jacket, light	0.17
Jacket, heavy	0.49	Jacket, heavy	0.37
Socks		Stockings	
Ankle length, thin	0.03	Any length	0.01
thick	0.04	Panty hose	0.01
Knee high	0.10		
Shoes		Shoes	
Sandals	0.02	Sandals	0.02
Oxfords	0.04	Pumps	0.04
Boots	0.08	Boots	0.08
Hat and overcoat	2.00	Hat and overcoat	2.00

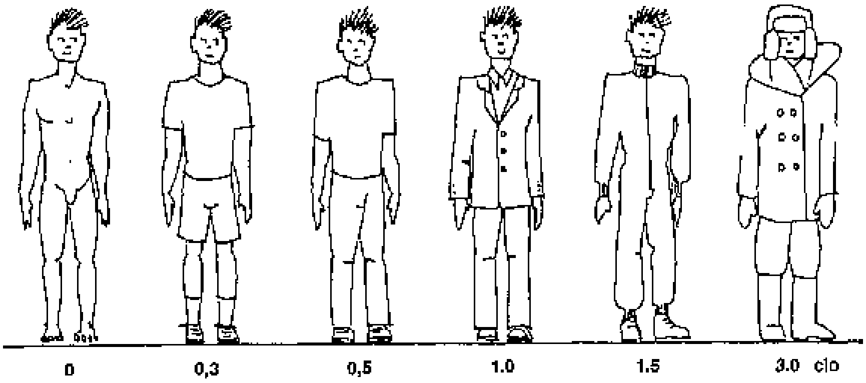


Figure 13: Insulation values of different kind of clothing (Gut and Ackerknecht, 1993)

2.3. Air Temperature

Air temperature is the surrounding air temperature the human being. Air temperature is the measurement of the heat. It is normally used in degrees Celsius (°C) or degrees Fahrenheit (°F). Thermometers are used to measure surrounding air heat. However, the loss or gain of the radiant heat is important too. The impact of hot and cold objects available in an area is the radiant heat and it may not affect over the air temperature.

The mean temperature of the air around the living persons in a building is known as the air temperature, with relation to time and location. As mentioned in ASHRAE standard, the environment average is depending in the waist, ankle and head levels, which are different for standing or seated persons. The temporary average is focused on three minutes intervals by taking in account at least 18 equally spaced points in time. The dry bulb thermometer is used to measure the air temperature and that is the reason it is named too as dry-bulb temperature.

Human body temperature is about 98.6°F (37.0°C) and human beings are known as constant temperature animals, which mean that temperature of the body doesn’t change. If the temperature of the inside begins to have some variations than its normal situation, physical and mental function is disturbed, and if the temperature variation is extreme, very bad physiological functioning or even death will be the result. It happens that the human’s own immunological system begins a body temperature to rise up in order to kill viruses or infections. By the fall of the temperature of the body, more heat is generated by the increase of respiratory activity particularly in muscle tissue automatically. Shivering is the extreme way of this type of human temperature control. (Bradshaw, 1993)

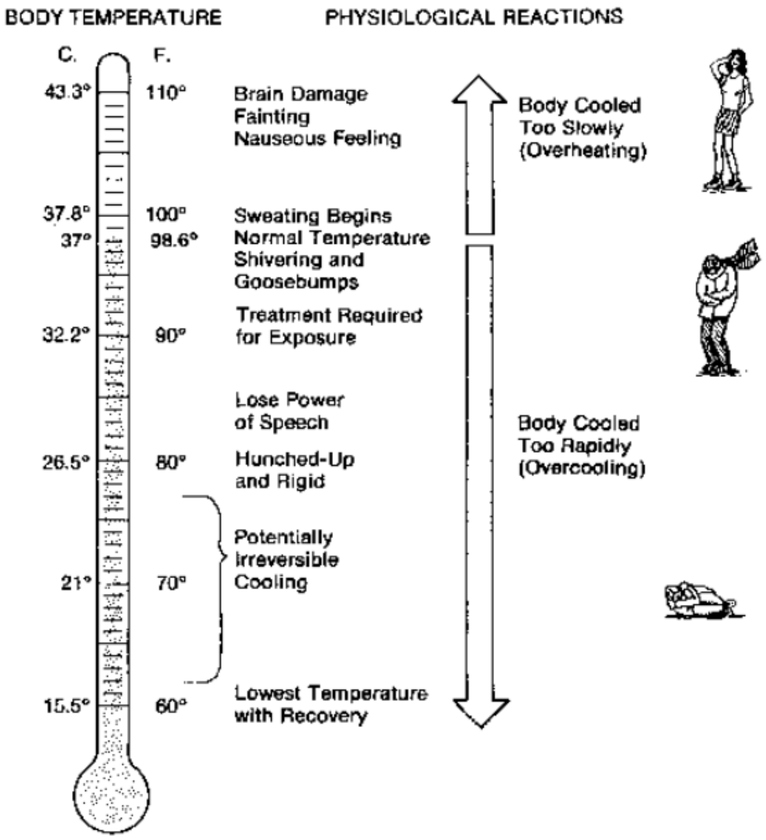


Figure 14: Physiological reactions to body temperature (Bradshaw, 1993)

2.4. Radiant Temperature

The relation between the surface radiant heat transferred value is called radiant temperature, this is depending on the functioning material absorption or emits heat, or its emissivity. Generally, the radiant temperature is depended on the surrounding surfaces temperatures and emissivity or the value of the surface that is experienced by an object. So the radiant temperature that is affecting the human in a close area is in a variation when it is exposed under the sunlight over the time which his body is exposed under the sun.

The mean radiant temperature is known as the constant temperature of a hypothetical closed area in where the radiant heat transfer from the radiant heat transfer in the actual non constant closed area is equal to the human body heat transfer. The mean radiant temperature is a definition coming up to the principle that, when the net exchange of radiant energy between two surfaces is nearly in a relation to their temperature difference multiplied by their ability to absorb and emit heat (emissivity). It is generally the area weighted mean temperature of all the surrounding objects of the person. Any object which is in contact and can be related to thermal comfort in an enclosure is in relation with the influence of both the surfaces temperature and the air temperature in that environment. The mean radiant temperature is defined as this temperature of surface and is controlled by that place performances. Keeping a balance between the mean radiant temperature and the operative temperature will produce a better comfortable area. This is due to a good interior design of the building and with the use of high temperature radiant cooling and low temperature radiant heating (Sassi, 2006).

2.5. Relative Humidity

The proportion of the value of water vapor existing in the air with the value of water vapor that the air is keeping at a special pressure and temperature is called relative humidity. The ability of the sensors situated under the skin that are enough efficient to let the human body feel the heat and cold, is in a way that relative humidity is not detected directly. Sweating is a mechanism which let the heat loss from the body that relies on evaporation from the skin. In an upper relative humidity, where the air has reached to the maximum water vapor that it could keep, in this case evaporation is done, and therefore there is lower heat loss. Also, areas which are very dry (Relative humidity < 20-30%) are known as uncomfortable too because it is effecting on the membranes named mucous. The value of humidity which is accepted inside the building is in the percentage of 30-60% in air conditioned cases, but now a day’s standard permit lower and higher humidity, which depends on the different factors of thermal comfort.

One of the ways to rate the value of relative humidity existing in the air is the use of wet-bulb system and dry-bulb thermometers. However the previous, measures the temperature without considering the moisture (as in weather reports) the latter has a small wet cloth twisted around the bulb at its base, so the measurement is taking in consideration the water evaporation available in the air. The wet bulb value will also be at its minimum somehow lower than the dry bulb one. The differences between both temperatures can be used to find out the relative humidity: the higher the temperature differences between the two thermometers is, the lower will be the range of relative humidity.

Thermal comfort is also affected by the wetness of the skin in different areas of the body. Wetness can be increased by humidity on different areas of the body, bringing the notion of discomfort. It is normally perceived in different body parts and local thermal comfort limits for skin wetness is differed by different parts of the human body. More sensitivity is observed in the extremities of the body to thermal discomfort from wetness than the middle parts of the body. Although wetness is the cause of local thermal discomfort, the thermal comfort of complete body will not be touched by the wetness of other parts.

Some researches have been made over the effects of high air velocity and low relative humidity and were tested on persons after showering. The result obtained from those researches was that low relative humidity brought thermal discomfort just like the sensation of itching and dryness. So it may be better to hold relative humidity ranges upper in a bathroom than into other rooms of the building for better conditions. (Sassi, 2006)

Table 6: Range of comfort in relation to humidity, with light summer clothes or 1 blanket at night (Gut and Ackerknecht, 1993)

Humidity %	**Day temp °C**	**Night temp °C**
0-30	22-30	20-27
30-50	22-29	20-26
50-70	22-28	20-26
70-100	22-27	20-25

2.6. Air Velocity

The rate of air movement in a point, without taking in account the direction can be defined as air velocity (or air speed). This is the average air speed where the human body is faced, by keeping its relation to time and location. The provisional average is equal to the air temperature, while the environmental average is based on the presumption that the body is faced to a uniform air velocity. However, some spaces are provided strongly non uniform air speed fields and as a result the skin losses its heat that cannot be considered constant. So, the designer has to choose the right average results, mostly adding air velocity incident on not wearing clothes person parts that get upper cooling effect and potential for local discomfort (ASHRAE Standard, 2013).

Table 7: Air circulation influences over temperature felt (Gut and Ackerknecht, 1993)

Indoor air speed m/sec	**Mechanical effect**	**Effect on human**	**Cooling effect (C)** Dry skin, Ambient air temperature 15C	20C	25C	30C	moist skin 35C
0.1	Minimum likley in domestic situation	May feel stuffy	0	0	0	0	0
0.25	Smoke from cigarette indicates movment	Movment not noticable except at low air temperature	2	1.3	0.8	0.5	0.7
0.5	Flame from a candle flickers	Feel fresh at comfortable temperatures, but draughty at cool temperatures	4	2.7	1.7	1.0	1.2
1.0	loose papers mabye mooved, equivalent to walking speed	Generally pleasant when warm or comfortable, but causing constant awarness of motion, maximum limit for night comfort	6.7	4.5	2.8	1.7	2.2
1.5	Too fast for desk work with loose papers	Draughty at comfortable temperatures, maximum limit for indoor activities	8.5	5.7	3.5	2.0	3.3
2.0	Equivalent to a fast walking speed	Acceptable only in very hot and humid conditions when no other relief is available	10	6.7	4.0	2.3	4.2

2.7. Comfort Zone

The optimum thermal condition can be considered as the situation in which the lower extra movement is needed to keep the person thermal balance. As much as the activity needed has to be higher, then the climate condition is less comfortable. It is normally hard to reach the maximum comfort and even it's impossible to reach it. The goal of the designer is to build buildings that consider an interior climate near to a comfortable situation, by a certain level in which thermal comfort has been experienced before. This level is known as comfort zone. The factors in which the comfort zone is depending on are: age, physical activity, clothing and health situation. The differentiation between genetics are not important, the geographical emplacement has a role because of habit and of the acclimatization capacity of persons (Gut and Ackerknecht, 1993).

Four important elements, determine the comfort zone: air temperature, radiant temperature, relative humidity, air velocity, that they were explained in the last part. By relating those factors, an illustration of the comfort zone will be obtained as follow:

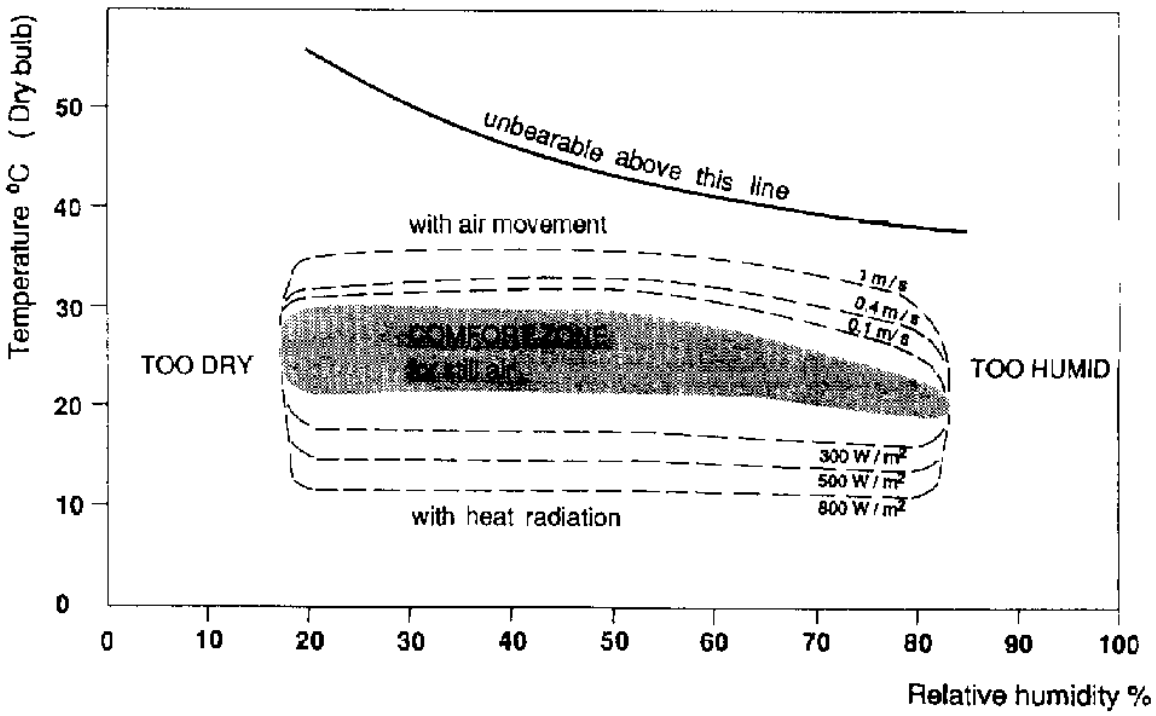


Figure 15: Bioclimatic chart according to the main factors of comfort zone (Gut and Ackerknecht, 1993)

The Figure 15 shows the places which comfort can be felt in a normal climate situation, wearing normal clothing with an activity in a low range. In this situation the indoor air temperature is in the same range than the surface surrounding in that area.

The heat felt by a person or a surface is brought by the effect of temperature and radiation. This is defined as the solar temperature and is mainly composed of three temperatures: solar radiation absorbed by the body or surface, exterior air temperature and long-wave radiant heat exchange with the environment.

Generally there is variation between surface temperature and air temperature. This variation is normally observed mostly when there is differentiation between day and night temperature and also where building different parts is exposed to high solar radiation. The differentiation between surfaces and air temperature normally has not to be more than 10 - 15°C if comfort has to be kept. In some of the situations, upper air temperatures can be restituted by low surface temperatures or contrariwise, as is shown in the following figure:

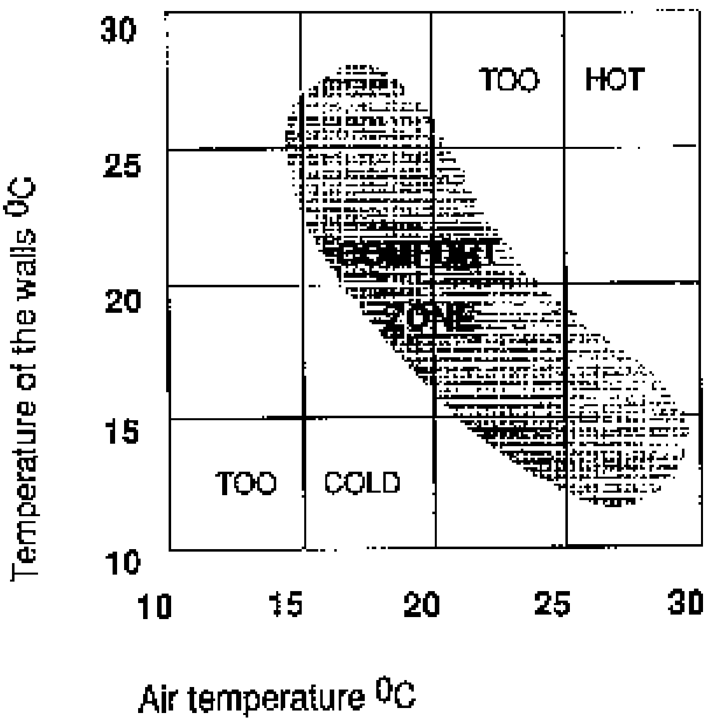


Figure 16: Comfort zone in differing air and surface temperatures (Gut and Ackerknecht, 1993)

The analyzing of those factors with their relations, the comfort zone can be applied by considering parameters as follows:

· The temperature between surface and air has not to be more than 10 - 15°C.

· Ceiling temperature is favorable to be in accordance with the temperature of the room.

· In a high comfortable situation, the temperature has to be lower with less humidity.

· If the air temperature will increase, an air circulation has to be provided.

· The comfortable temperature will change by the change of seasons.

· The temperature that is known as comfortable it is in depends on the degree of acclimatization.

· The clothing worn and the physical activity level temperature is affecting situation known as comfortable.

· With more layers of clothing and higher activity, the tolerable temperature level extends.

· Intense temperature variations, like the situation in air-conditioned buildings, must be avoided.

2.8. Predicted Mean Vote

The Predicted Mean Vote (PMV) is referred to a thermal range that goes from Cold (-3) to Hot (+3), mainly worked on by Fanger and afterwards has been used as an ISO standard. The main information was gathered by using a large number of persons in different situations within a climate chamber and letting them choose a position to the scale in which they would have the best comfort situation.

From the PMV, the Predicted Percentage of Dissatisfied people (PPD) can be known. As PMV goes higher or less from neutral (PMV = 0) in each direction, PPD gets low. The maximum population of persons dissatisfied with their comfort situations is 100% and as it is hard to make everybody happy in a same time, the minimum value even in a situation known as complete comfortable situation is 5%.

The PMV equation for thermal comfort is a permanent state model. It is an experimental equation to predict the average vote of a large amount of persons on a 7 point scale (-3 to +3) of thermal comfort. The equation needs the permanent state heat balance of the human body and produce a relation between the degree of stress or load on the body and the thermal comfort vote (for example: vasoconstriction, sweating and vasodilation) resulting by any process from perfect balance. When the weight gets heavier, more the comfort vote will turn out from the 0 value.

The sectional derivative of the load process is counted by the use of enough persons to enough different situations to complete a curve. PMV is surely the most common used thermal comfort index now days. Mild Thermal Environments, determination of the PMV and PPD indices and specification of the situations in which thermal comfort uses some limitations on PMV as a precise definition of the comfort zone.

The PMV equation is applied just on people being under a long period to permanent conditions at a permanent metabolic rate. Maintenance of energy reaches to the next heat balance equation:

$$H - Ed - Esw - Ere - L = R + C$$

Where:

H = internal heat production

Ed = heat loss due to water vapor diffusion through the skin

Esw = heat loss due to sweating

Ere = latent heat loss due to respiration

L = dry respiration heat loss

R = heat loss by radiation from the surface of a clothed body

C = heat loss by convection from the surface of a clothed body

The equation can be reformulated by replacing each element with a function derivable from basic physics. The whole functions have experimental values with taking in account the convective heat transfer coefficient and the clothing surface temperature which are functions of each other. To resolve the equation, a primary value of clothing temperature is needed, the convective heat transfer coefficient can be then calculated, and then a new clothing temperature computed. This is followed by repetition until both are reaching a reasonable temperature. If there is no thermal balance in the body, the heat equation can be formulated as following:

$$L = H - Ed - Esw - Ere - R - C$$

Where: L is the thermal load on the body.

Define thermal sensation or strain Y as some unknown function of L and metabolic rate. Keeping all variables constant without metabolic rate and air temperature, it uses mean votes from climate chamber experiments to write Y as function of air temperature for different activity ranges. By replacing L for air temperature, determined from the heat balance equation above, evaluate the partial derivative of Y with respect to L at Y=0 and plot the points versus metabolic rate. An exponential curve is fit to the points and integrated with relation to L. L is simply renamed "PMV" and in simplified form will be:

$$PMV = \exp(Met) * L$$

PMV is mentioned to find out thermal sensation votes on a seven point scale (hot 3, warm 2, slightly warm 1, neutral 0, slightly cool -1, cool -2, cold -3) by considering the fact that for any physical situation, Y is the mean vote of all subjects under that condition. The main restriction of the PMV model is the precise limitation of skin temperature and evaporative heat loss to values for comfort and neutral sensation at a specific activity range (INNOVA, 1997).

2.9. Adaptive Comfort

Adaptive comfort model is adding kind of more human comportment to the subject. The fact is accepted as, if variations are done in the thermal environment to bring the discomfort, then the persons will normally change their comportment and change the situation in a way that will bring again the comfort. Those kinds of acts is such as undressing and wearing lighter clothes, opening windows and even reducing activity ranges. The most important effect of such models is to have upper levels of conditions that the designers has to consider it as comfortable, mostly in naturally ventilated buildings where the persons living in a building have a higher range of their thermal environment over control (ASHRAE, 1998).

Table 8: The effect of adaptive behaviors on optimum comfort temperatures (ASHRAE, 1998)

BEHAVIOUR	EFFECT	OFFSET
Jumper/Jacket on or off	Changes Clo by ± 0.35	± 2.2K
Tight fit/Loose fit clothing	Changes Clo by ± 0.26	± 1.7K
Collar and tie on or off	Changes Clo by ± 0.13	± 0.8K
Office chair type	Changes Clo by ± 0.05	± 0.3K
Seated or walking around	Varies Met by ± 0.4	± 3.4K
Stress level	Varies Met by ± 0.3	± 2.6K
Vigour of activity	Varies Met by ± 0.1	± 0.9K
Different postures	Varies Met by ± 10%	± 0.9K
Consume cold drink	Varies Met by -0.12	+ 0.9K
Consume hot drink/food	Varies Met by +0.12	- 0.9K
Operate desk fan	Varies Vel by +2.0m/s	+ 2.8K
Operate ceiling fan	Varies Vel by +1.0m/s	+ 2.2K
Open window	Varies Vel by +0.5m/s	+ 1.1K

CHAPTER IV

VARIABLES AFFECTING THERMAL PERFORMANCES

Generally thermal performances of a building is due to on how good a building is insulated from outside and inside from the external weather conditions in order to keep a comfortable temperature for the resident living inside the specific building. This means to keep the inside temperature of the house higher than external temperature in winter time and keep the inside temperature of the house lower than the external temperature during hot summers. The comfortable range of temperature is mostly from 19 to 22 degrees.

There are different factors which they are affecting the thermal performance of a building, which the main factors are: insulation, the color of the façade, building orientation, building shape, windows, ventilation, shading and the building materials.

The thermal performance is mostly measured with the U-value which is most common; more the U-value is higher more there is energy consumption and the lower amount of U-value shows energy gain and if this value reach to 0 it would prevent any energy to be lost. (http://www.shomera.ie/thermal-performance-in-buildings)

3.1. Color of the Façade

The color of the facade of a building is considered one of its most important features. When the color of the facade is dark, the building absorbs the energy from sunlight and its temperature increases as a result, but when this color is light, the sunlight is reflected and therefore temperature change is minimal. (Vancouver city council, 2009)

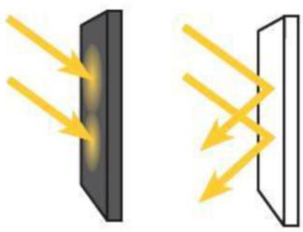


Figure 17: Absorption and reflection of sunlight in dark and light colored facades (Vancouver city council, 2009)

While designing the façade the chosen color has usually on purpose the aesthetic look of the building and to achieve a desirable view, but in the environmental point of view it is very inappropriate to use dark colors with high absorption of solar and diffused radiation. The façade color has influence on façade surface temperature in external and internal walls, temperature of the air in their surroundings and day lighting of the interior.

In a dark colored façade the heat spreads from the heated surface, increases the temperature of the structure and the air in the surrounding space where it releases from external to the internal surface of the wall. Negative consequences of the increased heating of sunlight surfaces of buildings especially in summer time are as following: increased mechanical stress especially in the surface layers of the building envelopes and insulation systems and with the combination with other effects the increased risk of their damage with cracks, increase of the temperature of internal surface of perimeter walls cause warming of interior air with impact to decrease of thermal comfort of the users of the building interiors and possible increase of energy consumption for operation ventilation providing summer temperature stability of the rooms. So the light color is recommended for facades especially for locations with hot summers (Pasek and Bosova, 2014).

3.2. Building Orientation and Location

There are a number of points to consider while determining the orientation of a building. The building orientation must be in count in the early design process of the building. Orientation is measured by the azimuth angle of a surface relative to true north. Well done orientation rotates the building to minimize energy consumption and maximize free energy from the wind and sun. So the best idea will be to locate the places of the building, which are mostly used frequently throughout the morning time in the southern part, and place the areas used mostly at night in the north facing part of the building (in the case of Tehran which the sun light is coming from the south side). So when planning the design, it is better to put areas such as the kitchen (used during the day) in the south side and put areas such as the bedrooms (used mostly at night) in the north side of the building.

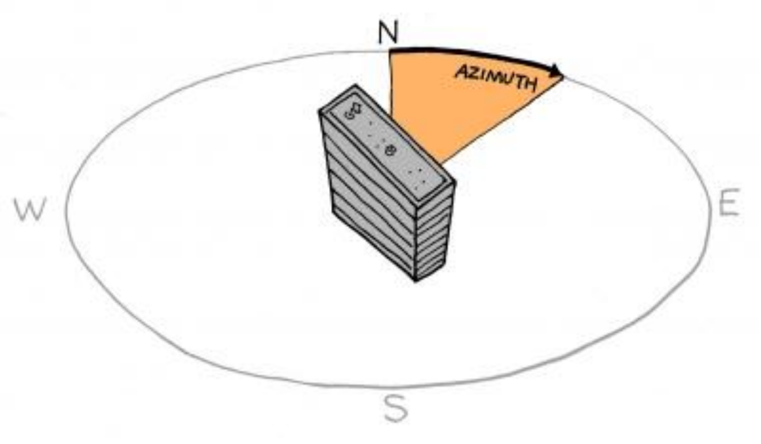


Figure 18: Building orientation measured by its azimuth
(http://sustainabilityworkshop.autodesk.com/buildings/building-orientation)

Well done orientation will also win an advantage of different site situations, such as collecting the rainwater due to dominant winds. It will even help the building to increase the health and vivacity of the surrounding economic and social organizations, by orienting courtyards and playing areas and gardens or other social spaces to connect to street life.

(http://sustainabilityworkshop.autodesk.com/buildings/building-orientation)

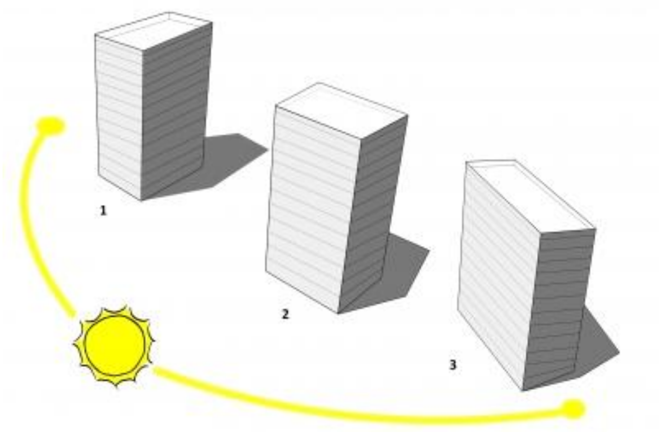


Figure 19: Different building orientation
(http://sustainabilityworkshop.autodesk.com/buildings/building-orientation)

Generally the optimal orientation for buildings is with large side aligned from east to west. But a building with a façade opening to the west is a bad case encountered, which is not profiting the heat gain of sun and the surrounding environment during the day, which let the sun’s rays penetrating to the interior of the building.

The northern façade is least exposed to the sun, so exposure to the sun light will be available only in the early and late hours of summer time. The advantage of rooms opened to this façade is that their illumination is always distributed, making them ideal for buildings such as hospital operating rooms and for school classrooms.

The southern façade is the most exposed to the sun day light, in summer when the sun is high in horizon it can be shade with small over hangs and in winter time when the sun is low in the horizon is penetrating to the building and the heat is nicely used for warming the building. The only disadvantage of the southern façade is that the wind is less blowing from this side in the north hemisphere, but in a way that the airflow can be manipulated and the sun light cannot be, then sun lighting has to be considered first. So spaces which are used mostly in the day time can be located in this part of the building such as living rooms and sitting areas.

The eastern façade is faced to the sun light just while the sun rise so the walls gets colder considerably by evening time, making this facade more appropriate for the bedrooms than the western facades (Fathy, 1986).

3.3. Shape of the Building

The higher the volume of the building will be the more surface area it has to lose, or gain, heat from. Various plan shapes can have more or less wall area for the same plan area. The surface area, volume ratio is very important in keeping heat transfer into and out of a building enclosure. To keep heat or cold the building enclosure has to be designed with a compact form to minimize the efficiency of the building as a heat exchanger.

To maximize the benefits of thermal performances of a building, the designer should keep corners and joints in the building plan to a minimum. A complex design with a high number of joints and corners creates more surface area, which can result in loss of heat and thus reduce efficiency. So less there is surfaces contacting with the external climate, less will be heat transfers. (Roaf, et al. 2001)

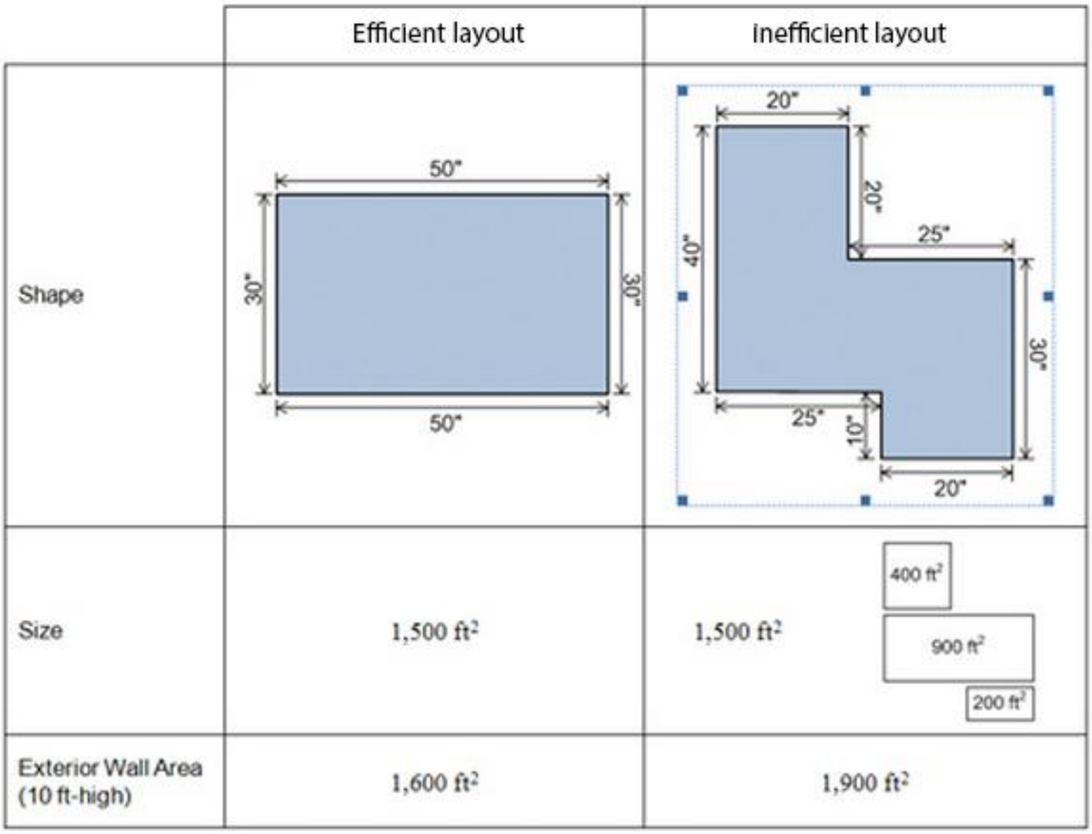


Figure 20: Impacts of joints and corners on efficiency (http://pubs.ext.vt.edu/2908/2908-9019/2908-9019.html)

Another important issue in the building shape is the height. Two story building is considered more preferable than a single one because of a small roof area which decreases heat gain in summer and heat loss in winter. Also, increasing building's height can increase the area of south walls and enhance solar access and heat gain. It's more easily to control solar radiation with vertical surfaces (Vancouver city council, 2009).

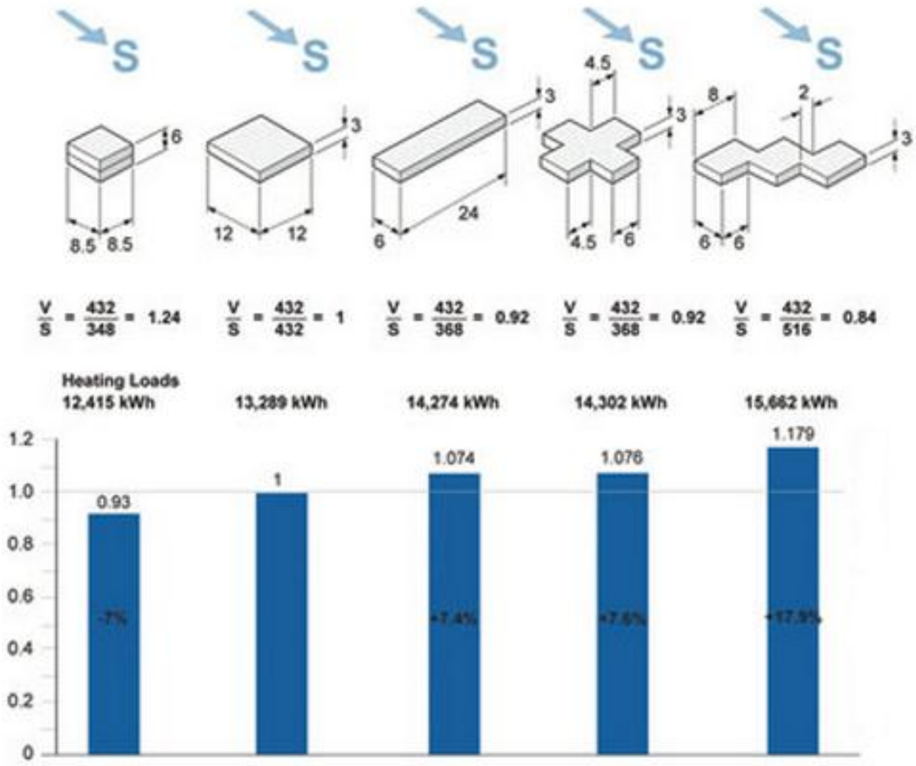


Figure 21: Impact of building shape on annual heating energy for a small 144 m2 (1500 ft2) building (http://www.buildingscience.com/documents/insights/bsi-061-function-form-building-shape-and-energy)

3.4. Insulation

Insulation is another important task in construction of a sustainable designed building. The building should be insulated as effectively as possible. Insulation is an efficient means of reducing heat waste. It could be applied to internal or external walls, as well as to the roof and floor. A well done insulated building can bring the heat loss to its minimal value. Fiberglass, spray-applied foam, aerogels and rigid polystyrene are good examples of a new generation of materials used in insulation nowadays. Insulation in places such as thermal rooms is more important than other areas of the building. (Michael Bauer, et al. 2009)

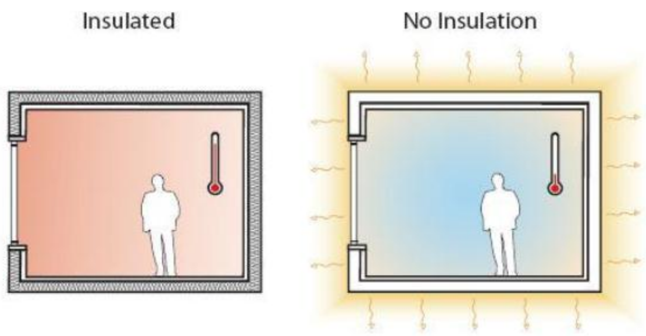


Figure 22: Insulated and non-insulated buildings (Vancouver city council, 2009)

Insulation means the control of heat flow, for which three different mechanisms can be distinguished: reflective, resistive and capacitive.

Reflective insulation: where the heat transfer is primarily radiant, such as across a cavity or through an attic space, the emittance of the warmer surface and the absorptivity of the receiving surface determine the heat flow. A reflective surface in contact with another material would have no effect, as heat flow would take place by conduction. In a hot climate, where the downward heat flow is to be reduced, this solution could be very effective, but almost useless in a cold climate.

Resistive insulation of all common materials, air has the lowest thermal conductivity, as long as it is still. However, in a cavity, convection currents will effectively transfer heat from the warmer to the cooler face. The purpose of resistive insulation is just to keep the air still, dividing it into small cells, with the minimum amount of actual material. The best ones have a fine foam structure, consisting of small closed air cells separated by very thin membranes or bubbles, or consist of fibrous materials with entrapped air between the fibers.

The most often used insulating materials are expanded or extruded plastic foams, such as polystyrene or polyurethane or fibrous materials in the form of bats or blankets, such as mineral wool, glass fibers or even natural wool. Loose cellulose fibers or loose exfoliated vermiculite can be used as cavity fills or as poured over a ceiling. Second class insulators include strawboard, wood wool slabs (wood shavings loosely bonded by cement), wood fiber soft boards and various types of lightweight concrete (either using lightweight aggregate or autoclaved aerated concrete).

Capacitive insulation or material layers of a high thermal capacity (massive construction) affect not only the magnitude of heat flow, but also its timing. Both reflective and resistive insulation respond to temperature changes instantaneously. As soon as there is a heat input at one face, a heat output on the other side will appear, though at a controlled rate. Not so with capacitive insulation. This relies on the thermal capacity of materials and their delaying action on the heat flow (Szokolay, 2008).

Different types of insulations are available with different advantages which each of them are applicable in a special area for its best performance, those insulations are as follows:

Blanket batts and rolls, this insulation materials are fiberglass, mineral wool, plastic fibers and natural fibers. It is applicable in unfinished walls including foundation walls and in floors and ceiling. This insulation is appropriate for standard stud and joist spacing that is normally free from obstructions and it is generally inexpensive.

Concrete block insulation and insulating concrete blocks, this insulation material are foam board, to be placed on outside of wall (usually new construction) or inside of wall (existing homes) and Some manufacturers incorporate foam beads or air into the concrete mix to increase R-values. It is applicable in unfinished walls, including foundation walls, for new construction or major renovations and it requires special skills for the installation. Insulating concrete blocks are sometimes stacked without mortar (dry-stacked) and surface bonded. Insulating outside of concrete block wall places mass inside conditioned space can moderate indoor temperatures. Autoclaved aerated concrete and autoclaved cellular concrete masonry units have 10 times the insulating value of conventional concrete.

Foam board or rigid foam, this insulation material are polystyrene, polyisocyanurate and polyurethane. It is applicable in unfinished walls, including foundation walls, floors and ceiling and unvented low-slope roofs. In interior applications it must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety and in exterior applications it must be covered with weatherproof facing. The advantage of this insulation is in its high insulating value for relatively little thickness and it can block thermal short circuits when installed continuously over frames or joists.

Insulating concrete forms (ICFs), this is composed of foam boards or foam blocks. It is applicable over unfinished walls, including foundation walls for new construction and it is installed as part of the building structure. This insulation is literally built into the home's walls, creating high thermal resistance.

Loose-fill and blown-in, this is composed of cellulose, fiberglass and mineral wool. It is applicable in enclosed existing wall or open new wall cavities, unfinished attic floors and other hard to reach places. It is blown into place using special equipment, sometimes poured in. It is good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.

Reflective system, this is composed of foil-faced Kraft paper, plastic film, polyethylene bubbles or cardboard. It is applicable over unfinished walls, ceilings and floors. It is fitted between wood-frame studs, joists, rafters, and beams. It is suitable for framing at standard spacing and the bubble-form is suitable if framing is irregular or if obstructions are present. It is most effective at preventing downward heat flow and the effectiveness depends on spacing.

Rigid fibrous or fiber insulation, this is composed of fiber glass and mineral wool. It is applicable in ducts and in unconditioned spaces or other places requiring insulation that can withstand high temperatures. This insulation can withstand high temperatures.

Sprayed foam, this is composed of cementitious, phenolic, polyisocyanurate and polyurethane. It is applicable in enclosed existing wall, open new wall cavities and unfinished attic floors. It is applied using small spray containers or in larger quantities as a pressure sprayed (foamed in place) product. This insulation is good for adding to existing finished areas, irregularly shaped areas, and around obstructions.

Structural insulated panels (SIPs); it is composed of foam board or liquid foam insulation core and straw core insulation. It is applicable in unfinished walls, ceilings, floors, and roofs for new construction. Construction workers fit SIPs together to form walls and roof of a house. SIP built houses provide superior and uniform insulation compared to more traditional construction methods; they also take less time to build (Wilson and Piepkorn, 2008).

3.5. Windows

The window is an open space in a wall or side of a building letting the sunlight and even air to the interior. In old times windows were used before the invention of glass, so early windows were generally open to the outside environment, or filled by some shape of closure to decrease the heat loss at night. Windows are mostly divided into two main types, first the window applied in the side walls of a building (horizontal and vertical), and second the opening light applied into the roof, commonly known as roof lights.

The horizontal windows are the most known shape of window which it was used from the historic time till now and it is most applied in domestic architecture today. The horizontal window is generally used high in the wall to let day lighting penetrating well into the interior space, but other features has to be considered such as the outside view, which brought the extended horizontal windows. A normal development of the extended horizontal window is the floor to ceiling window; as structural techniques were developed perfectly, this type of window has become almost international in some types of architectural program such as the office.

Vertical windows, set apart by masonry at intervals, provided a simple structural solution and this formed the pattern of development in residential and other building types for several centuries. This type of window can be said as one of the most architectural features because it is making a vital relationship with the exterior.

Glazing is one of the important parts of the window. Now a day there is a big number of alternative glazing for windows, and it is important for the architect, in at the same time with his services consultant, to write a detailed specific performance, this has to get the orientation of the window, its acoustic and thermal properties, both with its capacity for solar shading. Definitely this glazing a long side with the main function of the window which is the admission of daylight and the introduction of the exterior view. Although different factors could be considered are even desirable to have open able windows or fixed ones, and to keep its relationship to ventilation. Glazing types are mainly clear, tinted and miscellaneous and can affect or reduce the impression of day lighting; they can darken the interior and exterior view (Phillips, 2004).

Window is one of the most important elements in direct heat gain system; as much as the weather and the climate gets colder, the insulation of the windows gets its importance. The high performance window will be helpful in evening time hours and cloudy days to reduce heat loss and will provide to prevent an energy gain. There are variety of new materials and methods, which are used in the design and the produce of new windows, in aim to reduce this waste of energy. One example is the use of insulated and fix profiles in window frames. The most effective change in new windows is in their glass panes. Today, double pane glasses are used in buildings instead of single pane glasses and the use of triple pane glasses is becoming widespread as well. The U-factors of sunlight passing through a single pane, double pane and triple pane windows are; 1.04, 0.50 and 0.15 respectively (Image 23). Therefore triple pane windows are an efficient way of reducing energy use as well as maintaining health and safety. The location and size of the windows are also important which depends on the area that the building will be constructing (Chiras, 2002).

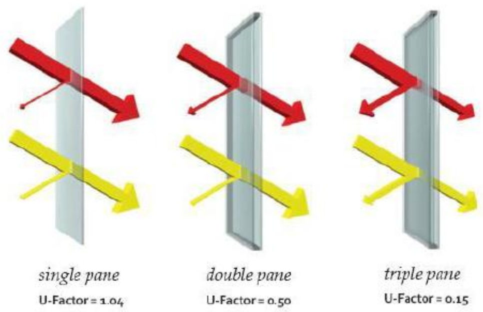


Figure 23: Different types of windows with their U-factors (Vancouver city council, 2009)

3.6. Ventilation

In naturally ventilated building no energy is in demand to ventilate the building and to move the air across the building. The only energy required is needed only during the cold season to warm up the air. So the energy in demand will increase with the ventilation rate and it varies as in function of time and it is in dependence with the wind characteristics and the thermal state of the building. At the same time, the resident behavior is in direct impact on the total energy consumption of the building, such as opening or closing doors and windows.

An acceptable indoor air quality can be kept by both sufficient air supply and natural air ventilation. Therefore, optimization is essential in order that a combined low energy demand and an acceptable indoor quality can be achieved while keeping ventilation rate within a certain range. (Allard, 1998)

In ventilation and cooling process elements such as moisture management, airtightness and material selection has to be taken in account as fundamental aspects. These contribute to good indoor air quality, wellbeing, energy efficiency, cost savings and enjoyment.

Buildings are ventilated for a wide variety of reasons. Improving thermal comfort and indoor air quality through provision of fresh air is known to be vitally important to individual perception of a space, their health and well-being, and productivity. Any ventilation system should be flexible because it will need to work under a wide range of conditions. The reasons that buildings are ventilated are: To remove excess heat from people and equipment, to remove moisture, smells and pollutants generated by people, pets and cooking, which can be unpleasant or hazardous to health or buildings, to remove gaseous emissions from materials, furnishings, cleaning agents and, in affected areas, the products of radon, to act as a carrier for heating, cooling or humidity control and to provide oxygen for breathing, although the safe requirement is a tiny proportion compared to the other needs.

Ventilation standards must rely on rates of external air supply, which depend on how much heat, moisture and pollution it is necessary to remove. Odor is a determining factor. For sedentary people, typical rates of outdoor air supply are between 5 and 25 l/s/person. For normal office occupancy levels with little or no smoking, this equates to 1–2 l/s/m2 of floor area, significantly less than was required in offices when smoking was common (Halliday, 2008).

The stack effect is one of the ways to ventilate a building with a hotter or colder condition on the inside than outside. The temperature differentiation plays such as the air inside the building is either more or less dense than the air outside. If an opening is available up of the building and one other down of the building then a natural air flow will be the result. If the air in the building is higher in temperature than the external temperature, this warmer air will run out of the upper opening, to be replaced with colder air from the exterior. If the interior temperature is colder than that exterior temperature, the colder air will run out the down opening, being replaced with hotter air from exterior.

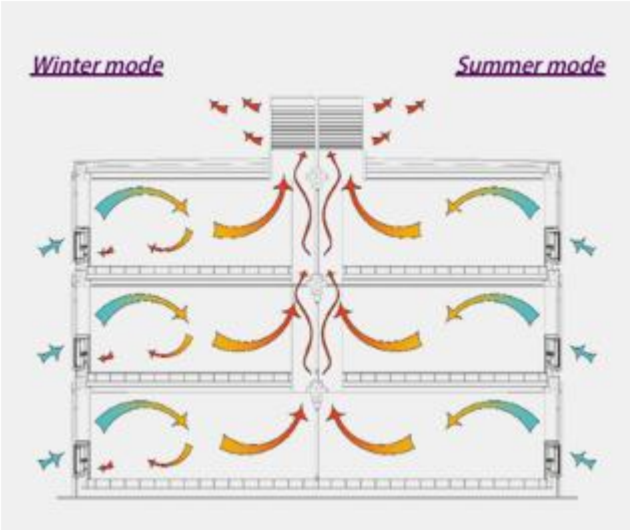


Figure 24: Stack effect in a building (http://www.tekintonat.co.uk/principles.asp)

Another way to ventilate a building is the cross ventilation, in this type the windows are situated in a way which there is an air follow in a way that the air is entering inside an area from an opening and getting out from another opening and a natural breezes are made inside the structure of the building. It is more effective if the ventilation passes from the whole space. (http://sustainabilityworkshop.autodesk.com/buildings/wind-ventilation)

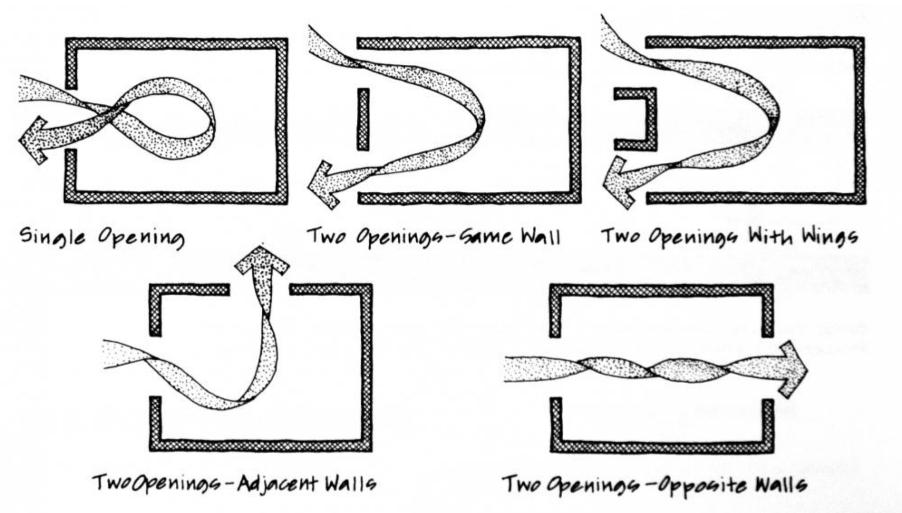


Figure 25: Different type of cross ventilation
(http://sustainabilityworkshop.autodesk.com/buildings/wind-ventilation)

Mechanical ventilation is another way to ventilate the building. Mechanical ventilation involves forced air movements, with pressure differences typically 100–1000 Pa. It may be needed when there is a perceived need for closer temperature control, where internal heat gains or pollutant levels are too great, where plan depth, external noise or air pollution restricts the use of natural ventilation, for all or part of the time, or where security or physical restrictors preclude adequately sized natural openings. Complete mechanical ventilation which denies occupants the opportunity to open windows is known to be unpopular, and mixed mode solutions in which mechanical ventilation is used in combination with opening windows is increasingly common. Clearly, care must be taken to design both strategies so that they can work to assist the preferred flow of air and do not undermine each other or the overall efficiency. There are essentially three types of mechanical ventilation: supply, extract and balanced.

Supply pressurizes a building to resist the inflow of uncontrolled infiltration. It is important that designed exhaust vents are provided and that the structure is airtight if interstitial condensation is to be avoided.

Extract is applicable to spaces with localized pollution, moisture and odor problems, and is used for extracting pollutants close to the source bathrooms, kitchens and densely occupied spaces such as meeting rooms. Heat recovery is often an option. However, if the building is not airtight, and designed openings are not provided, then infiltration air will give rise to draughts and inefficiency.

Balanced ventilation involves both controlled input and extract and provides opportunity for heat recovery between them but unless it is well designed and controlled, the energy advantages may not be sufficient to offset the energy and capital cost of fan power and two ducted systems. Also, balanced ventilation has the same potential interstitial condensation risks as supply ventilation. If this is a hazard then the extract rate should be made to exceed the supply, an energy cost to offset a health risk (Halliday, 2008).

3.7. Shading

The principle reasons that shading is needed in a building are first of all to reduce the effect of heat gain from the sun and to cut down sun glare experienced through the windows and in some circumstances it can be used for privacy purposes.

Shading can be divided in two groups: natural shading and artificial shading. The influence of shading in the inner temperature of a building is much more than windows orientation. Outer shade affects 90 percent and inner shades affects 25 percent over the decrease of temperature influenced by the sunlight.

The natural shading is composed from trees and their branches and the natural environment. The temperature under a tree is 15 degrees colder than the air temperature. If natural environment is used in a good manner in term of shading till 25 percent it can be gained in energy consumption. So trees can be an important element of the thermal factors.

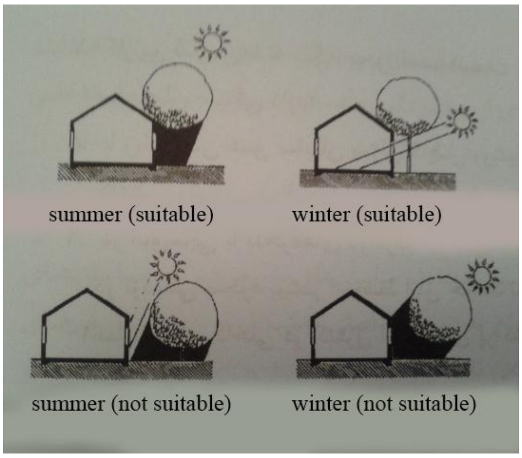
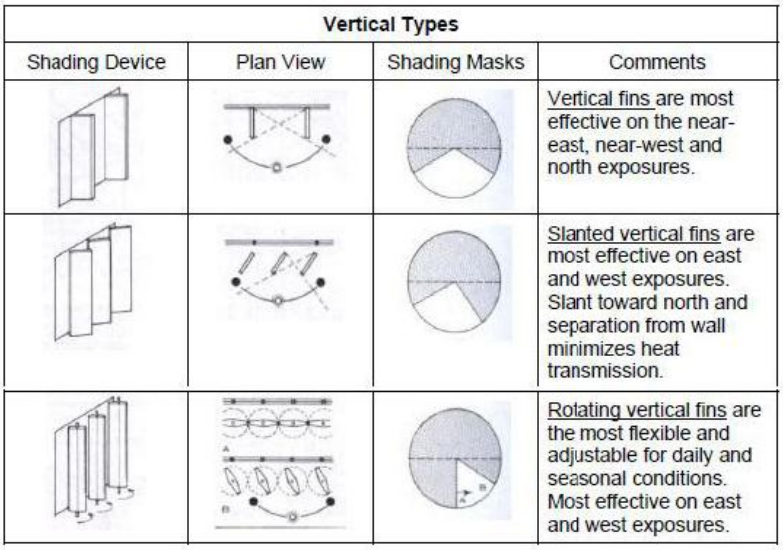


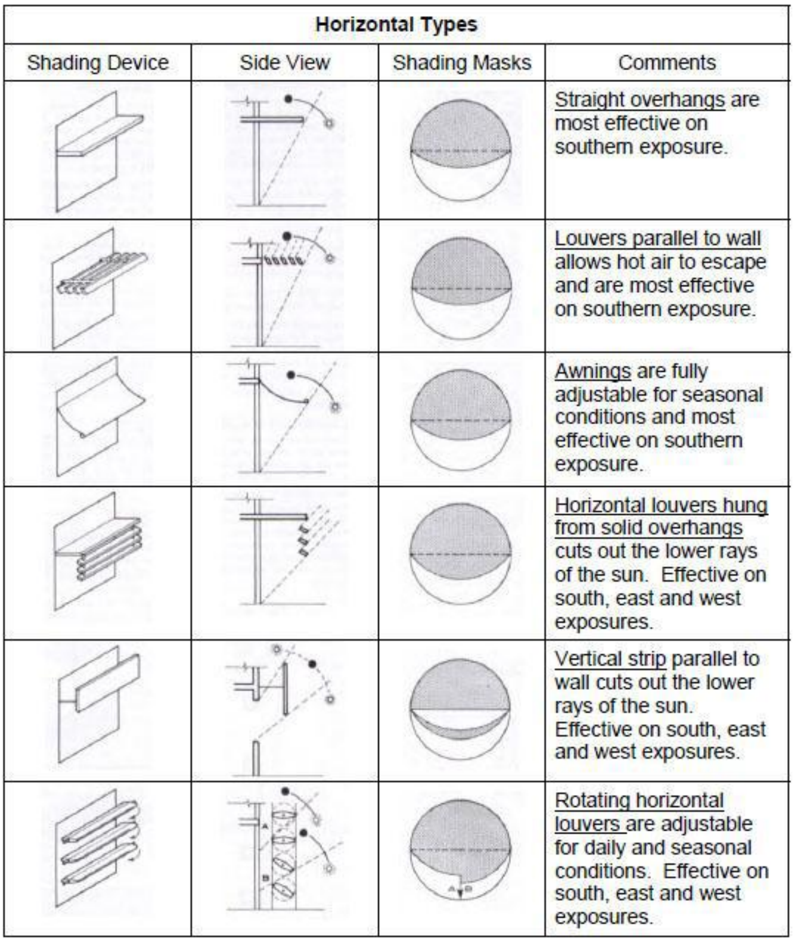
Figure 26: Natural shading positioning in different seasons (Akhtar Kavan, 2010)

The other types of shading are the artificial ones, which they are divided to movable and fixed. The movable ones can be adjust depending to different circumstances of days but the fixed ones needs to be calculated according to different locations and areas which the building is situated. These outer shades can absorb till 95 percent of energy of sunlight twisted over the windows. Different types of fixed shading are horizontal, vertical and mixed as following images: (Akhtar Kavan, 2010)



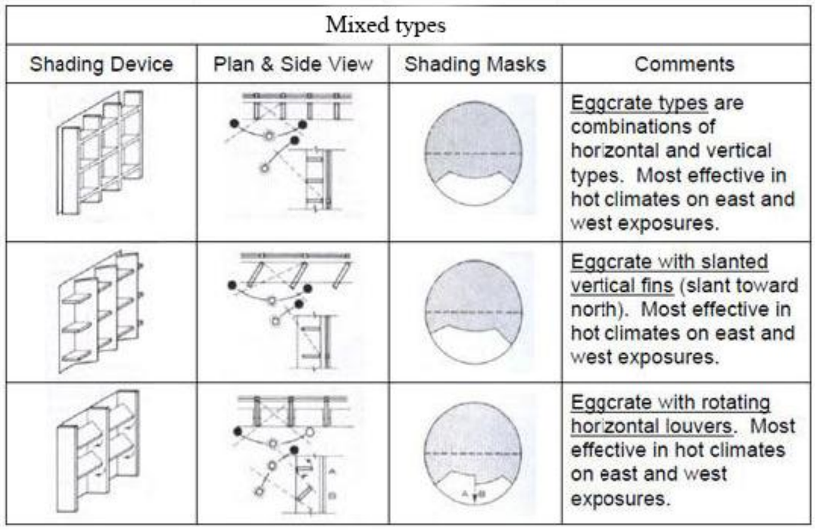
Vertical Types			
Shading Device	Plan View	Shading Masks	Comments
			Vertical fins are most effective on the near-east, near-west and north exposures.
			Slanted vertical fins are most effective on east and west exposures. Slant toward north and separation from wall minimizes heat transmission.
			Rotating vertical fins are the most flexible and adjustable for daily and seasonal conditions. Most effective on east and west exposures.

Figure 27: Different type of vertical shading (Akhtar Kavan, 2010)



Horizontal Types			
Shading Device	Side View	Shading Masks	Comments
			Straight overhangs are most effective on southern exposure.
			Louvers parallel to wall allows hot air to escape and are most effective on southern exposure.
			Awnings are fully adjustable for seasonal conditions and most effective on southern exposure.
			Horizontal louvers hung from solid overhangs cuts out the lower rays of the sun. Effective on south, east and west exposures.
			Vertical strip parallel to wall cuts out the lower rays of the sun. Effective on south, east and west exposures.
			Rotating horizontal louvers are adjustable for daily and seasonal conditions. Effective on south, east and west exposures.

Figure 28: Different type of horizontal shading (Akhtar Kavan, 2010)



Mixed types			
Shading Device	Plan & Side View	Shading Masks	Comments
			Eggcrate types are combinations of horizontal and vertical types. Most effective in hot climates on east and west exposures.
			Eggcrate with slanted vertical fins (slant toward north). Most effective in hot climates on east and west exposures.
			Eggcrate with rotating horizontal louvers. Most effective in hot climates on east and west exposures.

Figure 29: Different type of mixed shading (Akhtar Kavan, 2010)

The effectiveness of a shading device depends on the proportionate success with which it covers a given surface during the summer period without interception of the sun's energy during winter times. So the efficiency of a shade should be considered on its yearly performance and on the relative balance between its shading performance and heating efficiency. The importance of heat gain as opposed to cooling shade can be interpreted by different ratios. In fully air conditioned buildings, according to the current heating versus cooling costs, the ratio could be as 1 to 5. In certain cases the ratio based on the economy of mechanical cooling is justified. But it seems that more permanent standard would be established by relating their importance to human reactions, where a reasonable ratio would be 1 to 2. So according to this shading in overheated period is twice as important as heat gain during the under heated period.

Means of determining the angles at which sunlight will fall on buildings at diffrent places, seasons and times of the day can be categorized as model measurements, and calculatives methodes. The great advantage of using models is the directness with which shading can be observed visually. Situations can be easily changed, perceived and compared. With calculative methods, even if they are less visual, the intensities of radiation, highly desirable for exact evaluations can be additionally defined (Aldar and Olgyay, 1957).

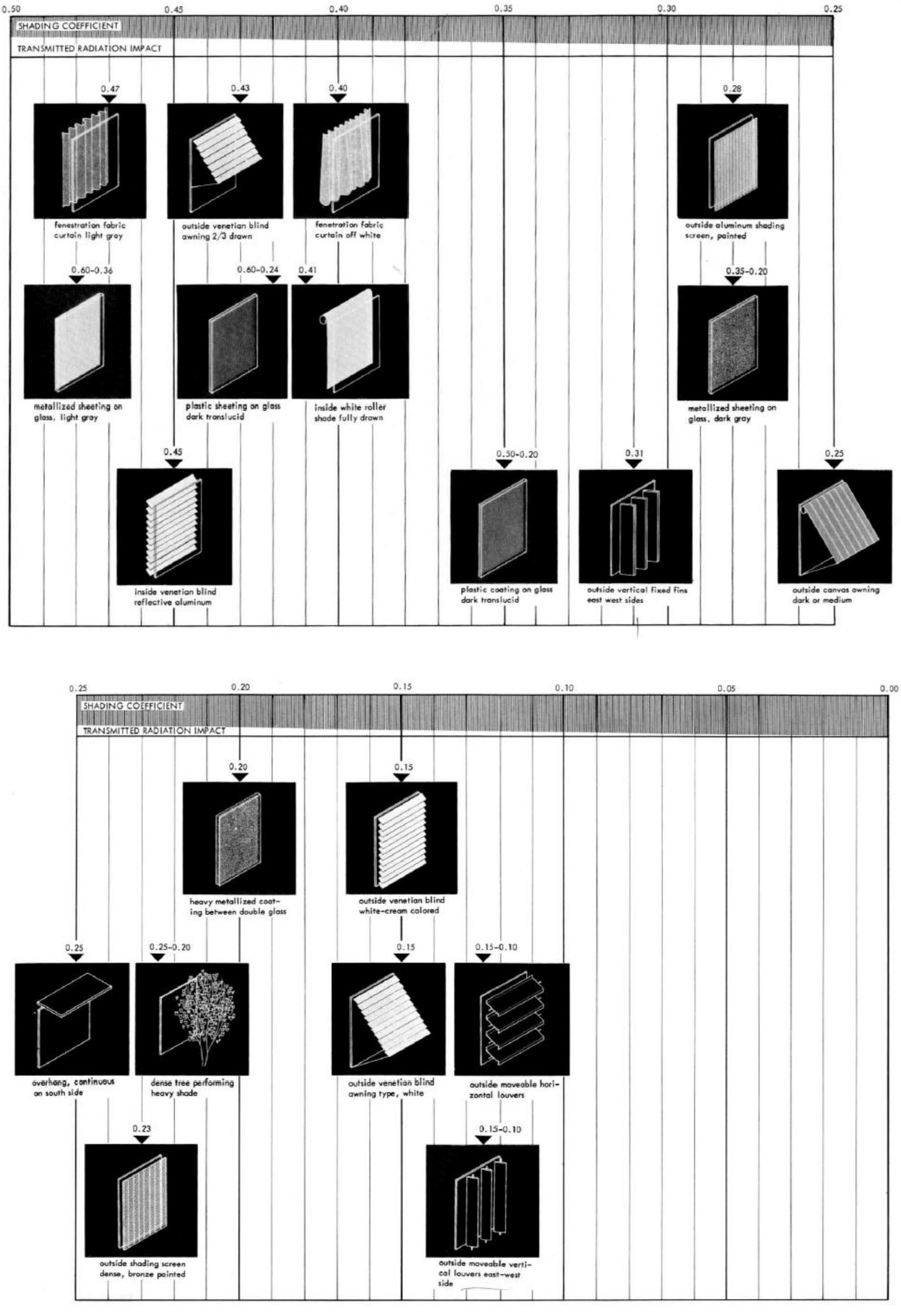


Figure 30: Various shade protections devices according to their shading coefficient (Olgyay, 1963)

The calculative method can be formulated as the summer shading performance (S_p) can be expressed by comparing the intercepted Btu values during the overheated times (S_o) with the full amount of Btu's which strike the surface during the overheated period (R_o):

$$S_p = \frac{S_o}{R_o} \cdot 100\%$$

The yearly effect can be expressed in terms of heat efficiency (H_e) by deducting the Btu losses during shaded under heated period (S_u) from S_o values and writing the results in percentages:

$$H_e = \frac{S_o - S_u}{R_o} \cdot 100\%$$

In the final evaluation both methods are of interest. The heat efficiency as a yearly balance for the use of shading device and the shading performance as an optimum for the summer season.

The average of the two equations gives a formula called the shading effect ratio (S_e):

$$S_e = \frac{S_p + H_e}{2} = \frac{\frac{S_o}{R_o} + \frac{S_o - S_u}{R_o}}{2} = \frac{S_o - \frac{S_u}{2}}{R_o} \cdot 100\%$$

3.8. Building Materials

The most performed building design is characterized by managing to use natural materials with a minimum of processing and transportation and an emphasis on healthy, non-toxic specification to decrease the pollution. Perfect materials have to contribute to passive shapes of environmental control also.

Lots of researches have been made to create a coordinated and comprehensive analysis tool for materials in the construction industry that can enable those specifies who are minded to do so, to make objective decisions about material selection. The life cycle of the materials got its special importance.

The materials surrounding the persons living in a building have the main importance to protect them against heat and cold. Well measure must be taken while choosing the wall and roof materials and their thicknesses by respecting their physical characteristics, such as thermal conductivity, resistivity, transmission and optical reflectivity.

By getting in consider the outside wall which is under a high exterior air temperature with a lower interior air temperature, the value of heat flow transferred through the wall from the exterior air to the interior air is in a relation to the air temperature difference, surface of the wall and rate of complete heat transmittance that can be specified from an analysis of the elements of the total resistance to heat flow. "*The total resistance is composed of the resistance to heat flow through the material, the interfacial resistance at the external surface and the interfacial resistance at the internal surfaces. Since the interfacial resistances are determined primarily by temperature conditions over which the builder has little control, his principal effect on the heat transmittance is on changing the resistance to heat flow through the wall material. To reduce the heat transmission from one side of a wall to the other, the thermal transmittance must be reduced as much as possible by either increasing the thickness of the wall or using materials of lower thermal conductivity and therefore of higher resistance".* Most walls are composed of different materials (which some of them are mentioned in the following tables), are used to bring the desirable thermal and aesthetic wall properties. Coefficients of thermal transmittance for variety of wall materials are provided in following tables. These coefficients are given in the practical units commonly used: kcal/hm^{2}C^o and Btu/hft^{2}F^o (Fathy, 1986).

In a building different building materials are used which each of them got different U-factors that is affected by its material range and its thickness, here are given the most common materials used in buildings and their U-factors (tables 9 to 13) to have a better idea in their thermal characteristics which are influencing the building:

Table 9: Different wall materials U-factor (www.combustionresearch.com/InfraSpec/infra-spec/uvalue.html.combustionresearch.com/Infra-Spec/infra-spec/uvalue.html)

Walls		
Material	**Description**	**"U" Factor**
Flat Metal	0" Fiberglass Insulation	1.20
	1" Fiberglass Insulation	0.22
	2" Fiberglass Insulation	0.12
	3" Fiberglass Insulation	0.09
	4" Fiberglass Insulation	0.07
	6" Fiberglass Insulation	0.05
	8" Fiberglass Insulation	0.041
	12" Fiberglass Insulation	0.027
Masonry	8" Brick	0.41
	12" Brick	0.31
	16" Brick	0.25
	8" Conic Block, Solid	0.39
	12" Conic Block, Solid	0.36
	4" Conic Block, Hollow	0.51
	8" Conic Block, Hollow	0.39
	12" Conic Block, Hollow	0.37
Poured Concrete	2" Thick	0.99
(140 lb. / ft3)	4" Thick	0.86
	6" Thick	0.75
	8" Thick	0.67
	10" Thick	0.61
	12" Thick	0..55
Poured Concrete	2" Thick	0.62
(80 lb. / ft.3)	4" Thick	0.42
	6" Thick	0.31
	8" Thick	0.25
	10" Thick	0.21
	12" Thick	0.18

Table 10: Different roof materials U-factor (www.combustionresearch.com/Infra-Spec/infra-spec/uvalue.html.combustionresearch.com/Infra-Spec/infra-spec/uvalue.html)

Roofs		
Material	**Description**	**"U" Factor**
Flat Metal - Roof	0" Fiberglass Insulation	0.90
	1" Fiberglass Insulation	0.26
	2" Fiberglass Insulation	0.16
	3" Fiberglass Insulation	0.11
	4" Fiberglass Insulation	0.071
	6" Fiberglass Insulation	0.05
	8" Fiberglass Insulation	0.039
	12" Fiberglass Insulation	0.027
Wood - Roof	0" Fiberglass Insulation	0.48
	1" Fiberglass Insulation	0.21
	2" Fiberglass Insulation	0.12
	3" Fiberglass Insulation	0.10
	4" Fiberglass Insulation	0.075
	6" Fiberglass Insulation	0.052
	8" Fiberglass Insulation	0.04
	12" Fiberglass Insulation	0.027
Concrete Deck - Roof	2" Thick	0.30
	3" Thick	0.23
	4" Thick	0.18
Sky Lights	Single Wall	1.15
	Double Wall	0.70

Table 11: Different door materials U-factor (www.combustionresearch.com/Infra-Spec/infra-spec/uvalue.html.combustionresearch.com/Infra-Spec/infra-spec/uvalue.html)

Doors		
Material	**Description**	**"U" Factor**
Steel	No Fiberglas Insulation	1.20
	Insulated	0.65
Wood	1" Thick	0.64

Table 12: Values of coefficients of thermal transmittance for different wall materials and combinations in kcal/hm^{2}C^o (Fathy, 1986)

	Wall Thickness (in m)						
Type of Masonry	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**
Limestone masonry:							
External wall plastered on exterior	2.40	2.00	1.80	1.60	1.45	1.33	1.22
External wall plastered on both sides	2.30	2.00	1.80	1.60	1.41	1.30	1.19
Internal wall plastered on both sides	1.90	1.70	1.50	1.37	1.25	1.16	1.08
Dense stone, including marble and granite:							
External wall plastered on exterior	2.90	2.60	2.40	2.20	2.00	1.90	1.70
External wall plastered on both sides	2.80	2.50	2.30	2.10	1.90	1.80	1.70
Internal wall plastered on both sides	2.20	2.00	1.90	1.80	1.60	1.50	1.45
	Wall Thickness (in m)						
	0.05	**0.10**	**0.15**	**0.20**	**0.30**	**0.40**	**0.50**
Concrete masonry (gravel, cement, and sand):							
External wall without plaster	4.20	3.60	3.10	2.70	2.20	1.80	1.60
Internal wall without plaster	3.10	2.70	2.40	2.20	1.80	1.60	1.36
External wall plastered on both sides	3.50	3.00	2.70	2.40	2.00	1.70	1.44
Internal wall plastered on both sides	2.70	2.40	2.20	2.00	1.70	1.44	1.27

	Wall Thickness (in m)						
	0.12	**0.25**	**0.38**	**0.51**	**0.64**	**0.77**	**0.90**
Red brick:							
External wall plastered on exterior	2.60	1.80	1.37	1.11	0.93	0.80	0.70
External wall on both sides	2.50	1.70	1.34	1.09	0.91	0.79	0.69
External wall plastered on interior	1.90	1.33	1.04	0.85	0.71	0.62	0.55
Light concrete block:							
External wall plastered on both sides	2.00	1.25	0.93	0.73	0.60	...	...
Internal wall plastered on both sides	1.70	1.12	0.85	0.68	0.57	...	...
Sand-lime brick:							
External wall plastered on exterior	2.90	2.00	1.60	1.27	1.08	0.93	0.82
External wall plastered on both sides	2.70	1.90	1.50	1.23	1.05	0.91	0.81
Internal wall plastered on both sides	2.10	1.60	1.24	1.03	0.89	0.78	0.69
	Wall Thickness (in m)						
	0.12	**0.25**	**0.38**	**0.51**	**0.64**	**0.77**	**0.90**
Red-brick double wall plastered on both sides with 5–12 cm cavity	...	1.38	1.11	0.93	0.81	0.70	0.63
Ordinary red-brick wall insulated with cork sheeting on internal wall only for insulation:							
2-cm thick insulation	1.11	0.93	0.80	0.70	0.63	0.57	0.52
5-cm thick insulation	0.61	0.55	0.50	0.46	0.43	0.40	0.37
10-cm thick insulation	0.34	0.33	0.31	0.29	0.28	0.27	0.25

Table 13: Values of coefficients of thermal transmittance for different wall materials and combinations in Btu/hft^{2}F^o (Fathy, 1986)

	Wall Thickness (in in)						
Type of Masonry	4.7	9.8	15	20	25	30	35
Red brick:							
External wall plastered on exterior	0.533	0.369	0.281	0.227	0.190	0.164	0.143
External wall on both sides	0.512	0.348	0.274	0.223	0.186	0.162	0.141
External wall plastered on interior	0.389	0.272	0.213	0.174	0.145	0.127	0.113
Light concrete block:							
External wall plastered on both sides	0.410	0.256	0.190	0.150	0.123	...	...
Internal wall plastered on both sides	0.348	0.229	0.174	0.139	0.117	...	...
Sand-lime brick:							
External wall plastered on exterior	0.594	0.410	0.328	0.260	0.221	0.190	0.168
External wall plastered on both sides	0.553	0.389	0.307	0.252	0.215	0.186	0.166
Internal wall plastered on both sides	0.430	0.328	0.254	0.211	0.182	0.160	0.141

	Wall Thickness (in in)						
	12	16	20	24	28	31	35
Limestone masonry:							
External wall plastered on exterior	0.492	0.410	0.369	0.328	0.297	0.272	0.250
External wall plastered on both sides	0.471	0.410	0.369	0.328	0.289	0.266	0.244
Internal wall plastered on both sides	0.389	0.348	0.307	0.281	0.256	0.238	0.221
Dense stone, including marble and granite:							
External wall plastered on exterior	0.594	0.553	0.492	0.451	0.410	0.389	0.348
External wall plastered on both sides	0.573	0.512	0.471	0.430	0.389	0.369	0.348
Internal wall plastered on both sides	0.451	0.410	0.389	0.369	0.327	0.307	0.297

	Wall Thickness (in in)						
	2	4	6	8	12	16	20
Concrete masonry (gravel, cement, and sand):							
External wall without plaster	0.860	0.737	0.635	0.553	0.451	0.369	0.328
Internal wall without plaster	0.635	0.553	0.492	0.451	0.369	0.327	0.279
External wall plastered on both sides	0.717	0.614	0.553	0.492	0.410	0.348	0.295
Internal wall plastered on both sides	0.553	0.492	0.451	0.410	0.348	0.295	0.260

	Wall Thickness (in in)						
	4.7	9.8	15	20	25	30	35
Red-brick double wall plastered on both sides with 13–31 cm cavity	...	0.283	0.227	0.190	0.166	0.143	0.129
Ordinary red-brick wall insulated with cork sheeting on internal wall only for insulation:							
0.8-in thick insulation	0.227	0.190	0.164	0.143	0.129	0.117	0.107
2-in thick insulation	0.125	0.113	0.102	0.094	0.088	0.082	0.076
4-in thick insulation	0.070	0.068	0.063	0.059	0.057	0.055	0.051

CHAPTER V

THE CASE STUDY BUILDING CHARACTERISTICS AND STIMULATIONS

4.1. Site Description

The building is situated in the north west of Tehran, Shahrake Gharb neighborhood in Kharazm Street. In this area all buildings are villas and detached from each other. The site is flat and fertile but there are no remarkable trees to be used as shading. As it is located in an upper level of the city it is less touched by the pollution.

The dimensions of the site are 24 x 12.58 meters with a floor area of 130 m^2. The street is in the south side of the site, and surrounded by neighbors from east west and north side with same heights. The building is located in the north side of the site and the main yard is on the south. The building is a villa house designed with two bedrooms, living room, dining room, kitchen and a bathroom on the ground floor and with two bedrooms and a bathroom on the gallery floor. (Plans are given in the appendices)

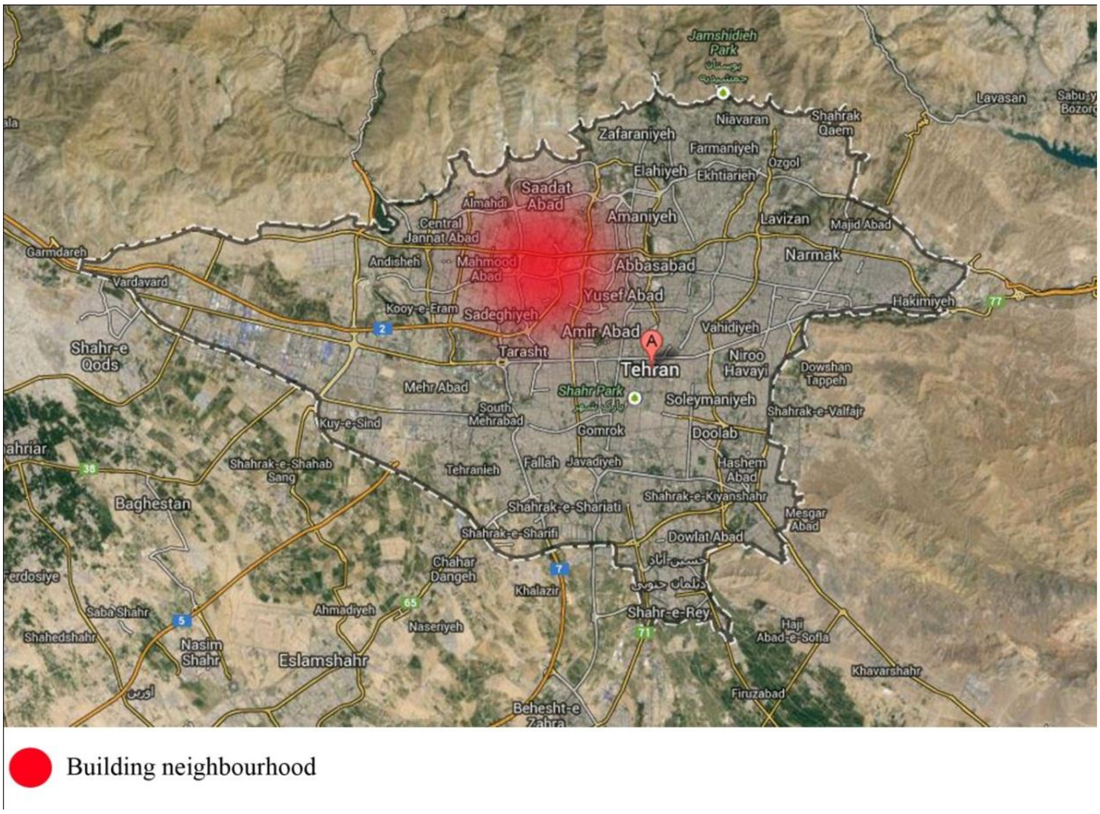


Figure 31: The case study building neighborhood

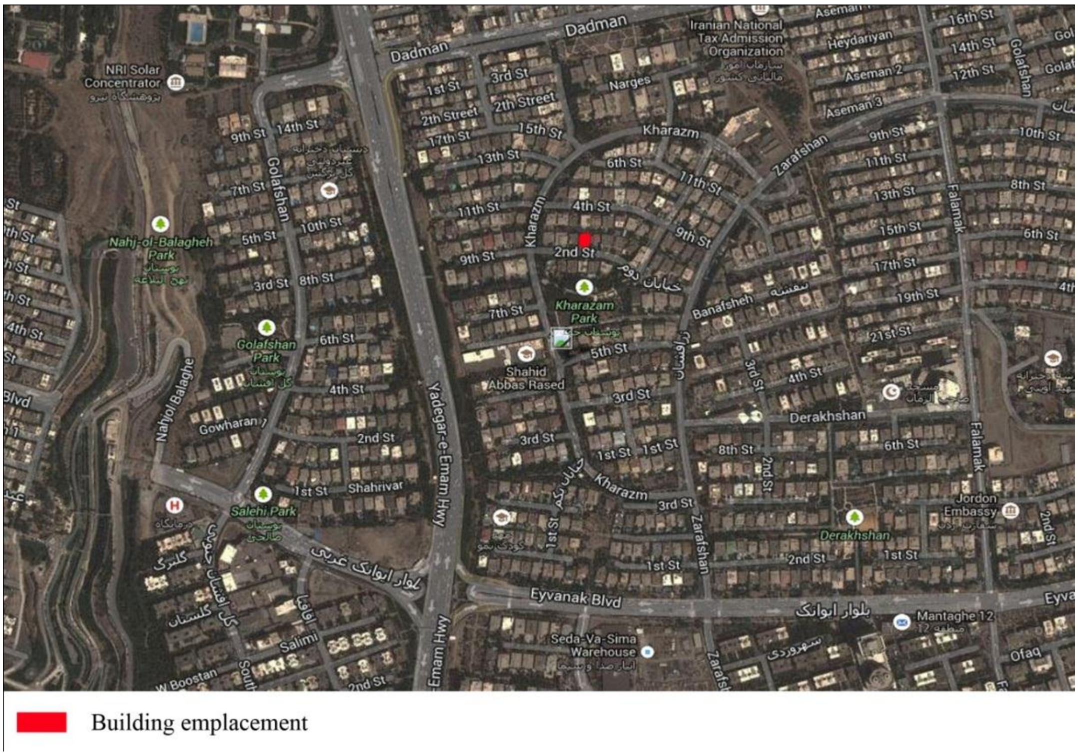


Figure 32: The case study building emplacement and site map

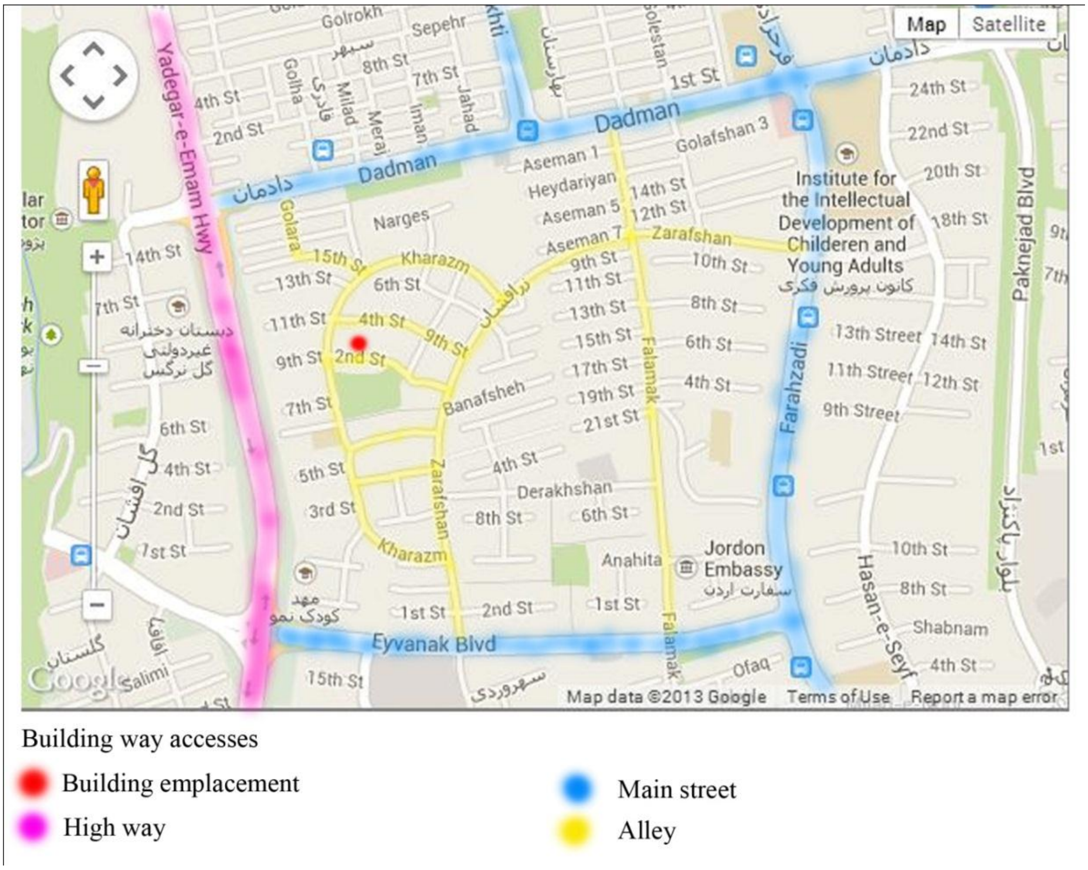


Figure 33: The case study building way accesses

4.2. Building Structure

To obtain the best winter solar heat gain, the main elevation of the house is oriented toward the south. The main and frequented space, the living room is situated in the south side, but unfortunately the dining room and kitchen are situated in the north side with other spaces such as bedrooms. The windows on the north side are much smaller than the south side because of the colder condition of the north side of the building during the winter. No opening is used in the east and west side of the building. No shading is used in front of the southern windows which will be a high rise of energy consumption during the summer time for cooling the area.

The building is ground coupled and the ground acts as a great thermal mass and insulator so temperature fluctuation between day and night would be at a minimum and less energy would be consumed. The roof is flatted because of the low amount of the snow and rain in Tehran.

Figure 34: Southern view of the subject house

Figure 35: Northern view of the subject house

4.3. Building Construction

The building has a conventional reinforced concrete frame with slab sided ceiling. In order to make the building fabric lighter and perforated clay bricks are used. Regular bricks are used for the basement. Reinforcing is also placed between the brick walls and structure in order to prevent walls from collapsing during earthquakes. The roof is flat and only doors, windows and mechanical and electrical equipments are prefabricated. The cooling system used is fan coil unit which it works by the electricity and for the heating the hot water circulation is used in the radiators which are heated by natural gas. No special isolation is used to preserve the energy. Potable water is transmitted to the building by polymer pipes and the wasted water is conducted to the ego system by polycab sewage pipes (p.v.c pipes). The main sources of energy used in the building are electricity and gas.

Figure 36: West construction work view of the subject house

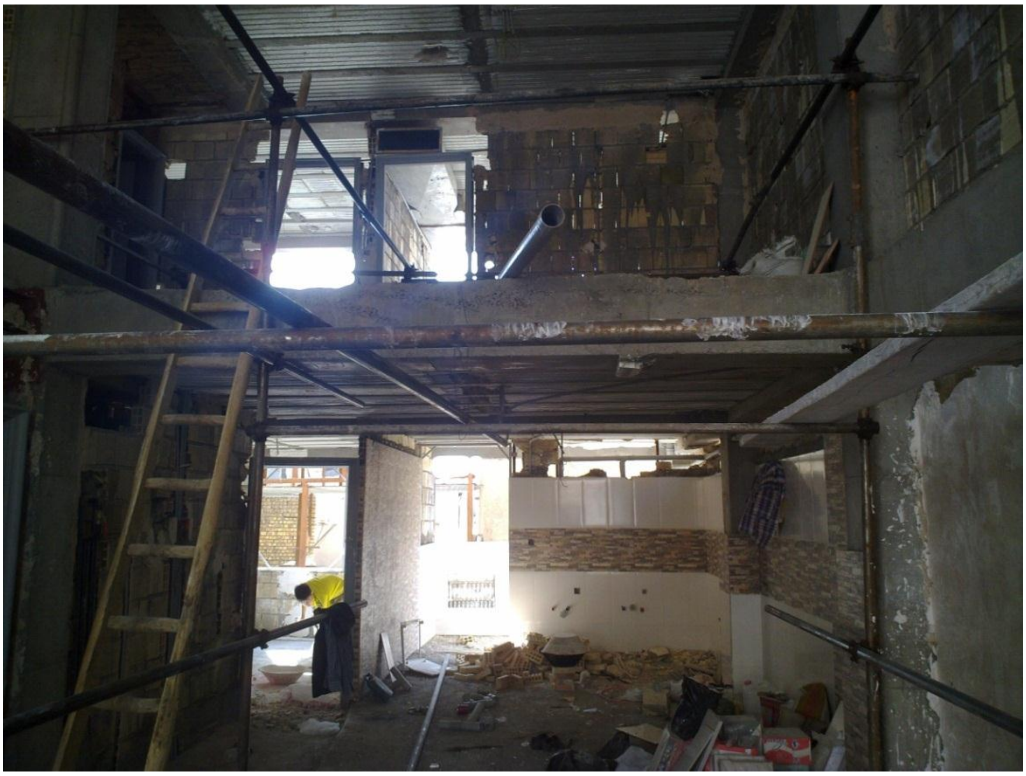


Figure 37: Northern construction work view of the subject house

4.4. Energy Plus and Design Builder Software

Design builder is a state of the art software tool for checking building energy, carbon, lighting and comfort performance which is developed to simplify the process of building stimulation. This stimulation is made with the cooperation of another software which is named energy plus, it is used for modeling building heating, cooling, lighting, ventilating, and other energy flows. Design builder has been specifically developed around energy plus allowing most of the energy plus fabric and glazing data to be input. Databases of building materials, constructions, window panes, window gas, glazing units and blinds are provided. Those programs are approved by BREEAM association.

4.4.1. Software Setting

To begin with the software first of all the location which the building is situated and the station most be specified in order to load the climate information (in this case Iran/Tehran/Mehrabad station), the weather characteristics of the specific area will be loaded and applied over the building (which will be designed later) after the stimulation as the following image:

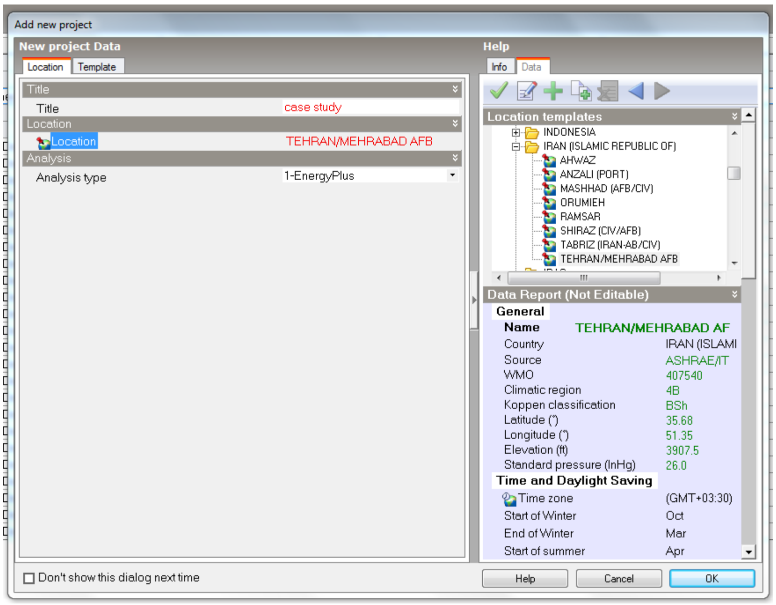


Figure 38: Location setting in design builder

Then with design tool different parts of the building must be design and drawn and then each area with their usage and applications will be specified with walls and partitions, which in this case there is bedrooms, sitting area, kitchen etc. The specification of the area is important to let the program knows which activities will be and with which equipment that will be set later according to their specification. For example if an area will be set as an office then options such as computers or printers will be available. To finish with designing process the opening will be added like doors and windows. In a normal set the windows will be defined automatically by the program but later the characteristics of the openings can be changed as wanted. The chosen window in this case is a 30% glazing with 13mm air and the door is a normal wooden door. As shown in the following image:

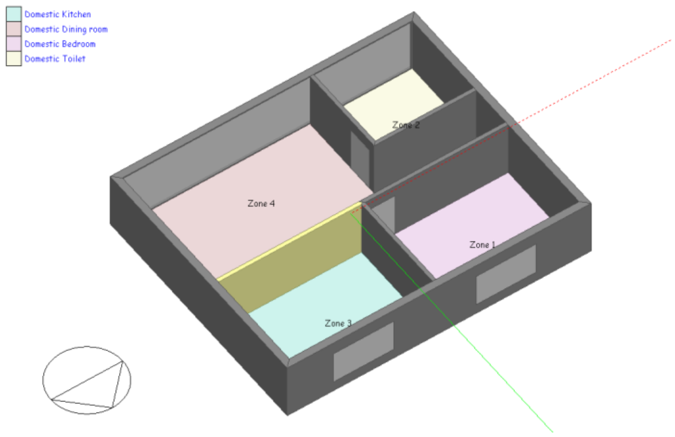


Figure 39: Zoning different parts of a house with design builder (a part of the building)

The next step is to enter the information concerning the activity in each zone of the building, such as the number of people living, electronic equipment and etc. Normally the number of people living is taken as the number of bedrooms plus one person so it means 4 persons, for the metabolic option men and women with children, the rate of summer clothing used is 0.5 clo and for winter 1 clo. A manual light work is set and office equipment also. As shown in the following image:

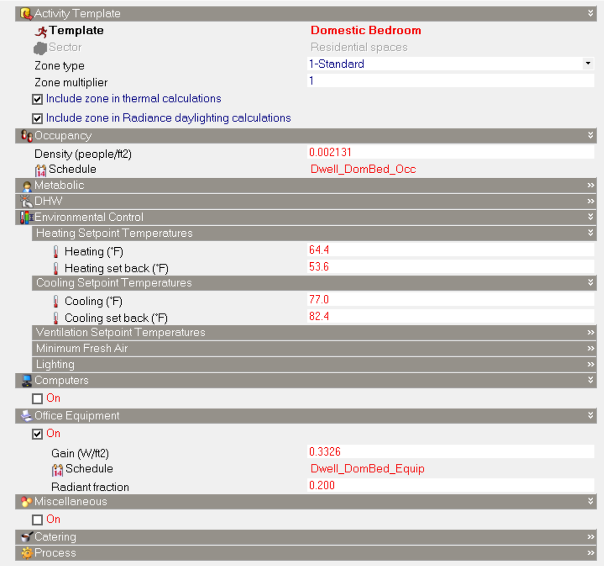


Figure 40: The activity setting in design builder

To continue the construction elements and opening materials and characteristics and heating and cooling systems has to be defined, and then the building is ready to be stimulated. The materials used in the building are explained in the construction part and details are given in the appendices. For the cooling and heating system a fan coil is chosen which for cooling electricity is used as energy and foe heating natural gas. The hot water is set as instantaneous hot water. As shown in the following images:

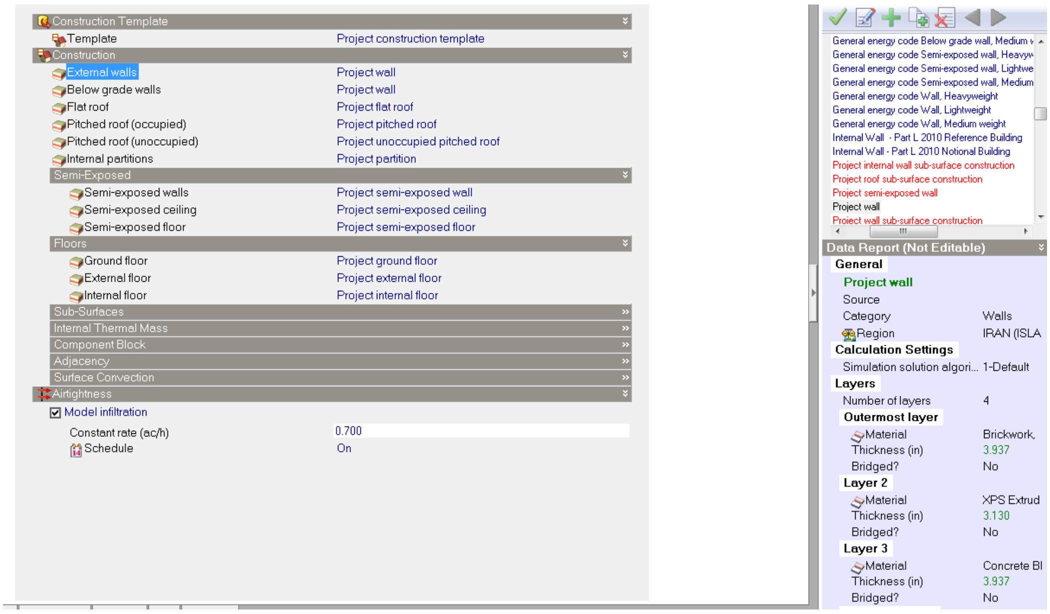


Figure 41: The construction settings in design builder

Figure 42: The cooling and heating setting in design builder

4.5. Stimulation and Analyzes of the Case Study by the Software

When the design of the building is finished and all main information were given the building is ready to be stimulated by the data base given from energy plus software. Four different stimulations are made in this case to have an idea how different factors are acting over the energy consumption and to reach a sustainable design through analyzes of the stimulations. The different cases are: without using insulations and without shading, with the use of insulation but without shading, without the use of insulation but with shading and to finish with the use of both shading and insulation.

The insulation used in cases which possessed it is foam polyurethane (in walls and roof) and the shading system used is the mixed type with 20 cm thickness which they are the standard properties used in Tehran and they were added in the southern windows.

To analyze the results, peak of cooling and heating zone data are taken as information in each case and percentages are obtained by the biggest amount of energy minus the lowest amount of energy and the result obtained from this subtraction is divided by the biggest amount. So then with those results some comparison will be made.

4.5.1. First Case: without Insulation and without Shading

This case is the real case which will show us how much loss of energy will appear in the absence of any thermal characteristic which is the actual case of the building. The total energy consumption is 47291 kWh over a year (which 32185 kWh is concerned to the consumption of electricity and 12324 kWh is concerned to the consumption of gas) with a CO2 emission equal to 24450 kg per year. The peak sensible zone of heating give the result of 17204.84 watts and the peak sensible zone of cooling give the result of 18745.98 watts. The results obtained from the software are as follow:

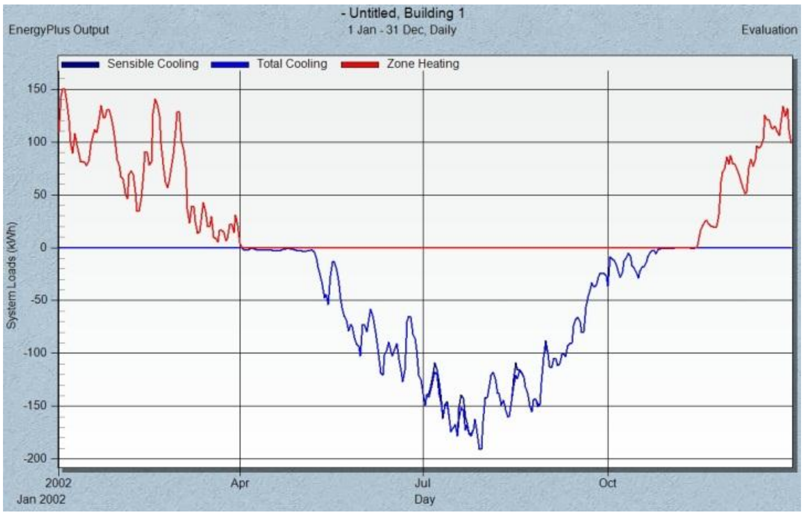


Figure 43: First case stimulation showing total cooling and heating evaluation

4.5.2. Second Case: with Insulation and without Shading

This case is the simulation of the building in absence of shading and with the presence of insulations. The total energy consumption is 45988 kWh over a year (which 31788 kWh is concerned to the consumption of electricity and 11554 kWh is concerned to the consumption of gas) with a CO2 emission equal to 24028 kg per year. The peak sensible zone of heating give the result of 16460.74 watts and the peak sensible zone of cooling give the result of 18021.22 watts. The results obtained from the software are as follow:

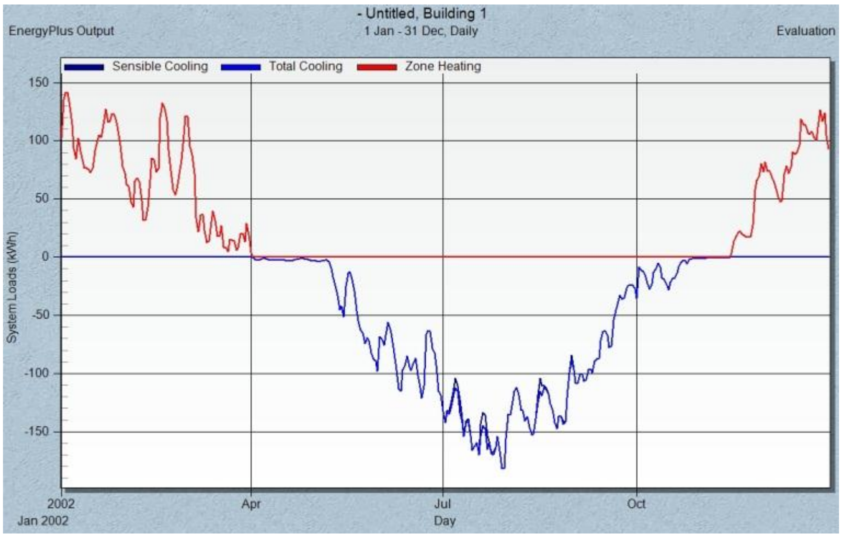


Figure 44: Second case stimulation showing total cooling and heating evaluation

4.5.3. Third case: without Insulation and with Shading

This case is the simulation of the building in absence of insulation and with the presence of shading. The total energy consumption is 46297 kWh over a year (which 31227 kWh is concerned to the consumption of electricity and 13054 kWh is concerned to the consumption of gas) with a CO2 emission equal to 23936 kg per year. The peak sensible zone of heating give the result of 17235.31 watts and the peak sensible zone of cooling give the result of 17314.94 watts. The results obtained from the software are as follow:

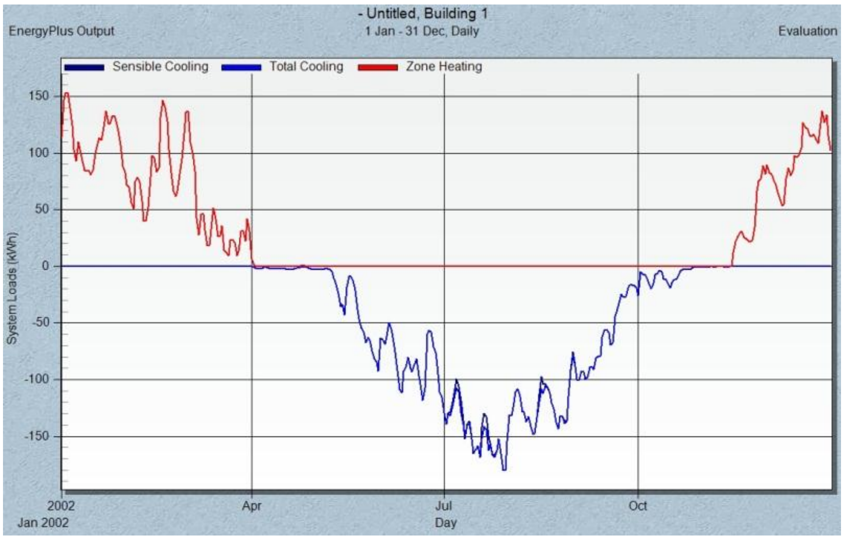


Figure 45: Third case stimulation showing total cooling and heating evaluation

4.5.4. Fourth Case: with Insulation and with Shading

This case is the simulation of the building with the presence of both insulation and shading. The total energy consumption is 45515 kWh over a year (which 31090 kWh is concerned to the consumption of electricity and 11913 kWh is concerned to the consumption of gas) with a CO_2 emission equal to 23620 kg per year. The peak sensible zone of heating give the result of 16753.98 watts and the peak sensible zone of cooling give the result of 16632.88 watts. The results obtained from the software are as follow:

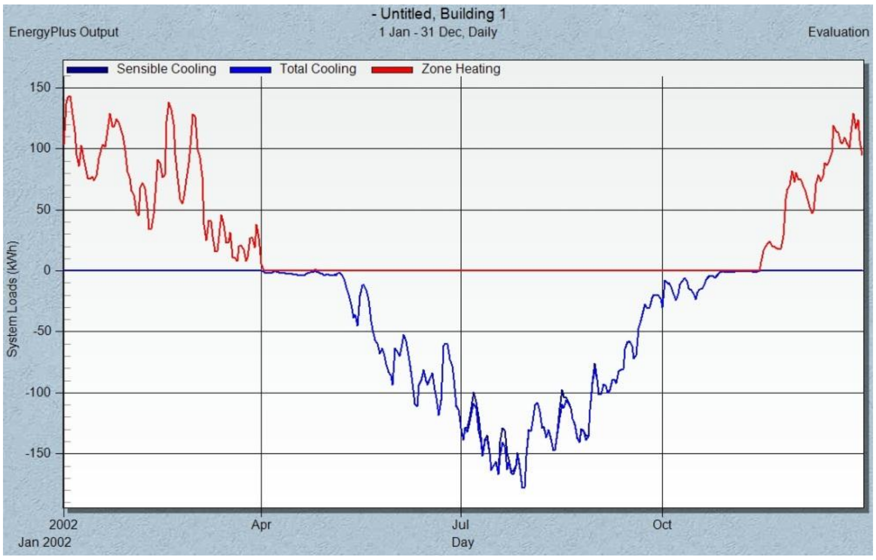


Figure 46: Fourth case stimulation showing total cooling and heating evaluation

4.5.5. Comparison of the Results

By calculating the percentages as explained in part 4.5 some results are obtained which it is managed in following tables while cooling and heating process, these information will show how shading and insulations are affecting the energy consumption (gas and electricity).

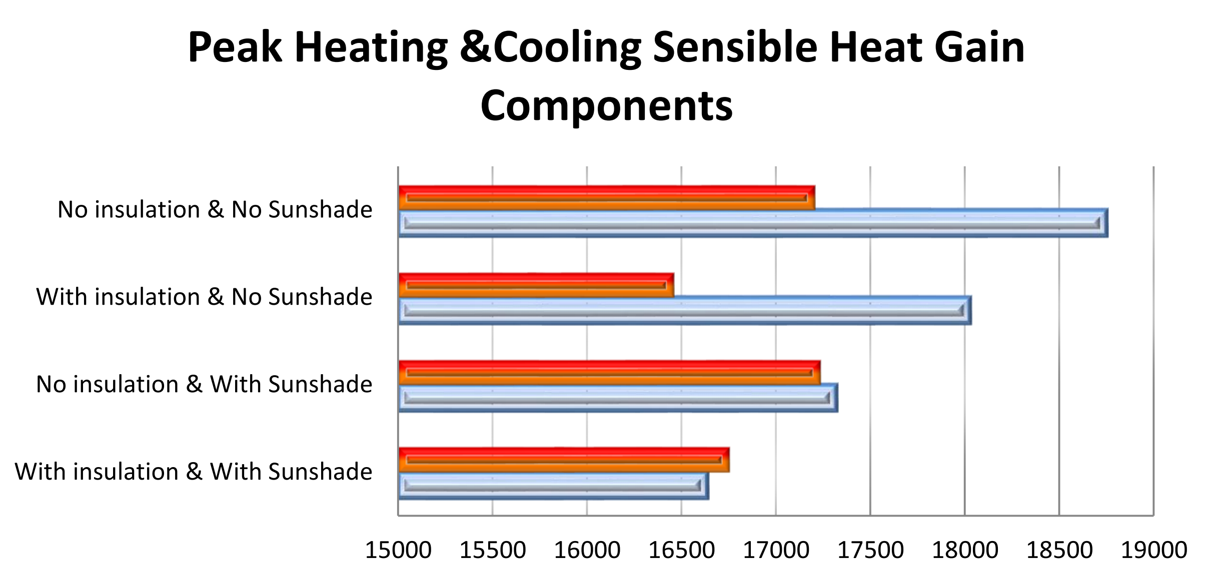
Table 14: Comparison of heating process in percentage in the case study

Comparison of Heating	No insulation & No Sunshade	With insulation & No Sunshade	No insulation & With Sunshade	With insulation & With Sunshade
No insulation & No Sunshade	-----	↓ 4.5 % (Reduce energy)	↑ 0.18% (Increased energy)	↓ 2.7% (Reduce energy)

Table 15: Comparison of cooling process in percentage in the case study

Comparison of cooling	No insulation & No Sunshade	With insulation & No Sunshade	No insulation & With Sunshade	With insulation & With Sunshade
No insulation & No Sunshade	-----	↓ 4.0 % (Reduce energy)	↓ 8.2% (Reduce energy)	↓ 12.7% (Reduce energy)

Table 16: Peak heating and cooling sensible heat gain components



	With insulation & With Sunshade	No insulation & With Sunshade	With insulation & No Sunshade	No insulation & No Sunshade
System Load(w)	16753,98	17235,31	16460,74	17204,84
System Load(w)	16632,88	17314,94	18021,22	18745,98

After the results obtained from energy plus, isolation has an important role to keep warm the building in winter time and keep it cool in summer time. With the use of isolation the building can get 5 degrees hotter in winter time and 10 degrees cooler in summer time. In this case the use of energy will reduce and it will help to reduce the pollution which is an important problem in Tehran. The important fact in choose of the insulations are the heat resistance of them. As much as this resistance gets higher the isolation will reduce the heat transfer which it will help in the economy. So instead of the thickness of the insulation the heat transfer of it has to be compared, different insulations with same heat transfer are equal just the price and the place of use has to be analyzed to be more economical in the use of the energy.

In this comparison we recognize that the insulation will reduce the heat transfer and the use of fuel. But in the comparison of the heat transfers while adding the shading we can recognize that it is useful in summer and reducing the heat transfer but in winter time the result is opposite and there is an increase of heat transfer in certain cases. To resolve this problem tree solution are available:

- Use of the shading with sensors

- Use of cloudy glasses in upper side of the windows

- Exact calculation of shading which will not let the sun radiation enter the house in summer and in another hand let the sun radiation enter the house in winter time.

CHAPTER VI

THE CASE STUDY ASSESSMENT BY BREEAM

The abbreviation of BREEAM corresponds to Building Research Establishment Environmental Assessment Methodology and it's the world primary environmental assessment method and rating system for sustainable buildings, which it was launched in 1990 in United Kingdom.

BREEAM is using a flexible upstanding assessment, transparent, easy to understand and based science which is supported by evidence and research which it tries to have a good effect on the construction, design and management of buildings to characterize and maintain a strong technical measure with high quality assurance and certification.

Broad sector of the users such owners and designers used to depend in BREAM in order to show an environmental responsibility to decrease the bad effects of their buildings on the environment. The buildings are judged by their measure and performance organized by the BRE and gained credits according to their ranges of performance.

The main goal of finding the BREEAM measure was to reduce the bad environmental influence of the buildings and to improve their reputation by their environmental benefits. The harm was to assessment the single building according to environmental performance in the scale of credits. There are 9 various elements measure in BREEAM, such as: materials, management, health and wellbeing, transport, power, pollution, land use and water. Each element contributes of different parts that are necessary to reach some criteria in order to attain BREEAM rating benchmark and to reach the less BREAM standards. In this case study the concentration will be over the energy assessment.

BREEAM certification and assessment is normally based on the performance of the building. When the construction is complete, the assessment will be conducted and certification will be given to the constructor. The diploma is based on reaching the assessor orders issued by a trusting ranking of serious proves of building compliance (BREEAM manual, 2008).

5.1. Benefits of BREEAM

The main benefits of BREEAM are varied from environmental to financial issues, these benefits are beneficial in order to have less impact over the environment with a lower cost in the construction of the building and then in the energy consumption and expenses. Those benefits can be mentioned as follow: (BREEAM manual, 2008)

- Improving sustainability credentials to the official planning authorities for a downy passage through the planning process

- Improving high quality of environmental design outcome

- Decreasing high costs through better power and water efficiency and decline the maintenance

- Healthy, Convenient and elastic internal environments

- Convenient access to local utilities

- Limit the reliance on the vehicles

- Permit the developers to be very close of the organization

- Show commitment with environmental requirements from the owners, planners development agencies and developers

- Environmental evidence of supporting high corporates strategy or as an individual input

- Incumbents benefits in order to provide a better place for users in the level working and living

- Marketing, as a selling point to possible tenants or customers

- Economically, to get the most better rental incomes and improve the building efficiency

- Best attitude to get checklist or tool for comparing buildings

- Client request give a big importance to the users requirements

5.2. BREEAM Assessment

The BREEAM assessment and weighting system is divided in different categories which is evaluating the building in every possible side to have a better definition of sustainability and a better practice of sustainable elements in a building, those different categories are: health and wellbeing, management, energy (which will be focused on for the thermal performances of the case study), water, transport, materials, waste, land use, ecology and pollution. An extra point is corresponded for innovations in each category of the assessment.

Management is one of the most important steps which will guide all the project of construction, so this will be to recognize and improve an appropriate level of building services commissioning that is considering in a coordinate and understandable manner and the best performance has to be ensured. Some elements have to be considered in this category such as: the sustainable procurement, a responsible construction practice, the impact of the construction site, the participation of the stakeholder and there must be a planning on the life cycle cost and services.

The health and wellbeing section has for aim to give the maximum use and access of the daylight which will bring a comfortable situation inside the building by considering elements such as: visual comfort, indoor air comfort, thermal comfort, water quality, acoustic performance and security and safety.

The energy section has to recognize and improve buildings that are planned to minimize the CO2 emissions incorporated with their operational power consumption by considering elements such as: reduction of emission, energy monitoring, external lighting, low and zero carbon technologies, energy efficient cold storage, energy efficient transportation system, energy efficient equipment and drying space.

The transport section has to recognize and improve development in order to achieve a good public transport networks, that could help to decrease transport related emissions and traffic congestion with considering elements such as: public transport accessibility, proximity to amenities, max car parking capacity and travel plan.

The water section is about to limit the consumption of drinkable water in sanitary applications by encouraging the use of low water use fittings by considering elements such as: water consumption, water monitoring, water leak detection and prevention and water efficient equipment.

The material section has to recognize and improve the use of construction materials with a less environmental effect on the total life cycle of the building by considering elements such as: life cycle impacts, hard landscaping and boundary protection, responsible sourcing of material, insulation and designing for robustness.

The waste section has to increase resource efficiency from the effective and improve management of construction site waste by considering elements such as: construction waste management recycled aggregate, operational waste and speculative floor and ceiling finishes.

The land use and ecology section has to support the reuse of land that used to be developed and discourages the use of last undeveloped land for building by considering elements such as: site selection, ecological value of site, mitigating ecological impact, enhancing site ecology and long term impact on biodiversity.

The pollution section has to decrease the contribution to climate differentiation from refrigerants with a high potential of global warming by considering elements such as: impact of refrigerants, NOx emission, surface water runoff, reduction of night time light pollution and noise attenuation.

5.3. BREEAM Rating and Weightings System

Environmental weightings are necessary to each environmental building assessment method as they supply a means of defining, and therefore ranting, the comparative contact of environmental subjects. BREEAM provide a clear weighting system made from a mixture of examination and questionnaire based weightings and rating by a group of experts. The results from this examination are then analyzed to define the respective value of the environmental sections used in BREEAM and their portion to the overall BREEAM grade.

This weighting system is characterized in higher detail within the BRE Global Core Process Standard and it’s supporting procedural documents. These form part of the overarching BREEAM Standard and the code for a sustainable built environment. The similar rating of impacts provide in BREEAM underpins the scoring systems in the BRE green guide to specification and the BRE Environmental Profiling Method for construction materials. BREEAM uses a means of adjust these weightings to carry out weightings special to the region or country of assessment (BREEAM manual 2008).

This table demonstrates the environmental weightings of the nine BREEAM parts for the type of building projects that BREEAM Buildings can be used to assess.

Table 17: BREEAM assessment ratings (BREEAM manual, 2008)

Environmental section	Weighting
Management	12%
Health & Wellbeing	15%
Energy	19%
Transport	8%
Water	6%
Materials	12.5%
Waste	7.5%
Land Use & Ecology	10%
Pollution	10%
Total	100%
Innovation (additional)	10%

After the weighting according to the percentage that the building could obtain the building will be rated and scored as unclassified, pass, good, very good, excellent and outstanding. The following table shows the rating section of the BREEAM assessment:

Table 18: BREEAM rating system (BREEAM manual, 2008)

BREEAM Rating	% score
UNCLASSIFIED	<30
PASS	≥30
GOOD	≥45
V GOOD	≥55
EXCELLENT	≥70
OUTSTANDING	≥85

5.4. Energy Assessment of the Case Study by BREEAM

To achieve the rating of the thermal performance of the case study by BREEAM requirements, the focus of the study will be over the energy section (ene01), which contains 15 credits and the available contribution to the overall scoring will be 11.40%. This part of the assessment will be calculated by an excel program which the name is BREEAM pre assessment estimator. To complete this calculation by the calculator data such as building floor area, notional building energy demand, actual building energy demand, notional energy consumption, actual building energy consumption, target emission rate and building emission rate has to be given and fulfilled in the grid as done in the following table:

Table 19: Rating calculation by the ene01 calculator of the case study

BREEAM 2011 New Construction Pre-Assessment Estimator BREEAM®

This assessment and indicative BREEAM rating is not a formal certified BREEAM assessment or rating and must not be communicated as such. The score presented is indicative of a buildings potential performance and is based on a simplified pre-formal BREEAM assessment and unverified commitments given at an early stage in the design process.

Ene01 Reduction of CO_2 Emissions

No. of BREEAM credits available	15	Available contribution to overall score	11.40%
No. of BREEAM innovation credits available	5	Minimum standards applicable	Yes

How do you wish to assess the number of BREEAM credits achieved for this issue?	Enter building performance data into the Ene01 calculator

Ene01 Calculator

Ene01 Calculator and Key Performance Indicators

Building floor area	130	m2
Notional building energy demand	610.00	MJ/m2/annum
Actual building energy demand	370.00	MJ/m2/annum
Notional building energy consumption	90.00	kWh/m2/annum
Actual building energy consumption	274.00	kWh/m2/annum
Target Emission Rate (TER)	63.00	kgCO2/m2/annum
Building Emission Rate (BER)	53.70	kgCO2/m2/annum
Building improvement over TER	15.00%	
Demand Energy Performance Ratio (EPR)	0.2343	
Consumption Energy Performance Ratio (EPR)	0.0000	
CO_2 Energy Performance Ratio (EPR)	0.1264	
Overall Building Energy Performance Ratio (EPR_{NC})	0.3606	

What is the equivalent % of the building's 'regulated' energy consumption that will be generated by carbon neutral sources and used to meet energy demand from 'unregulated' building systems or processes?	
Is the building designed to be 'carbon negative' ?	

Total indicative BREEAM credits achieved	6
Total indicative contribution to overall building score	4.56%
Total indicative BREEAM innovation credits achieved	0
Indicative minimum standard(s) level	Pre-Assessment result indicates the minimum standards for Very Good level

Notional building energy demand: A hypothetical building with an equal size and shape as the main building, but with pre-defined special properties for the building fabric, fittings and services. After Cambridge urban and architectural studies some approximate values are given, for houses the approximate energy demand is 610 MJ/m^2/year (Littler and Thomas, 2003).

Table 20: Delivered energy demand by Cambridge urban and architectural studies

Building type	Delivered energy demand (MJ/m^2 floor area/y)
(1) Commercial glass houses[a]	2500
(2) Large office buildings and large shops[b]	1700
(3) 1975 schools[c]	1280
(4) 2000 low-energy school target[c]	600
(5) 1982 house[d]	610
(6) Extremely well-insulated house of the future[e]	300

Actual building energy demand: This is the predicted building's energy demand as designed expressed as MJ/m^2/year and calculated in accordance with approved building energy calculation software (design builder). This value is equal to 370 MJ/m2/year.

Notional building energy consumption: this value is gotten from the EPC (energy performance certificate), which is divided from A to G. The A grade is for an energy consumption from less than 51 kWh/m^2/year which is the perfect situation. The grade B is for an energy consumption going from 51 to 90 kWh/m^2/year. The grade C is for an energy consumption going from 91 to 150kWh/m2/year. The grade D is for an energy consumption going from 151 to 230kWh/m2/year. The grade E is for an energy consumption going from 231 to 330kWh/m2/year. The grade F is for an energy consumption going from 331 to 450kWh/m2/year. The grade G is for an energy consumption for more than 451kWh/m2/year. Which in our case the grade B (90 kWh/m2/year) has been in account cause the minimum standards are for the very good level (Olivier and Plante, 2010).

Actual building energy consumption: This is the predicted building's energy consumption as designed expressed as kWh/m2/year and calculated in accordance with approved building energy calculation software (design builder). This value is equal to 274kWh/m2/year.

Target emission rate: is the minimum standard of CO2 emission of a house, expressed in $kgCO2/m^2$/ year. The recommended value of emission by BREEAM for a detached house is 63 kgCO2/m2/ year.

Building emission rate: This is the predicted building's CO2 emission rate as designed expressed as kgCO2/m2/year and calculated in accordance with approved building energy calculation software (design builder). This value is equal to 53.7kgCO2/m2/year.

So after the rating process the case study got 6 credits over 15. That can be translated as 40 percent of the total score attributed to the energy section. So after the BREEAM rating system this building in the energy section is qualified as pass.

Those points accredited to this building were actually gained by the help of getting in consideration while designed elements such as:

The building orientation, the main side of the building is faced to the south with high windows using the maximum solar energy.

The shape of the building, totally squared shaped so with fewer joints and less heat loss and high elevation in the south getting more contact with solar radiation and gaining more heat.

Windows emplacement and shape, high windows in the south for the daily used areas with more solar gain and small windows in the south for less used areas and less energy loss. Also the windows are double glazed which it can be considered as an insulation.

Material such as clay is reacting as insulation and getting the warm from the morning time and spread it to the building in the evening time which they are used in the walls. Being ground coupled has the same characteristic.

Those elements are sure not enough to reach BREEAM assessment goals. For the improvements in this rating systems better insulations and shading has to be used as shown in the appendix 3. Insulation such as fiber glass are not much expensive and can be applied easily, in the terms of shading a movable shade which will block the sun in the summer time and let it inside in the winter time will be favorable, as shown in the appendix 3. But as the main goal of BREEAM is to reach a small amount of CO_2 emission and energy consumption the element that has to be in consideration in first case is the use of solar panels and natural energy gaining.

CHAPTER VII

CONCLUSION

Tehran is the capital of Iran, which is situated in longitude 51, 23 E and latitude 35, 41 N. Tehran has a semiarid climatic condition with hot and dry summer and cold winter. This city has encountered a big agglomeration through years so a large amount of building construction has been done without taking care about its urban design and sustainable design, that now a days is suffering with a serious problem of pollution, due to traffic jams and irresponsible energy consumption by the habitants. The geographical situation of Tehran that the main characteristic is that it is situated in a pit surrounded by mountains from north, east and west makes the air pollution immovable, so finding a solution to decrease the energy consumption and CO2 emission in buildings which they are already built, will be a good help and a solution to this problem.

The case study is situated in the north east of Tehran, with 130 m2 of floor area. Structurally the building is well designed; the main elevation is oriented to the south with large windows using the daylight gratefully and small windows in the north side because of the colder conditions in winter time. The repartition of spaces is enough good the main areas used in morning time are situated in the south side using the daylight and others in the north, but the lake of shading is remarkable because of the hot summers in Tehran is causing problem. In terms of construction have not so much performances cause of the total absence of insulations the only positive point is that building is ground coupled so it is reacting as insulation for the ground area.

The factors affecting the thermal performances of a building which can be applicable in an already built building are the insulations and the shading. The stimulations made by the software approved by BREEAM, shows that by the use of insulations and shading we can reduce the energy consumption and CO2 emission, the normal case has a consumption of energy equal to 47291 kWh per year and a CO2 emission equal to 24450 kg per year and then by improving the situation with the use of insulation and shades this values are reduced to 45515 kWh per year for the energy consumption and 23620 kg per year for the emission of CO2. This can be translate as a gain of 1776 kWh of energy per year and with a reduce of 830 kg of CO_2 emission. This will be a remarkable value if the numbers of buildings existing in Tehran will be taken in account.

The case study building by being assessed by BREEAM criteria and requirements in the energy section got 6 credits over 15; in another way to express it is equal to 40 percent of the overall score so it is ranked as “pass” in the BREEAM assessment. This is a poor rate for a building. To increase the rate, the consumption of energy and the CO_2 emission has to be decreased, for that elements such as good insulation (fiber glass), movable shades and use of sun panels will be a good help. Those elements can be applicable over already built buildings with not much costs but good results.

After the appendix 2 and the calculation made by considering the geographical situation of the subject house designed by architect Amir Bazouvarz, the most suitable shading which can be used on this case is a movable over hang with 1 meter of thickness that is situated 50 cm up of the southern windows. The calculation gives the opportunity to have the extreme situations and the ability of being movable makes it in a way to use the best energy of sun light during the year and makes it more energy efficient. As the building is detached from other surrounding buildings for the best result outer insulation can be used for better energy preservation.

REFERENCES

Akhtar Kavan (2010). Setting in harmony with ecological and climatic conditions of Iran. Tehran: Vaziri (Shomiz).

Allard, F. (1998). Natural ventilation in buildings: a design handbook. London: James and James (Science Publishers) Ltd.

ASHRAE Standard (2013). Thermal Environmental Conditions for Human Occupancy. Atlanta, GA.

Bauer, M., & sle, P. (2010). Green building guidebook for sustainable architecture. Heidelberg: Springer.

Bradshaw (1993), Building control system. New York: John Wiley & Sons.

Cavendish, M. (2006). World and its peoples. New York.

Chiras, D. D. (2002). The solar house: passive heating and cooling. White River Junction, VT: Chelsea Green Pub.

Fathy, H., & Shearer, W. (1986). Natural energy and vernacular architecture: principles and examples with reference to hot arid climates. Chicago: Published for the United Nations University by the University of Chicago Press.

Gallo, C. (1998). Architecture comfort and energy. New York: Elsevier Science.

Gut, P., & Ackerknecht, D. (1993). Climate responsive building. St. Gallen, Switzerland: SKAT.

Halliday, S. (2008). Sustainable construction. Amsterdam: Elsevier Butterworth-Heinemann

Hamidpour, R. (2010). Land of lion, land of sun. S.l.: Authorhouse.

INNOVA (1997), HVAC handbook.

Jacobson, M. Z. (2002). Atmospheric pollution history, science, and regulation. Cambridge, UK: Cambridge University Press

Lang, K., & Rajabi, A. (2003). The book of Iran: a survey of the geography of Iran. Tehran: Center for International-Cultural Studies.

Littler, J., & Thomas, R. (1984). Design with energy: the conservation and use of energy in buildings. Cambridge [Cambridgeshire: Cambridge University Press].

Martinez (1995). Human thermal comfort.

Olgyay, A., & Olgyay, V. (1957). Solar control & shading devices. Princeton: Princeton University Press.

Olgyay, V. (1963). Design with climate: Bioclimatic approach to architectural regionalism, Princeton, N.I. Princeton University Press.

Pasek & Bosova (2014). Advanced material researches.

Phillips (2014). Day lighting: Natural light in architecture.

Plante, M. (2010). For energy efficiency (EE) a home energy rating system : research project final report. Montréal, Qué.: Union des consommateurs.

Roaf, S., & Fuentes, M. (2001). Ecohouse a design guide. Oxford: Architectural Press.

Sassi, P. (2006). Strategies for sustainable architecture. London: Taylor & Francis.

Szokolay, S. V., & Brisbin, C. (2010). Introduction to architectural science: the basis of sustainable design. Amsterdam: Elsevier, Architectural Press.

Vancouver city council. (2009). *"Passive design toolkit for homes".*

Wilson, A., & BuildingGreen, I. (2008). Green building products: the GreenSpec® guide to residential building materials (3rd ed.). Brattleboro, VT: BuildingGreen.

http://en.wikipedia.org/wiki/Tehran (15/10/2013)

http://en.wikipedia.org/wiki/Environmental_issues_in_Iran (20/10/2013)

http://www.shomera.ie/thermal-performance-in-buildings (10/01/2014)

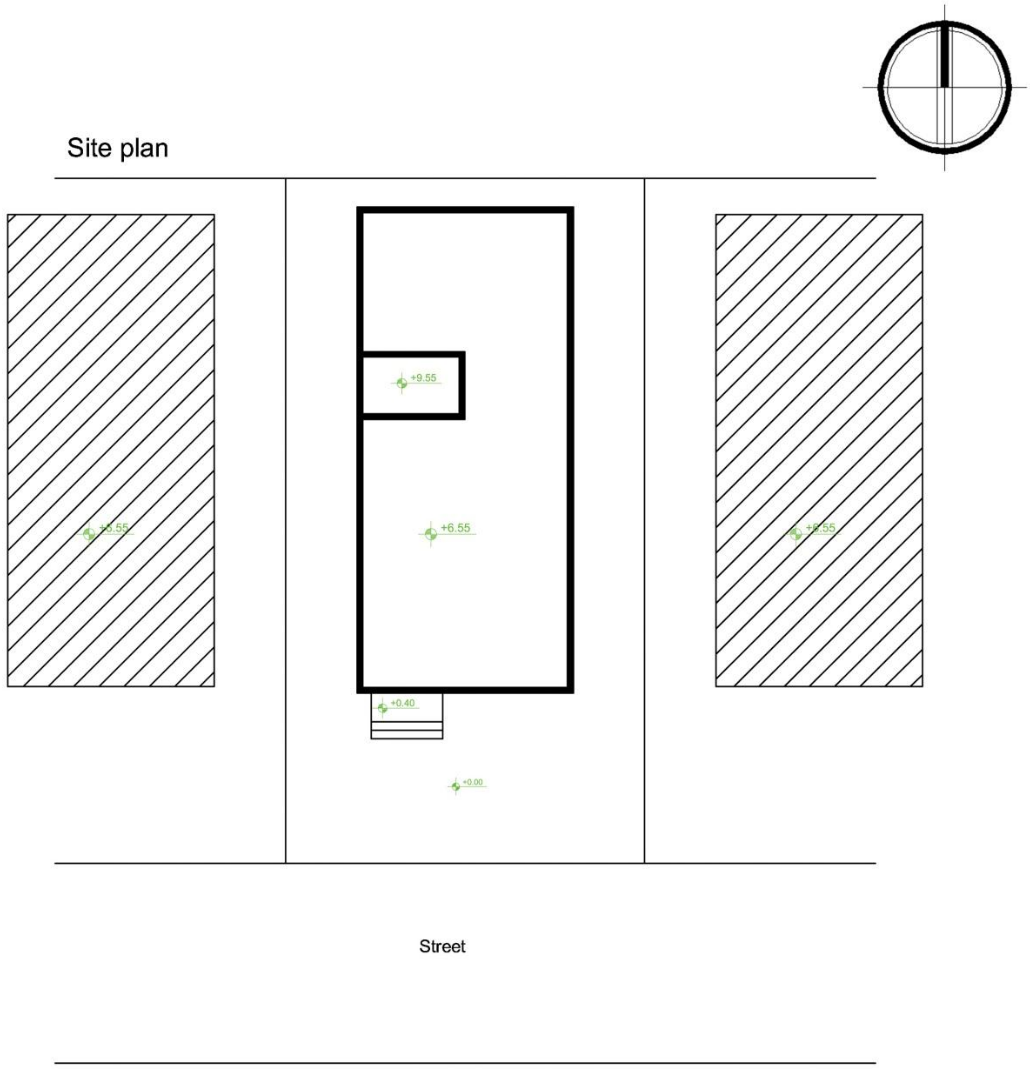
http://sustainabilityworkshop.autodesk.com/buildings/building-orientation (12/02/2014)

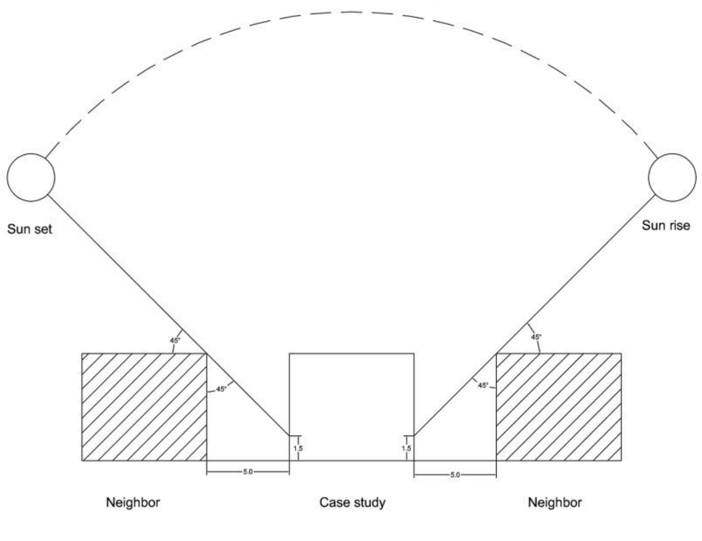
http://sustainabilityworkshop.autodesk.com/buildings/wind-ventilation (15/02/2014)

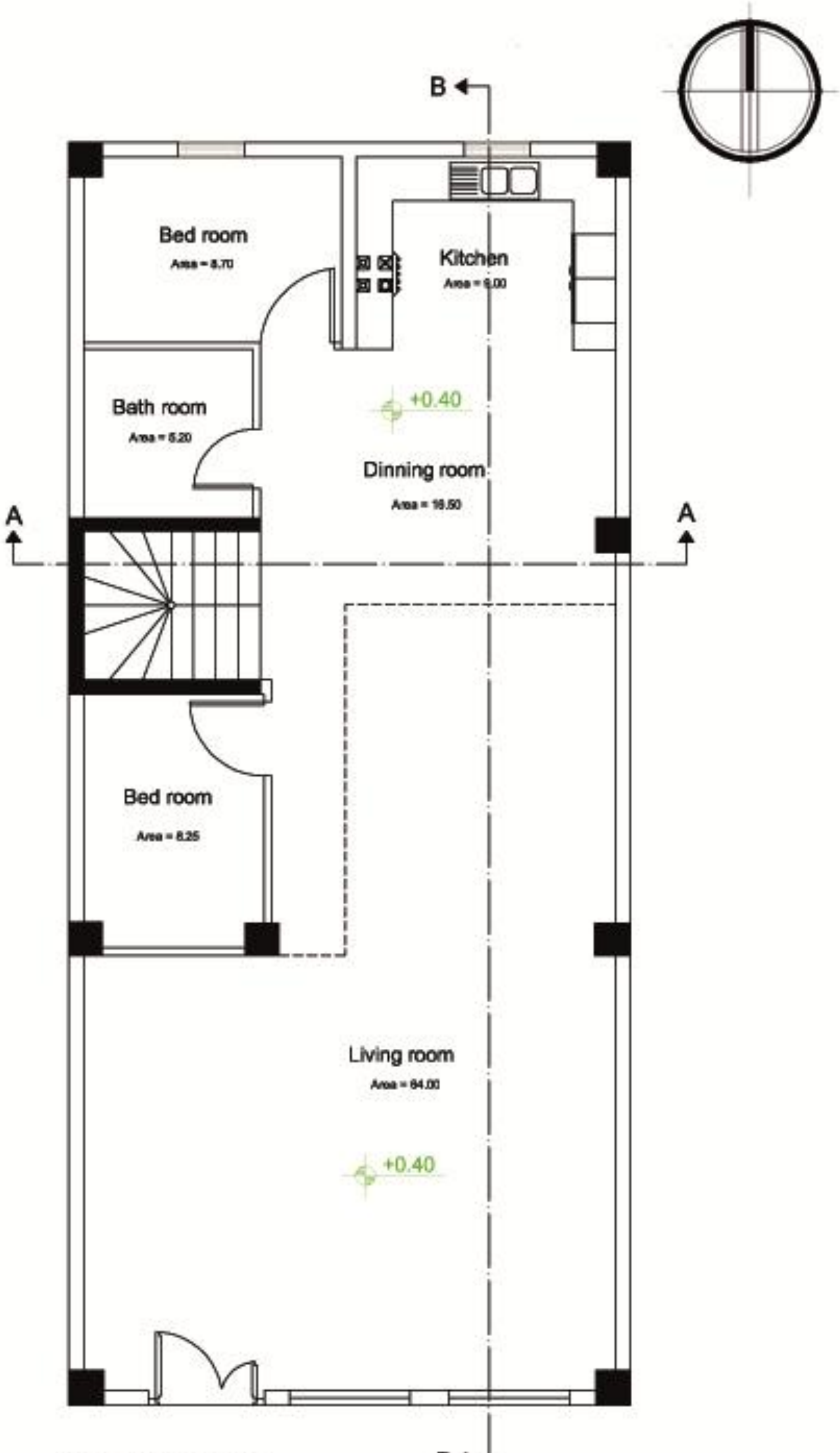
APPENDICES

APPENDIX 1:

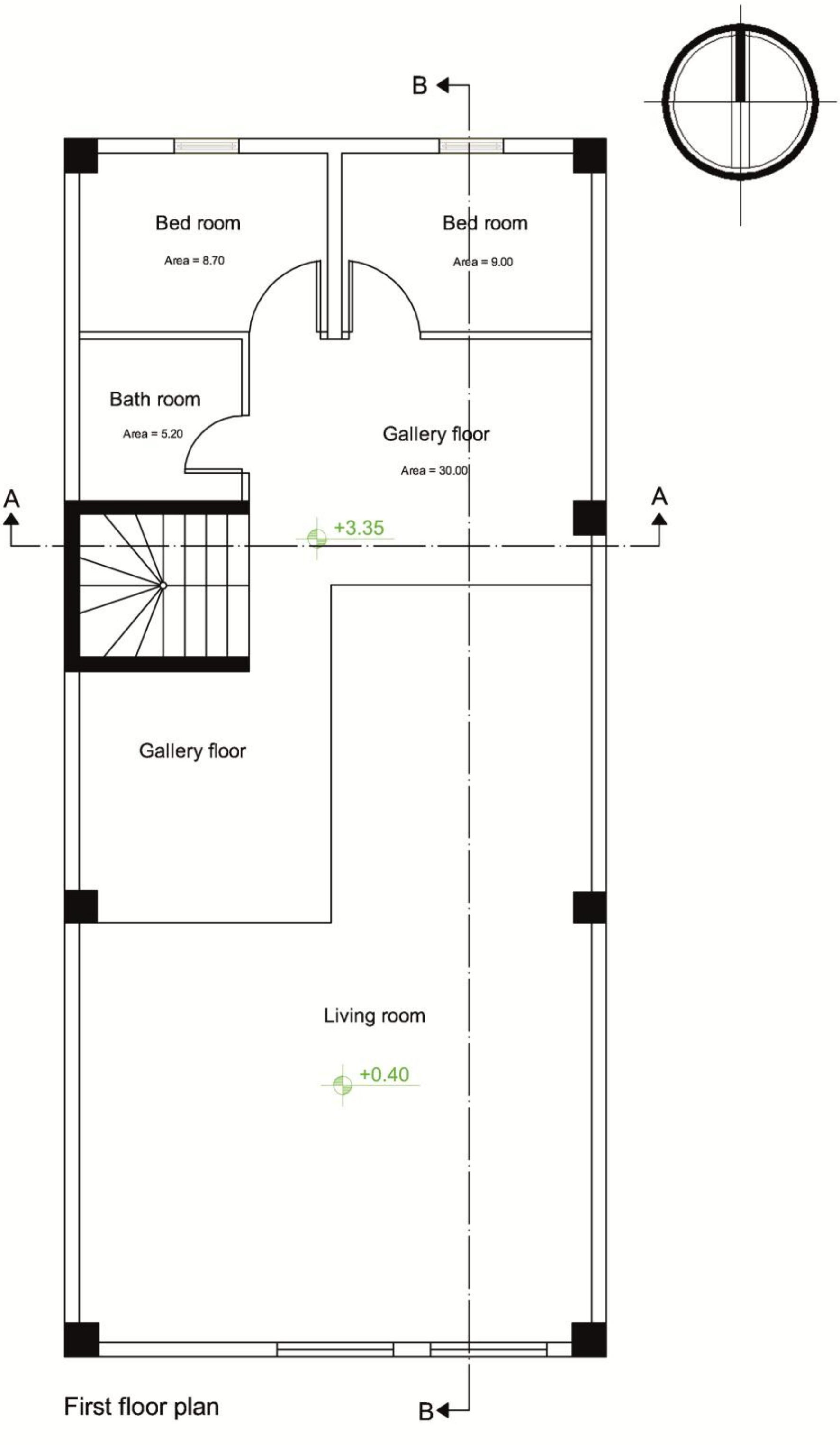
PLANS OF THE BUILDING



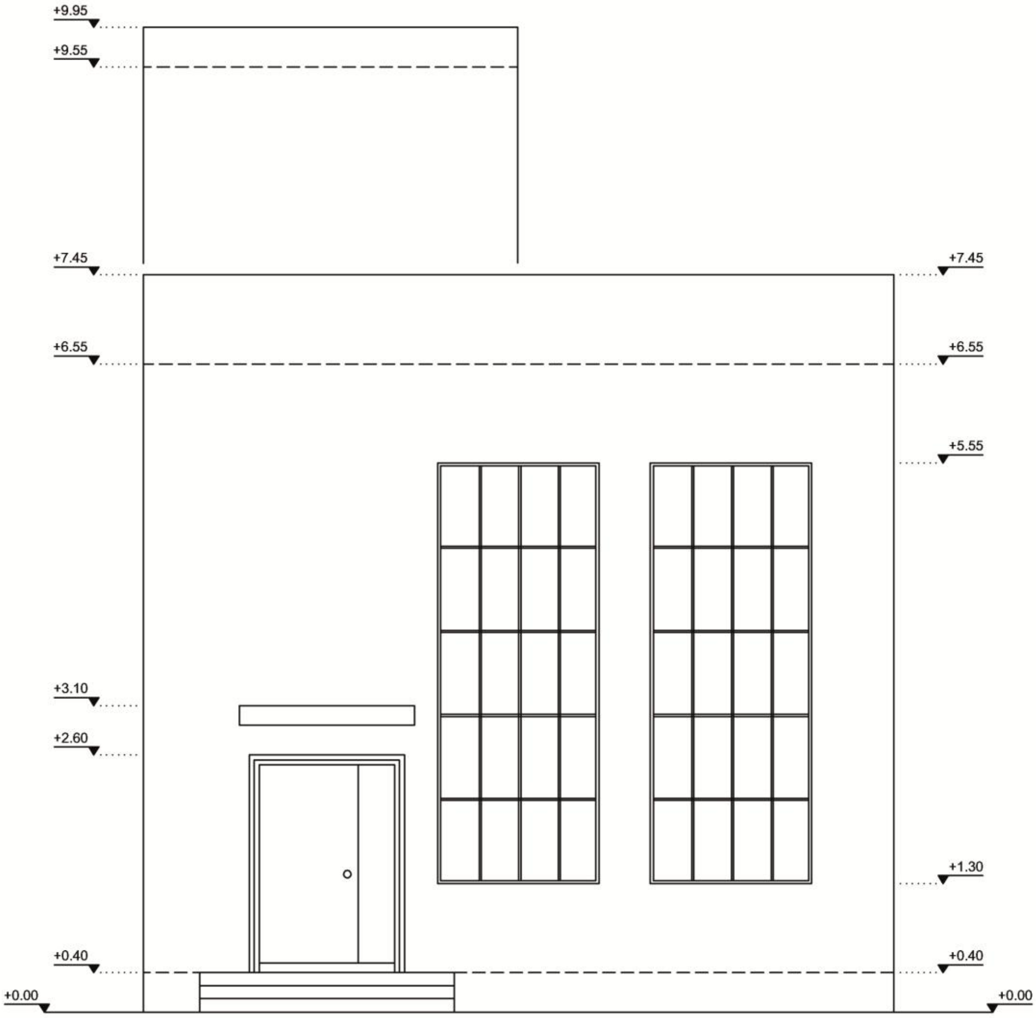




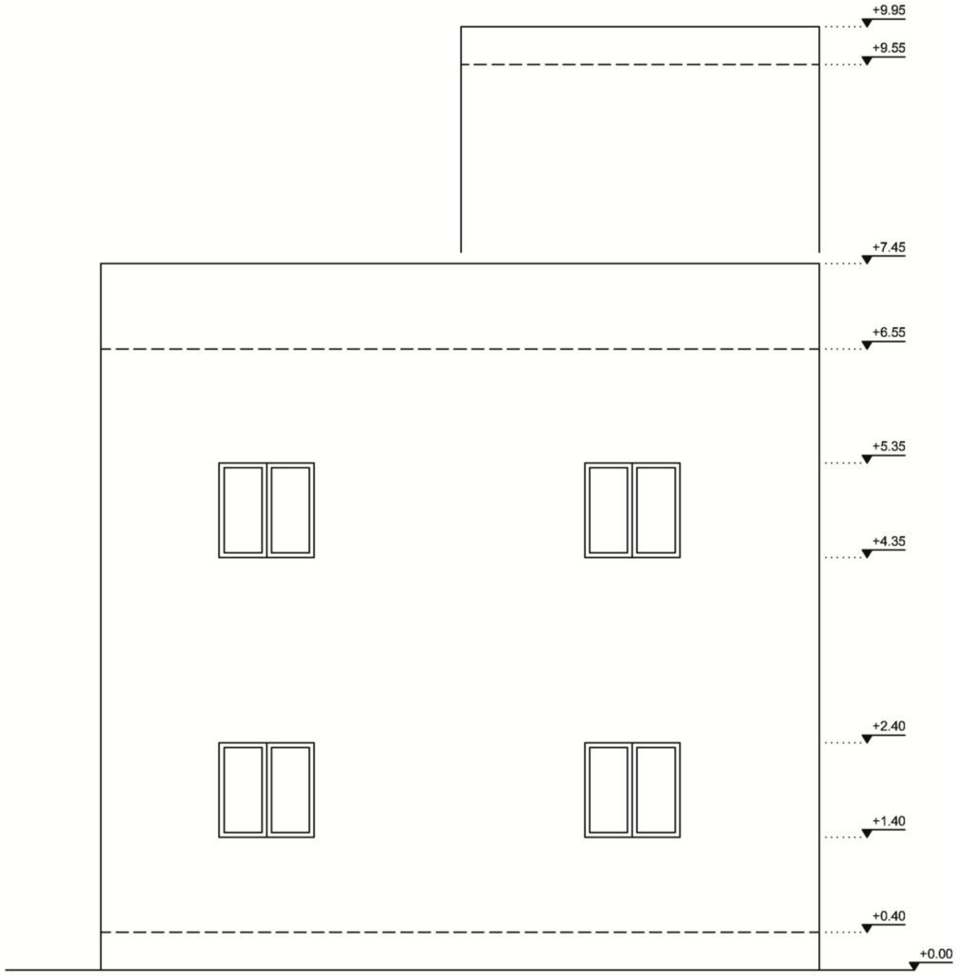
Ground floor plan



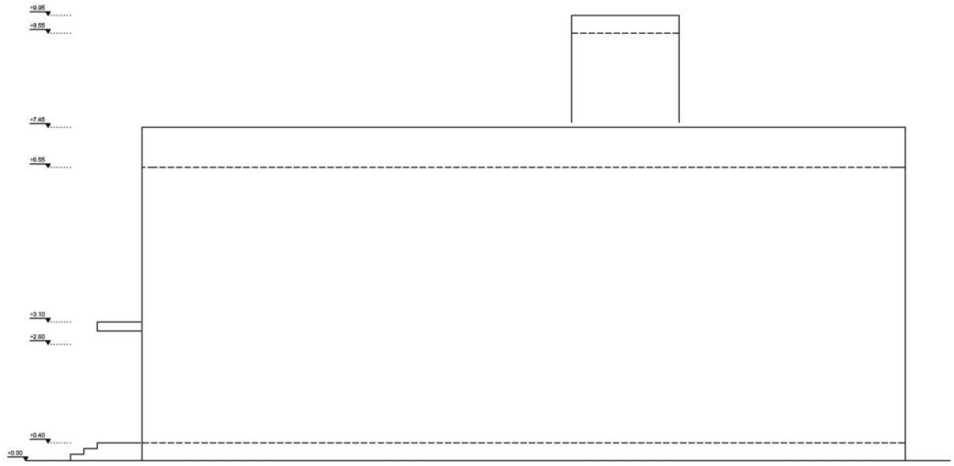
First floor plan



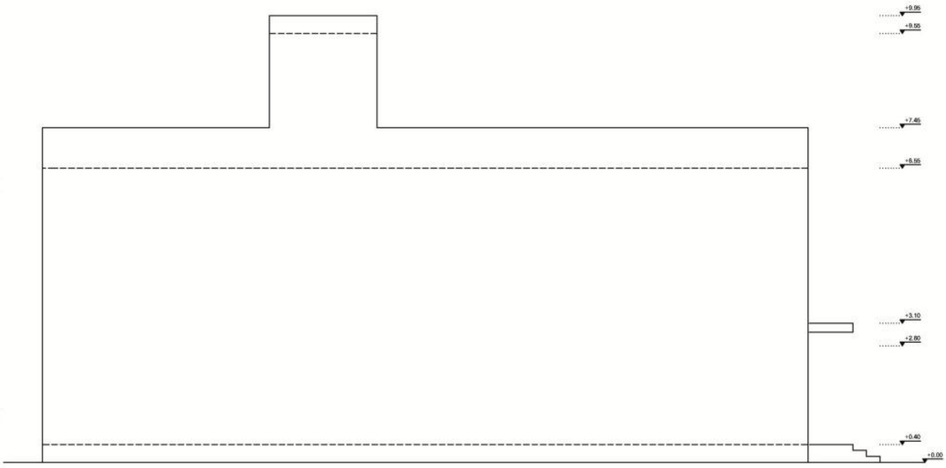
Front elevation



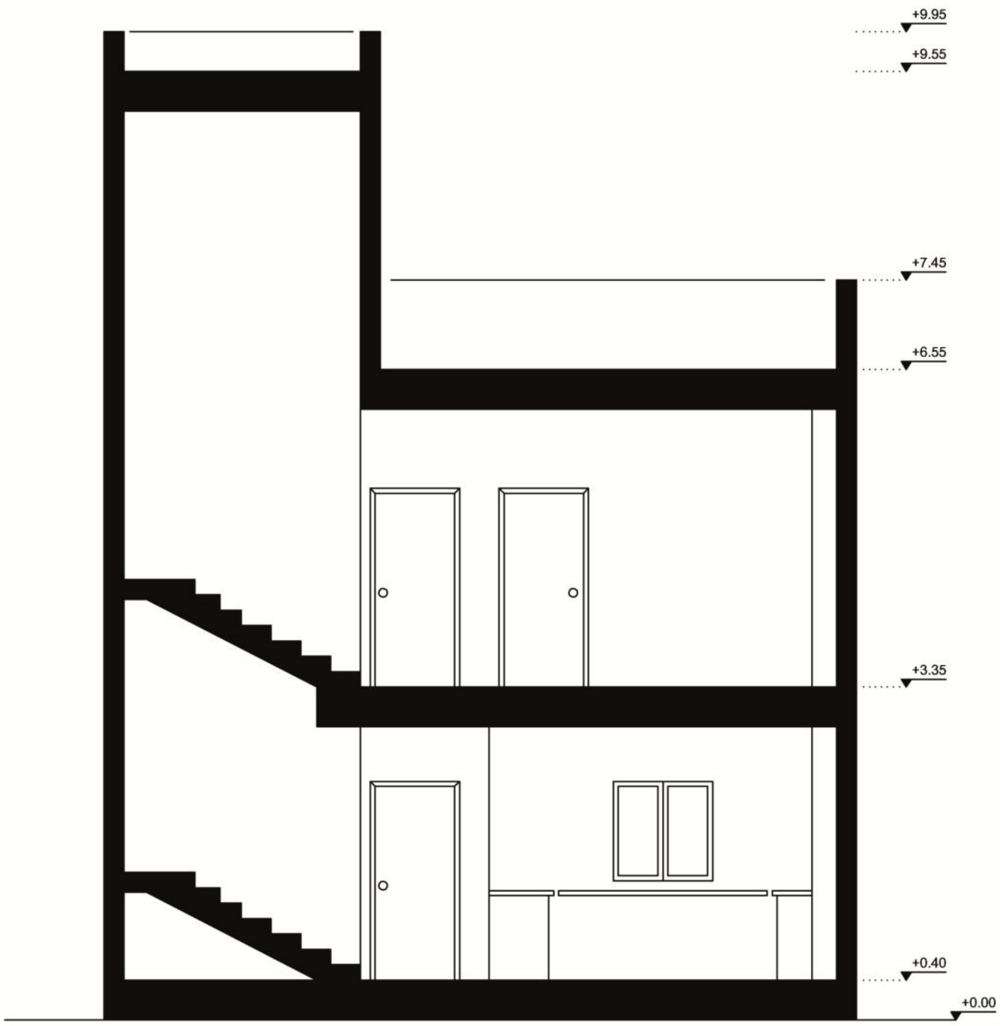
Back elevation



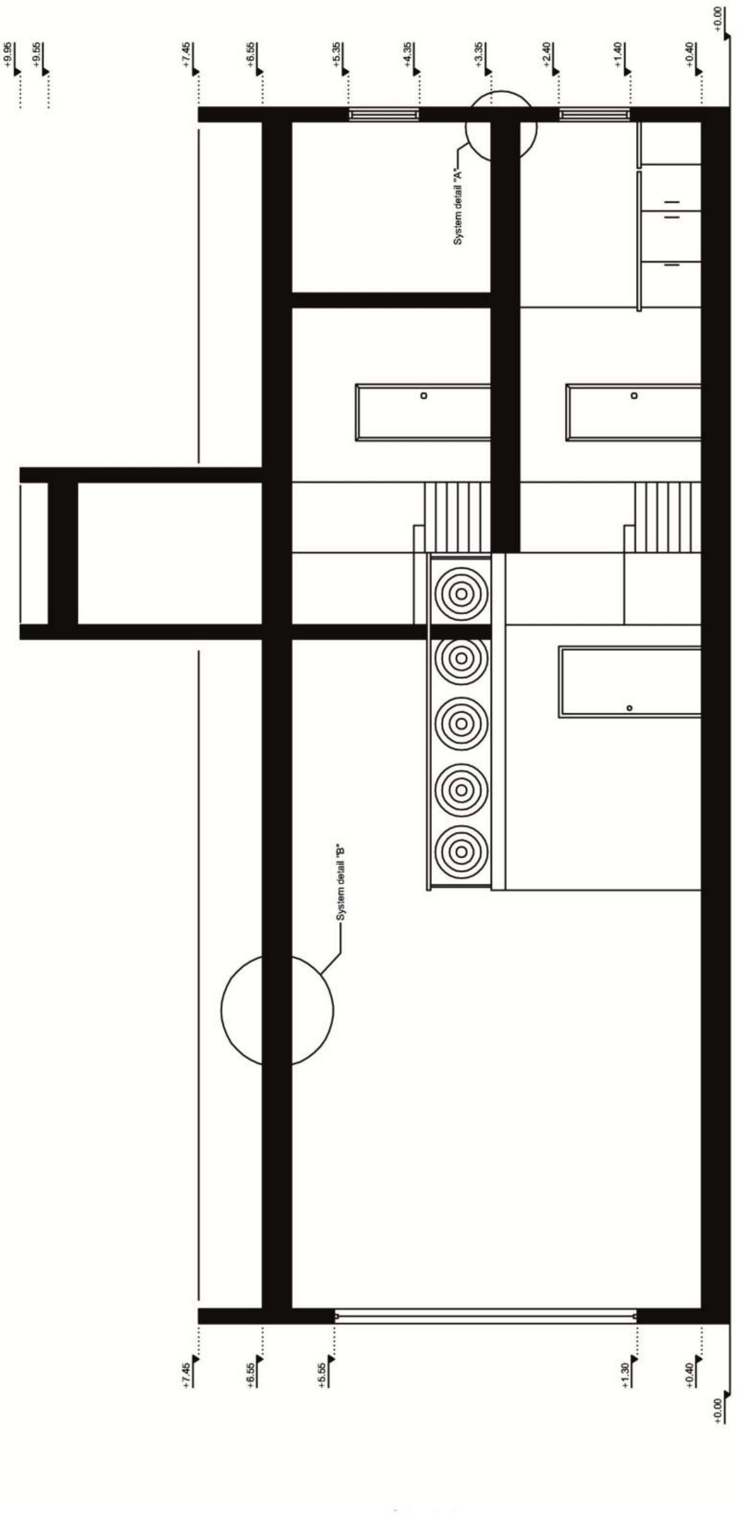
Right elevation



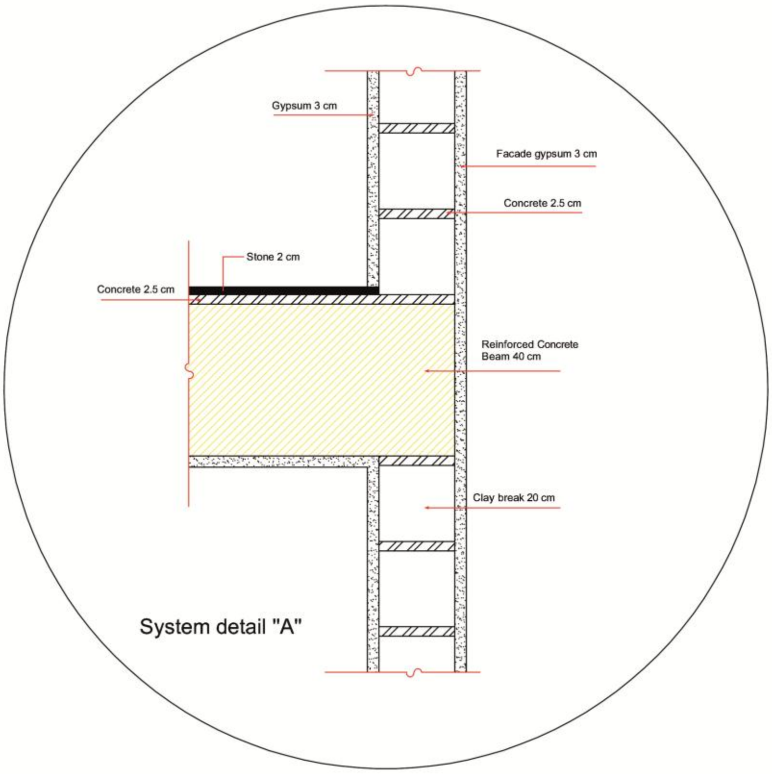
Left elevation

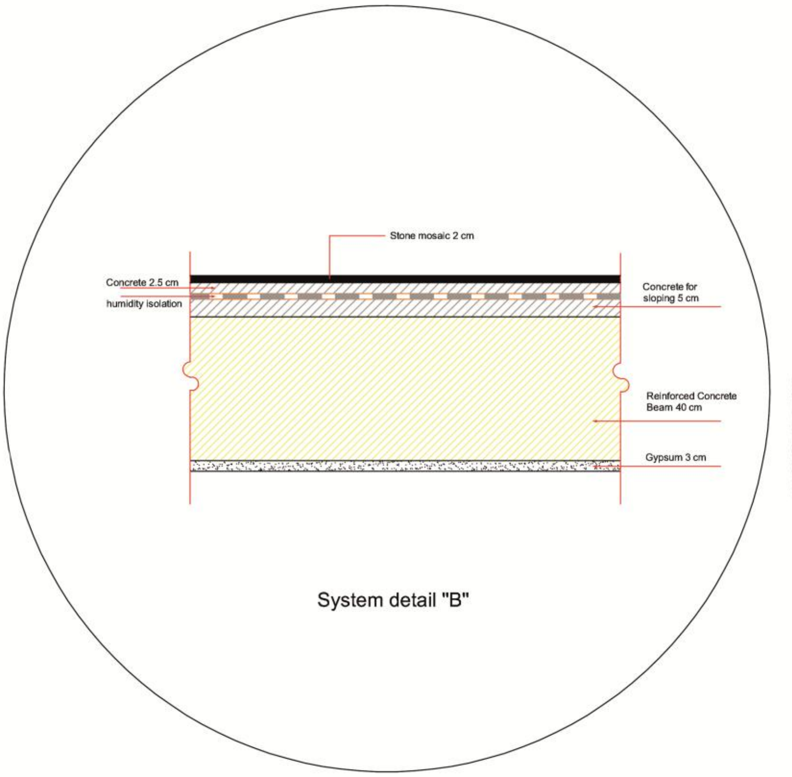


A-A Section


+9.96
+9.55
+7.45
+6.55
+5.35
+4.35
+3.35
+2.40
+1.40
+0.40
+0.00
System detail "A"
System detail "B"
+7.45
+6.55
+5.55
+1.30
+0.40
+0.00

B-B Section


Gypsum 3 cm
Facade gypsum 3 cm
Concrete 2.5 cm
Stone 2 cm
Concrete 2.5 cm
Reinforced Concrete
Beam 40 cm
Clay break 20 cm
System detail "A"


Stone mosaic 2 cm
Concrete 2.5 cm
humidity isolation
Concrete for
sloping 5 cm
Reinforced Concrete
Beam 40 cm
Gypsum 3 cm
System detail "B"

APPENDIX 2:

THE IMPROVEMENT IN INSULATION AND SHADING OF THE CASE STUDY

The latitude of Tehran is 35 N, and the case study building is situated directly to the south so the azimuth angle of it is 0.
To calculate the optimum shading for this case, Fuller Moore formulas will be used:

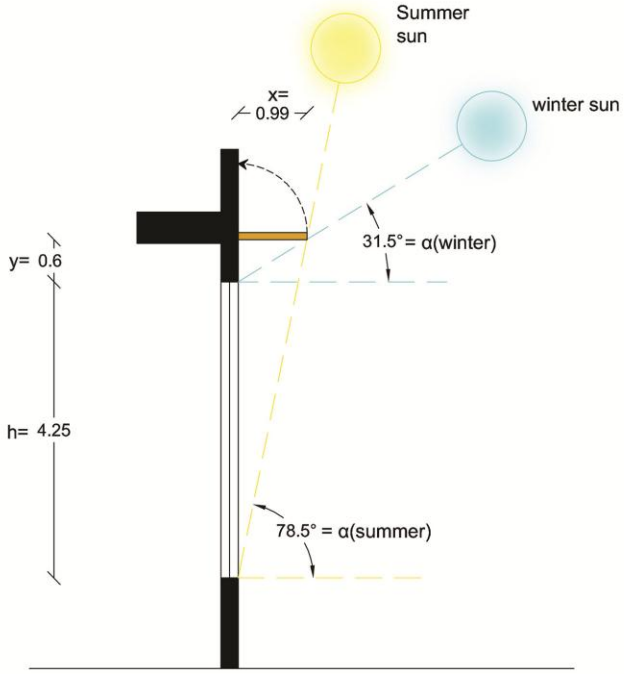
α(summer) = (90 - latitude) + 23.5 = 78.5

α(winter) = (90 - latitude) - 23.5 = 31.5

. h expresse the height of the window

. y expresse the vertical distance of overhang above the window

. x express the lenght of the over hang



South oriented shading process of the case study

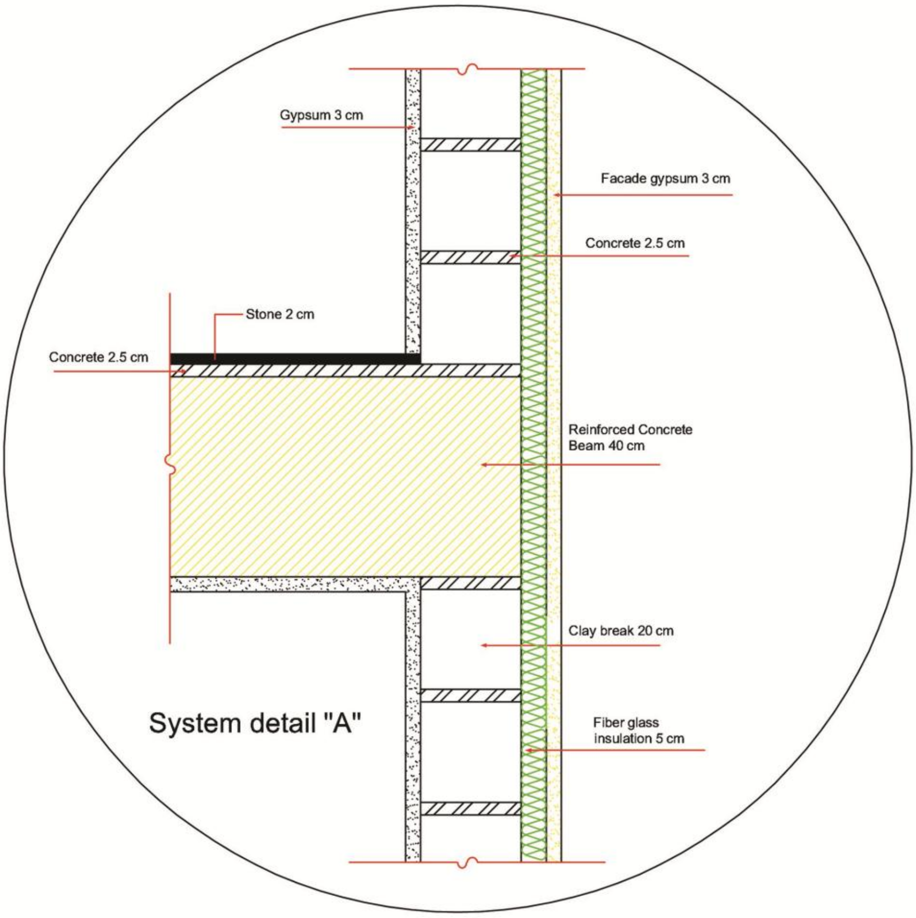
To obtain the two unknowns x and y two equations will be used as follow:

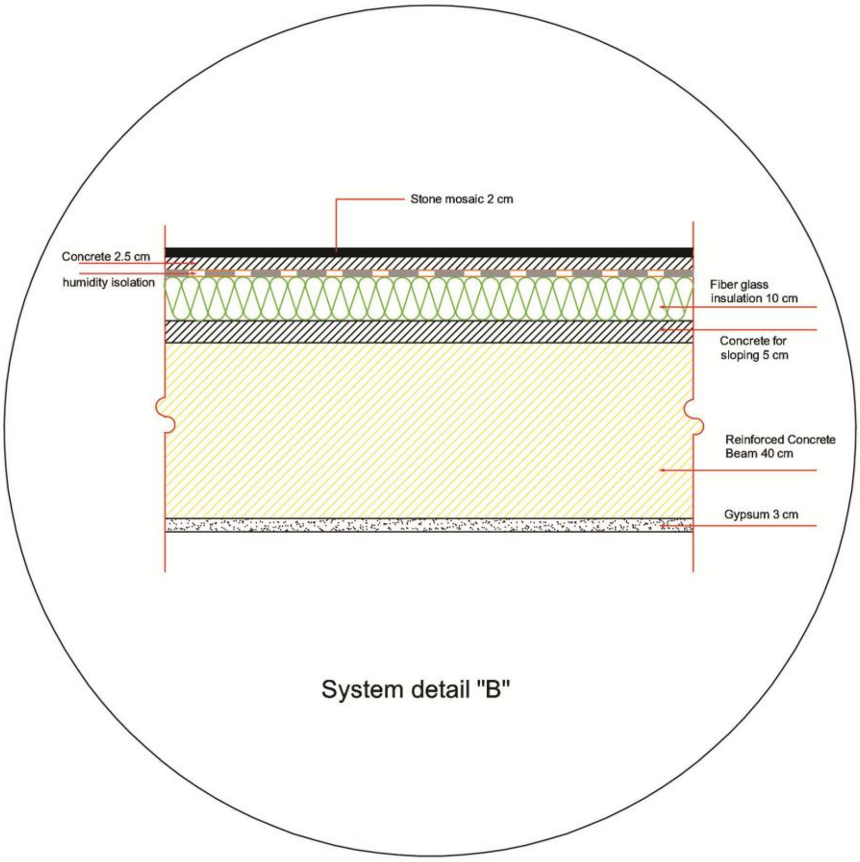
equation 1: with the use of α(winter)
tan α(winter) = y/x
tan 31.5 = y/x
so y = 0.61 x

equation 2: with the use of α(summer)
tan α(summer) = (h + y) / x
tan 78.5 = (425 + y) / x
4.92 = = (425 + y) / x
so y = 4.92 x - 425

with the use of these two equations x will be defined as:
0.61 x = 4.92 x - 425
4.92 x - 0.61 x = 425
4.31 x = 425
so x = 98.61 cm

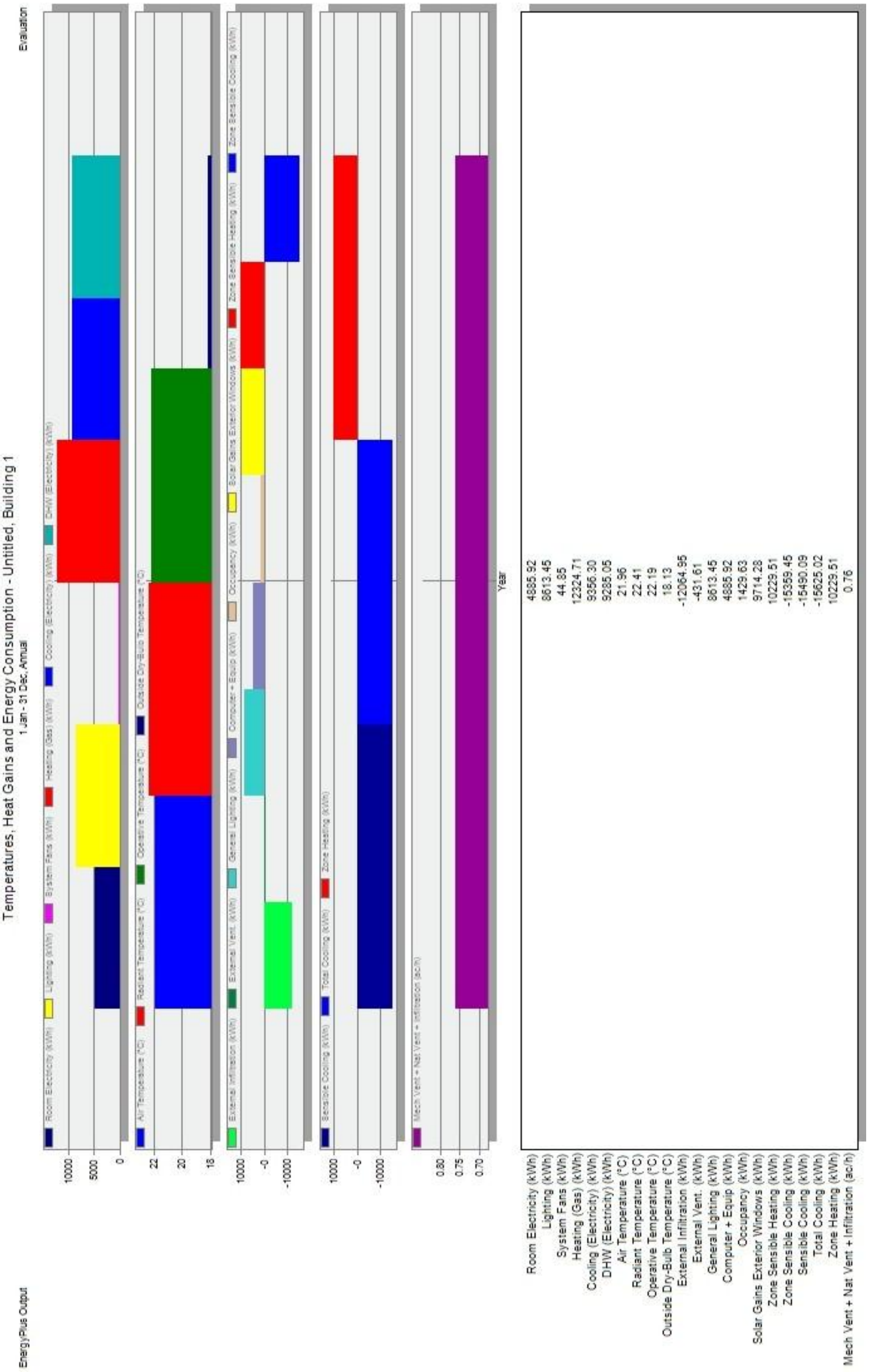
by the insert of x value founded in the equation y will be defined as:
y= 0.61 * 98.61= 59.84

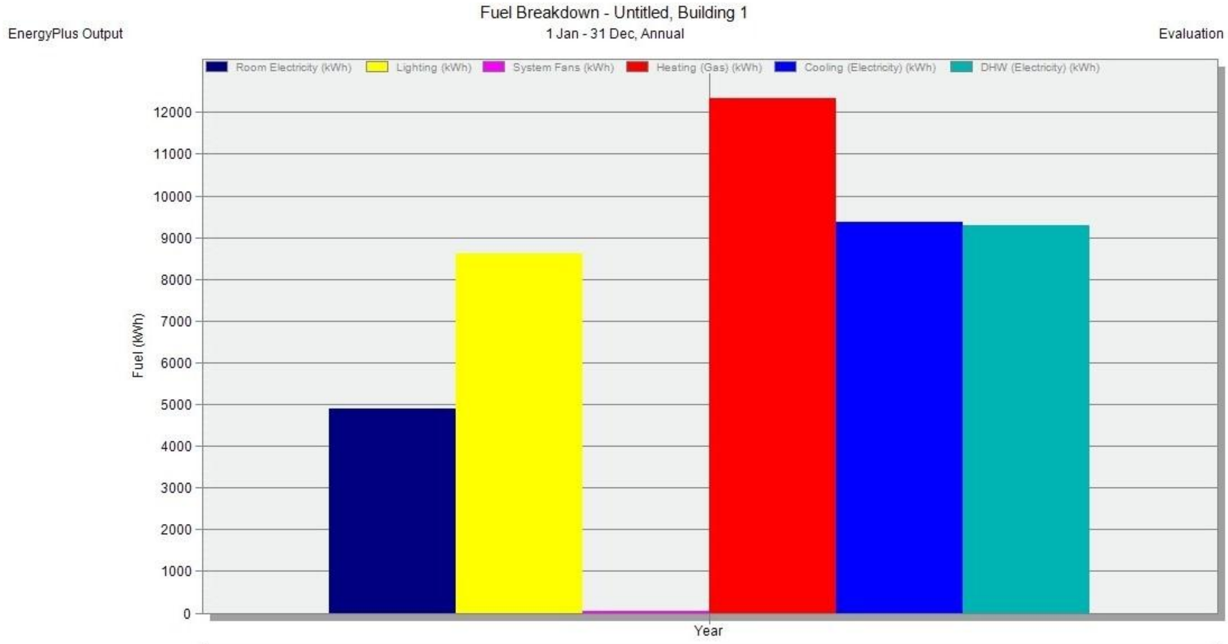

Gypsum 3 cm
Facade gypsum 3 cm
Concrete 2.5 cm
Stone 2 cm
Concrete 2.5 cm
Reinforced Concrete Beam 40 cm
Clay break 20 cm
System detail "A"
Fiber glass insulation 5 cm


Stone mosaic 2 cm
Concrete 2.5 cm
humidity isolation
Fiber glass insulation 10 cm
Concrete for sloping 5 cm
Reinforced Concrete Beam 40 cm
Gypsum 3 cm
System detail "B"

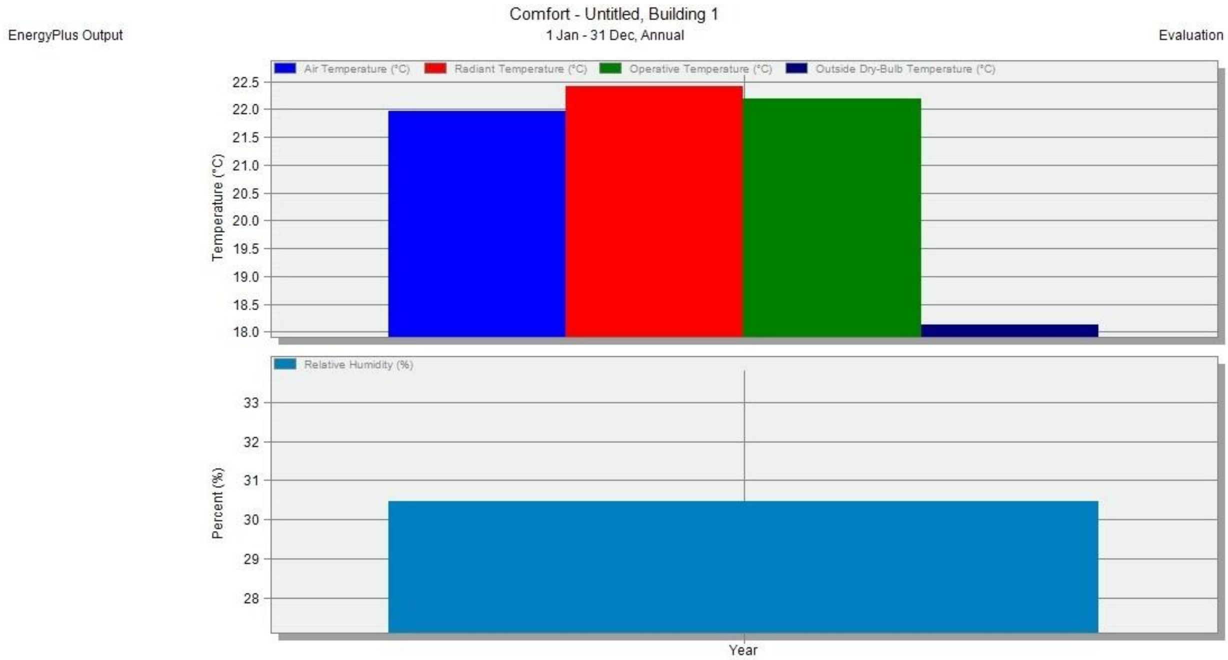
APPENDIX 3:

STIMULATION RESULTS FROM THE CASE STUDY WITHOUT INSULATION AND SHADING



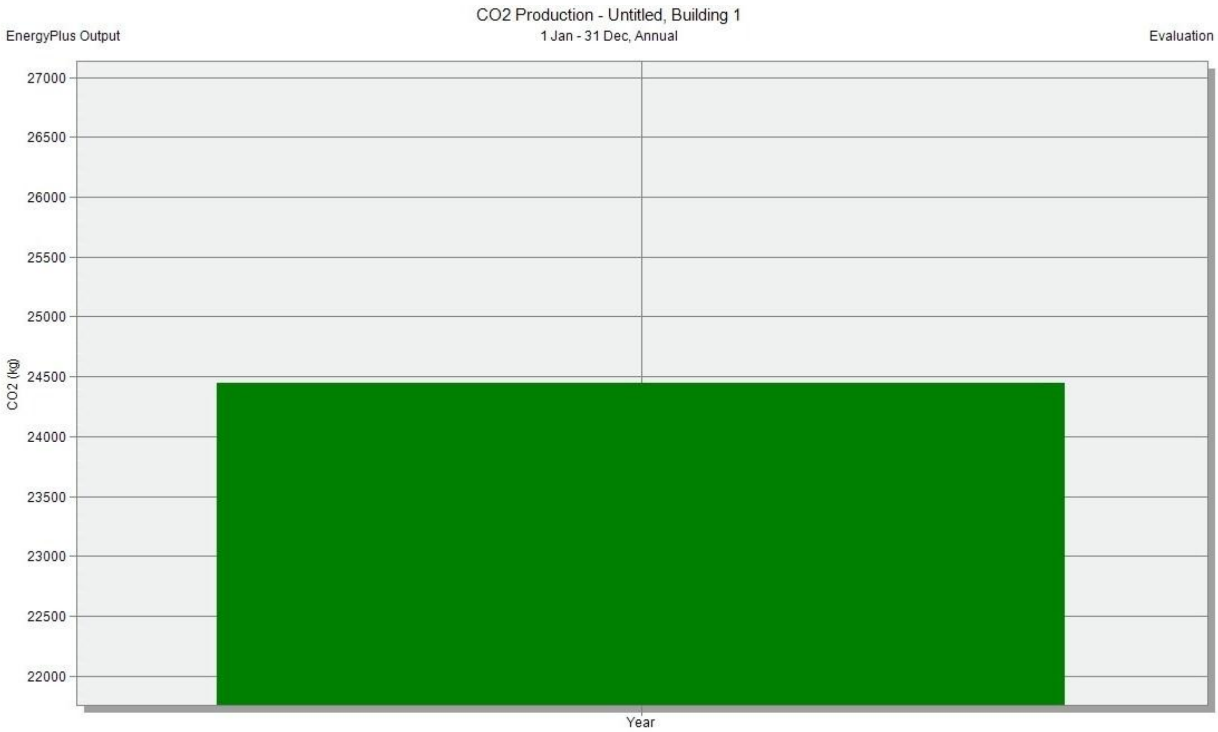


Room Electricity (kWh)	4885.92
Lighting (kWh)	8613.45
System Fans (kWh)	44.85
Heating (Gas) (kWh)	12324.71
Cooling (Electricity) (kWh)	9356.30
DHW (Electricity) (kWh)	9285.05



Air Temperature (°C)	21.96
Radiant Temperature (°C)	22.41
Operative Temperature (°C)	22.19
Outside Dry-Bulb Temperature (°C)	18.13
Relative Humidity (%)	30.47

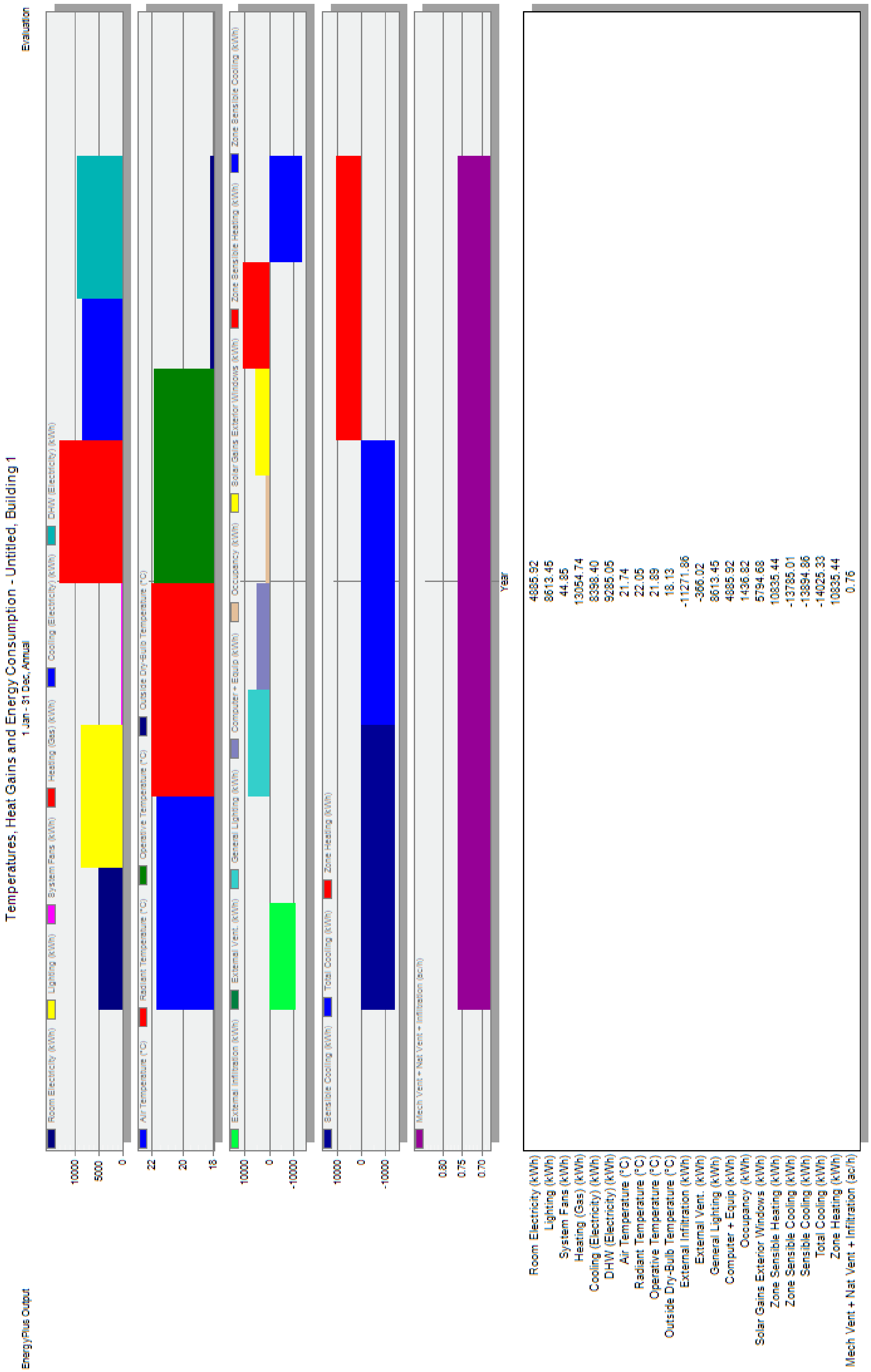
General Lighting (kWh)	8613.45
Computer + Equip (kWh)	4885.92
Occupancy (kWh)	1429.63
Solar Gains Exterior Windows (kWh)	9714.28
Zone Sensible Heating (kWh)	10229.51
Zone Sensible Cooling (kWh)	-15359.45

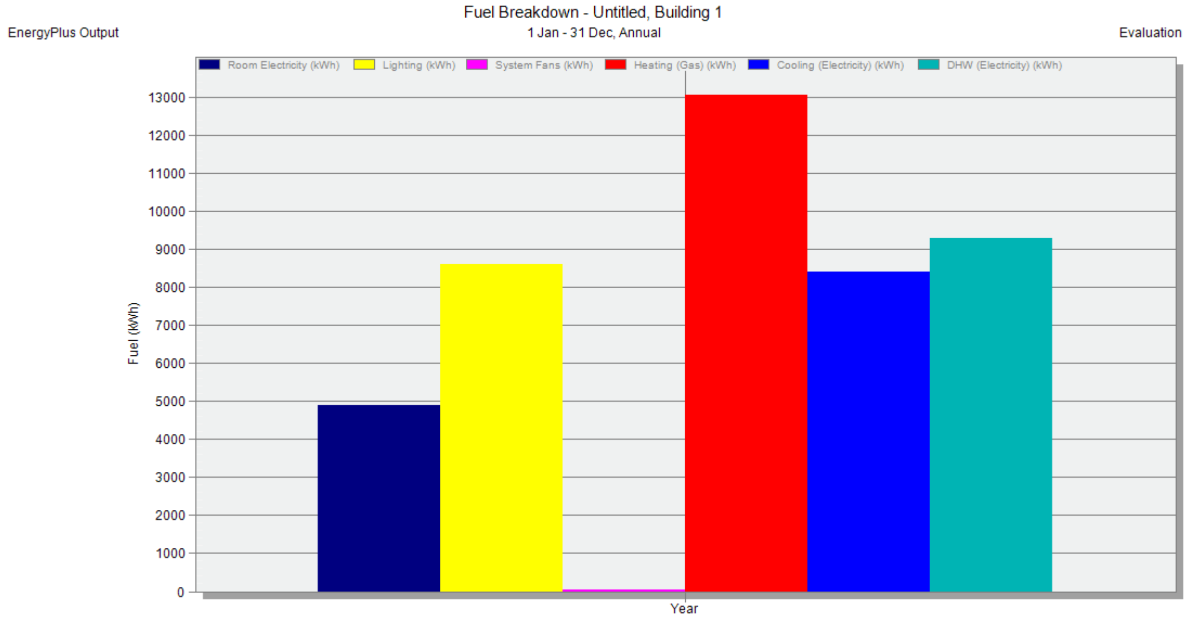


CO2 (kg)	24450.43

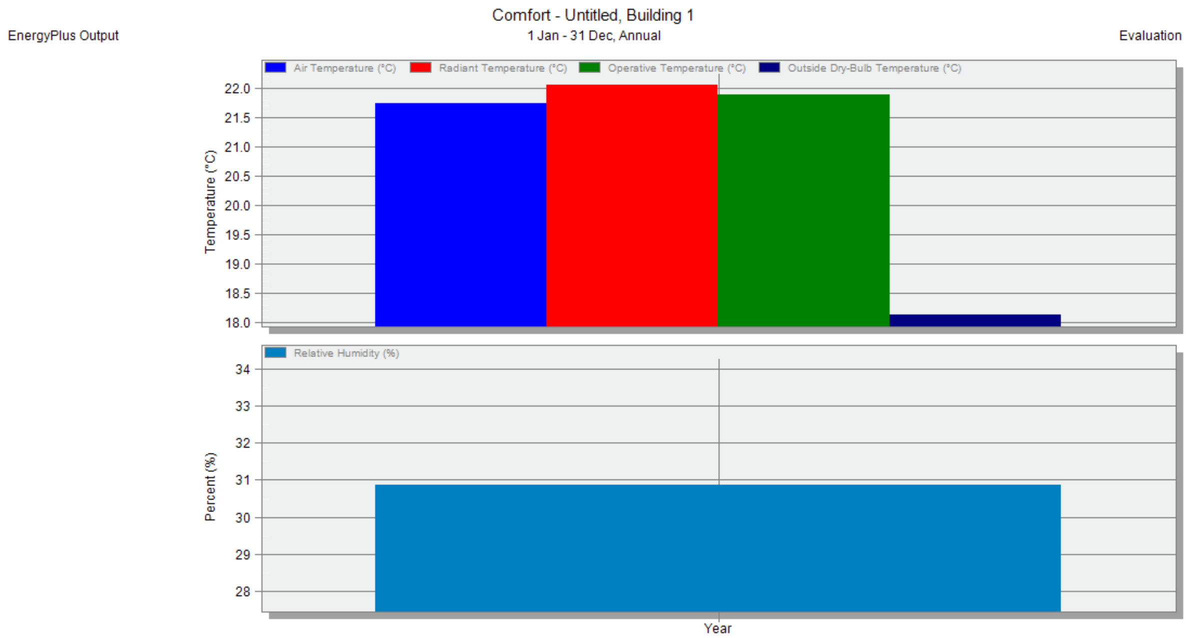
APPENDIX 4:

STIMULATION RESULTS FROM THE CASE STUDY WITHOUT INSULATION, WITH SHADING





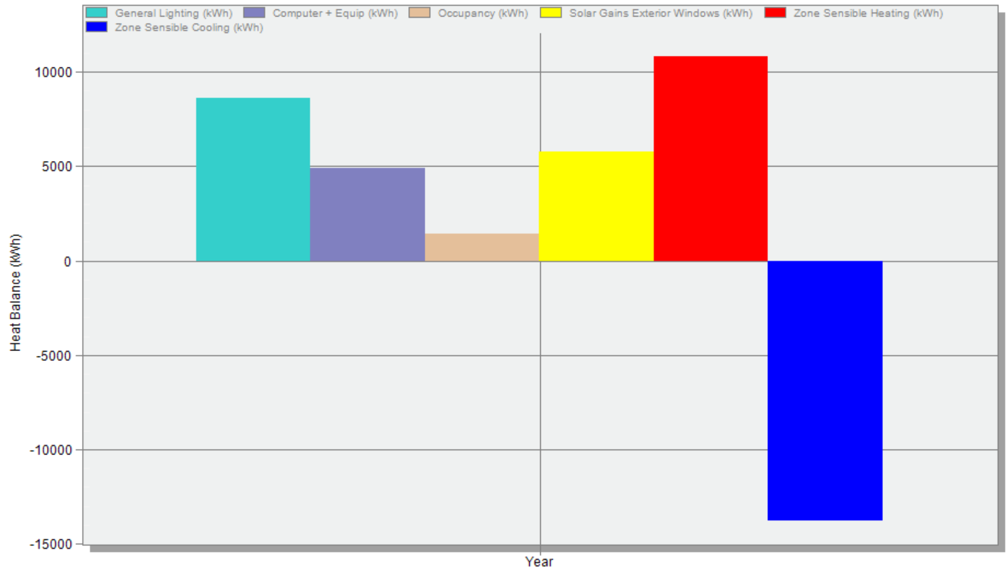
Room Electricity (kWh)	4885.92
Lighting (kWh)	8613.45
System Fans (kWh)	44.85
Heating (Gas) (kWh)	13054.74
Cooling (Electricity) (kWh)	8398.40
DHW (Electricity) (kWh)	9285.05



Air Temperature (°C)	21.74
Radiant Temperature (°C)	22.05
Operative Temperature (°C)	21.89
Outside Dry-Bulb Temperature (°C)	18.13
Relative Humidity (%)	30.87

Internal Gains + solar - Untitled, Building 1

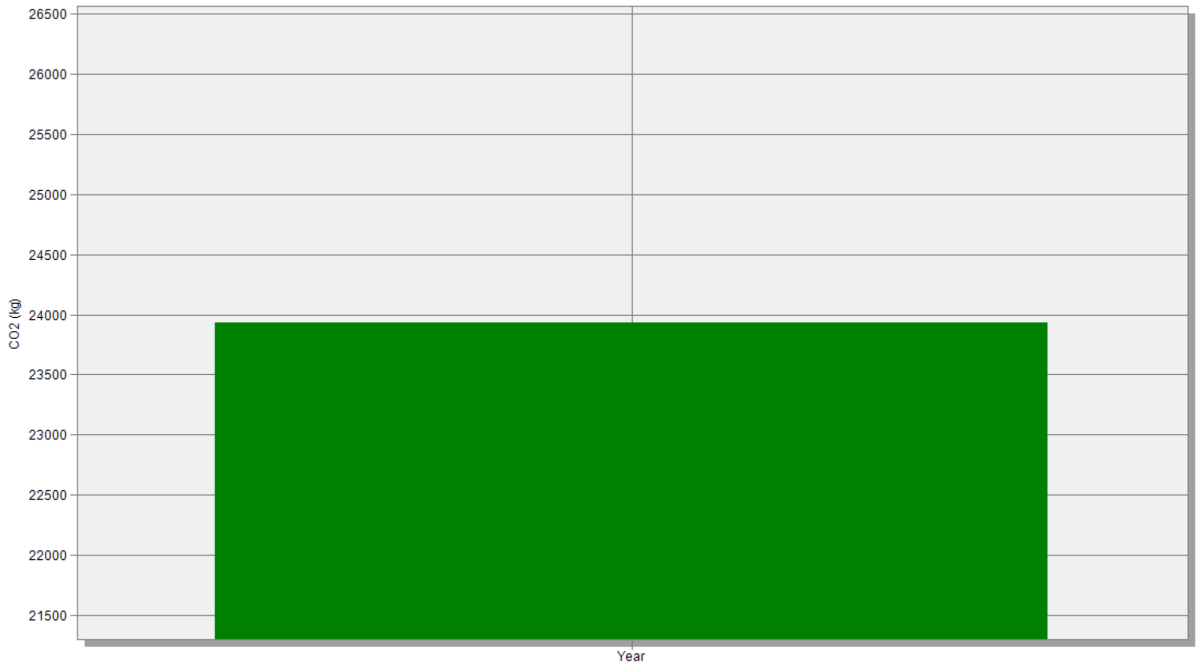
EnergyPlus Output | 1 Jan - 31 Dec, Annual | Evaluation



General Lighting (kWh)	8613.45
Computer + Equip (kWh)	4885.92
Occupancy (kWh)	1436.82
Solar Gains Exterior Windows (kWh)	5794.68
Zone Sensible Heating (kWh)	10835.44
Zone Sensible Cooling (kWh)	-13785.01

CO2 Production - Untitled, Building 1

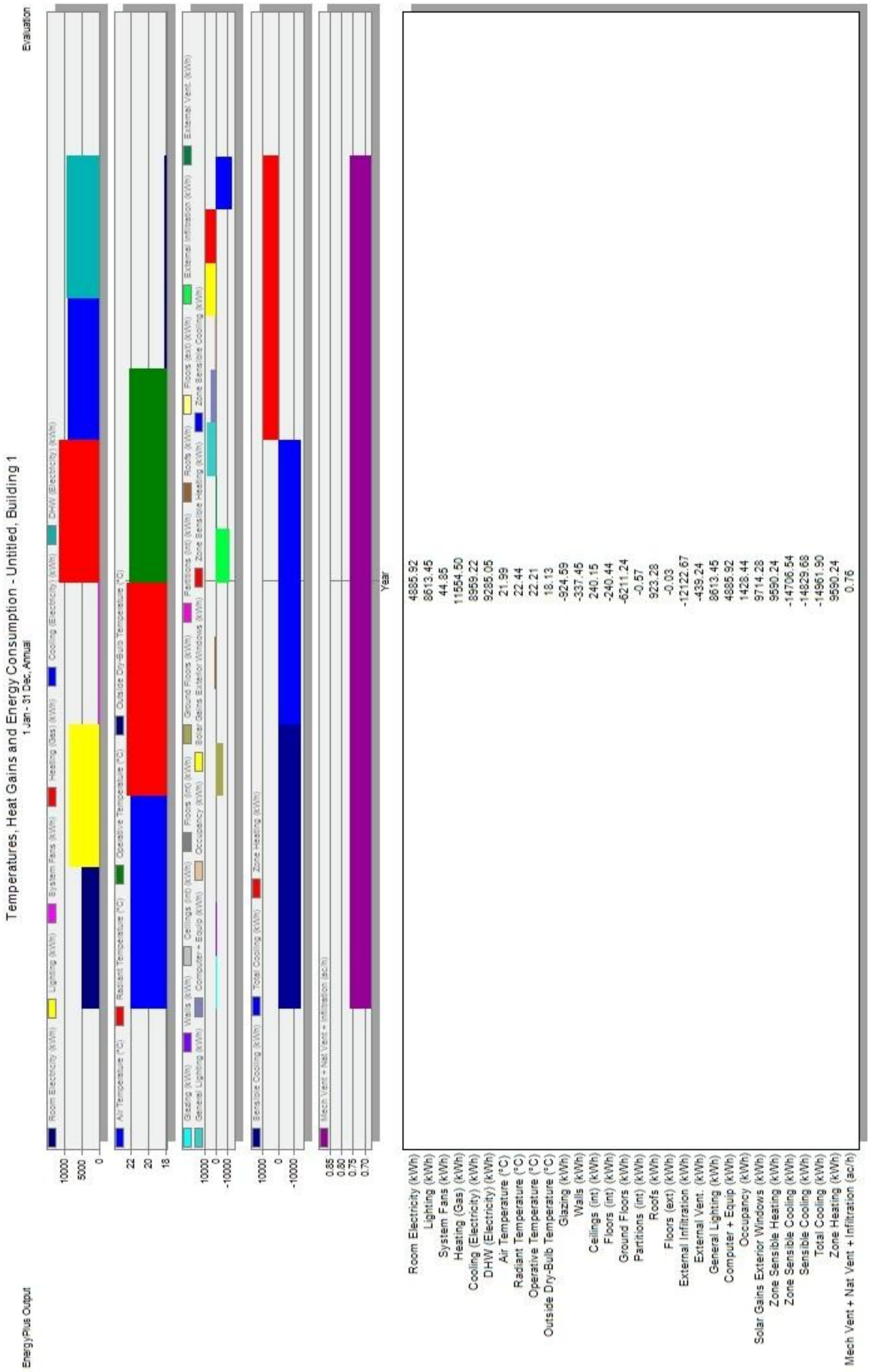
EnergyPlus Output | 1 Jan - 31 Dec, Annual | Evaluation



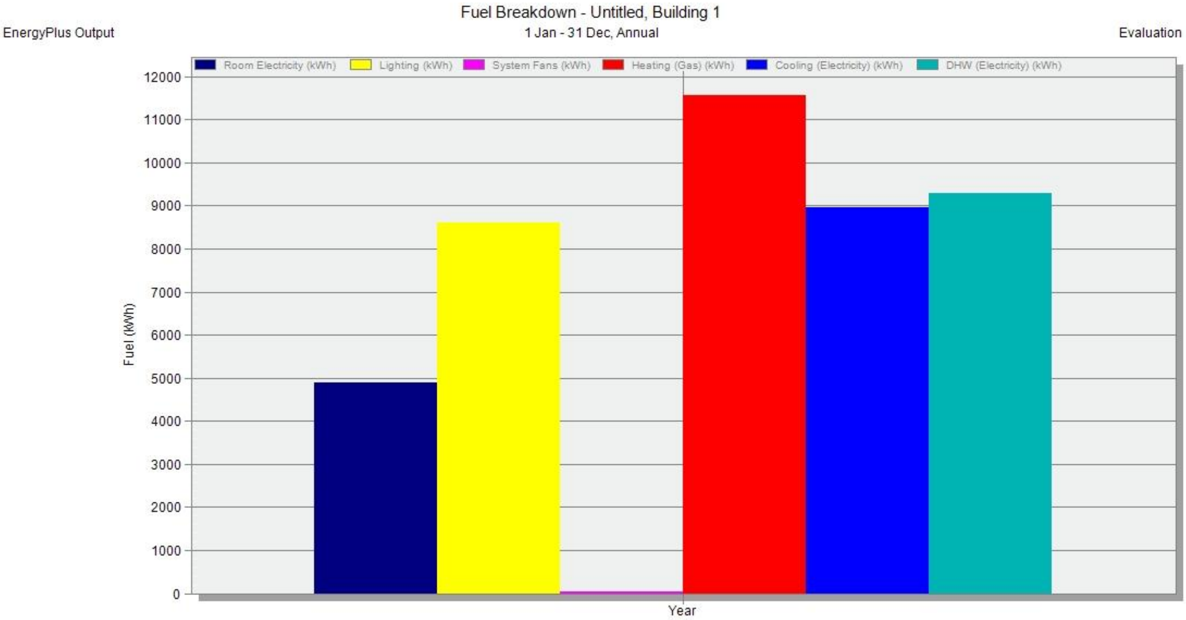
CO2 (kg)	23936.63

APPENDIX 5:

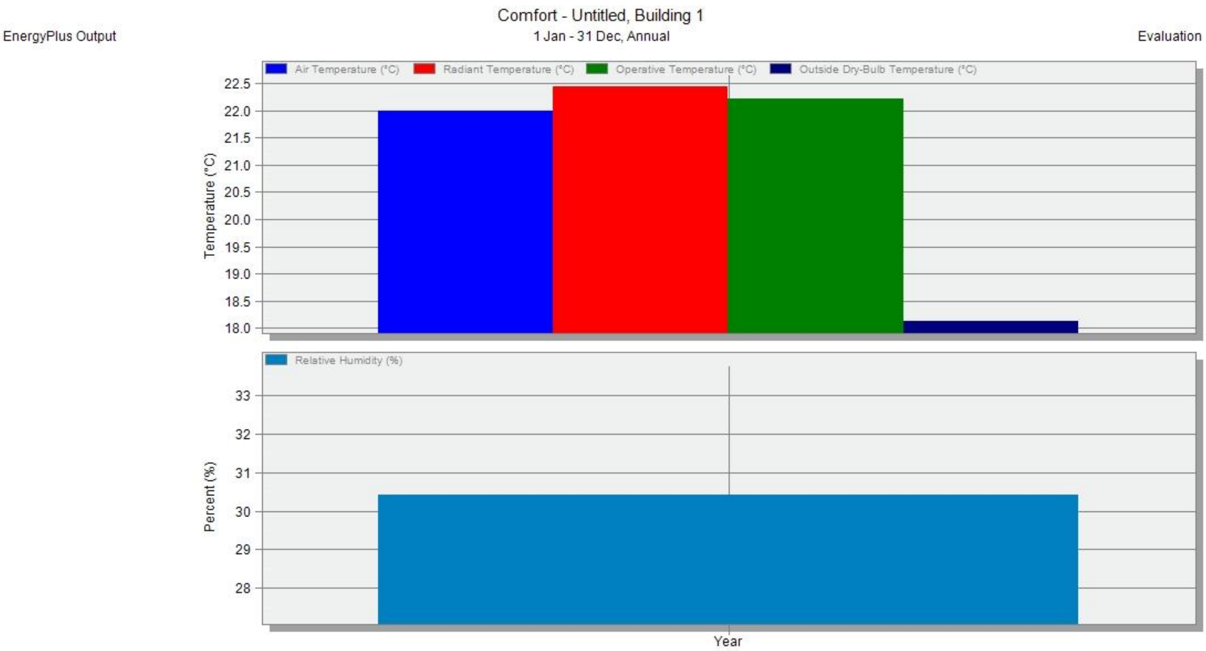
STIMULATION RESULTS FROM THE CASE STUDY WITH INSULATION, WITHOUT SHADING



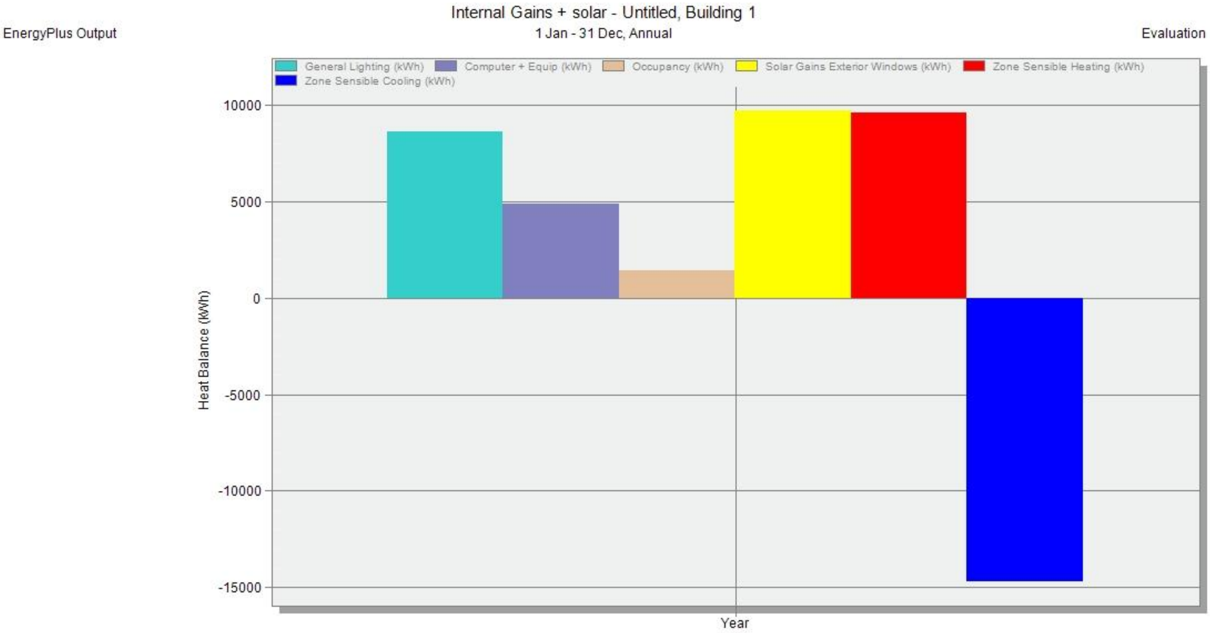
	Year
Room Electricity (kWh)	4885.92
Lighting (kWh)	8613.45
System Fans (kWh)	44.85
Heating (Gas) (kWh)	11554.50
Cooling (Electricity) (kWh)	8959.22
DHW (Electricity) (kWh)	9285.05
Air Temperature (°C)	21.99
Radiant Temperature (°C)	22.44
Operative Temperature (°C)	22.21
Outside Dry-Bulb Temperature (°C)	18.13
Glazing (kWh)	-924.59
Walls (kWh)	-337.45
Ceilings (int) (kWh)	240.15
Floors (int) (kWh)	-240.44
Ground Floors (kWh)	-6211.24
Partitions (int) (kWh)	-0.57
Roofs (kWh)	923.28
Floors (ext) (kWh)	-0.03
External Infiltration (kWh)	-12122.67
External Vent. (kWh)	-439.24
General Lighting (kWh)	8613.45
Computer + Equip (kWh)	4885.92
Occupancy (kWh)	1428.44
Solar Gains Exterior Windows (kWh)	9714.28
Zone Sensible Heating (kWh)	9590.24
Zone Sensible Cooling (kWh)	-14706.54
Sensible Cooling (kWh)	-14829.68
Total Cooling (kWh)	-14961.90
Zone Heating (kWh)	9590.24
Mech Vent + Nat Vent + Infiltration (ac/h)	0.76



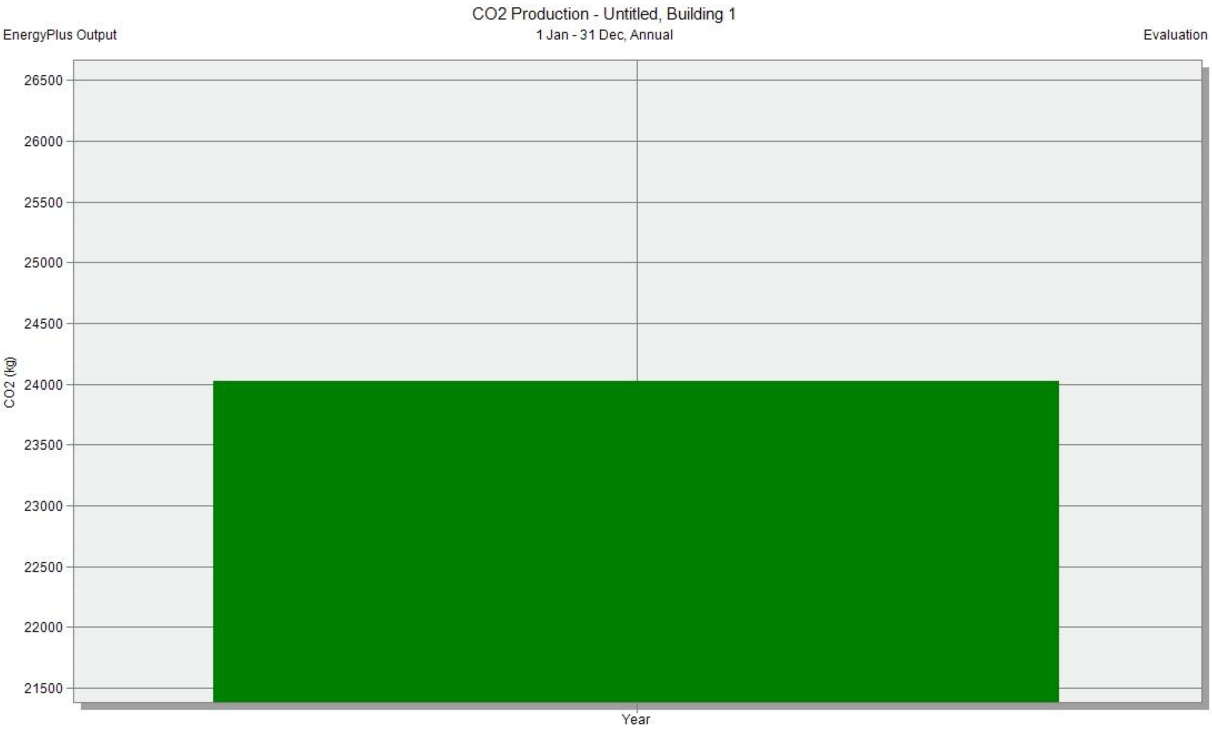
Room Electricity (kWh)	4885.92
Lighting (kWh)	8613.45
System Fans (kWh)	44.85
Heating (Gas) (kWh)	11554.50
Cooling (Electricity) (kWh)	8959.22
DHW (Electricity) (kWh)	9285.05



Air Temperature (°C)	21.99
Radiant Temperature (°C)	22.44
Operative Temperature (°C)	22.21
Outside Dry-Bulb Temperature (°C)	18.13
Relative Humidity (%)	30.42



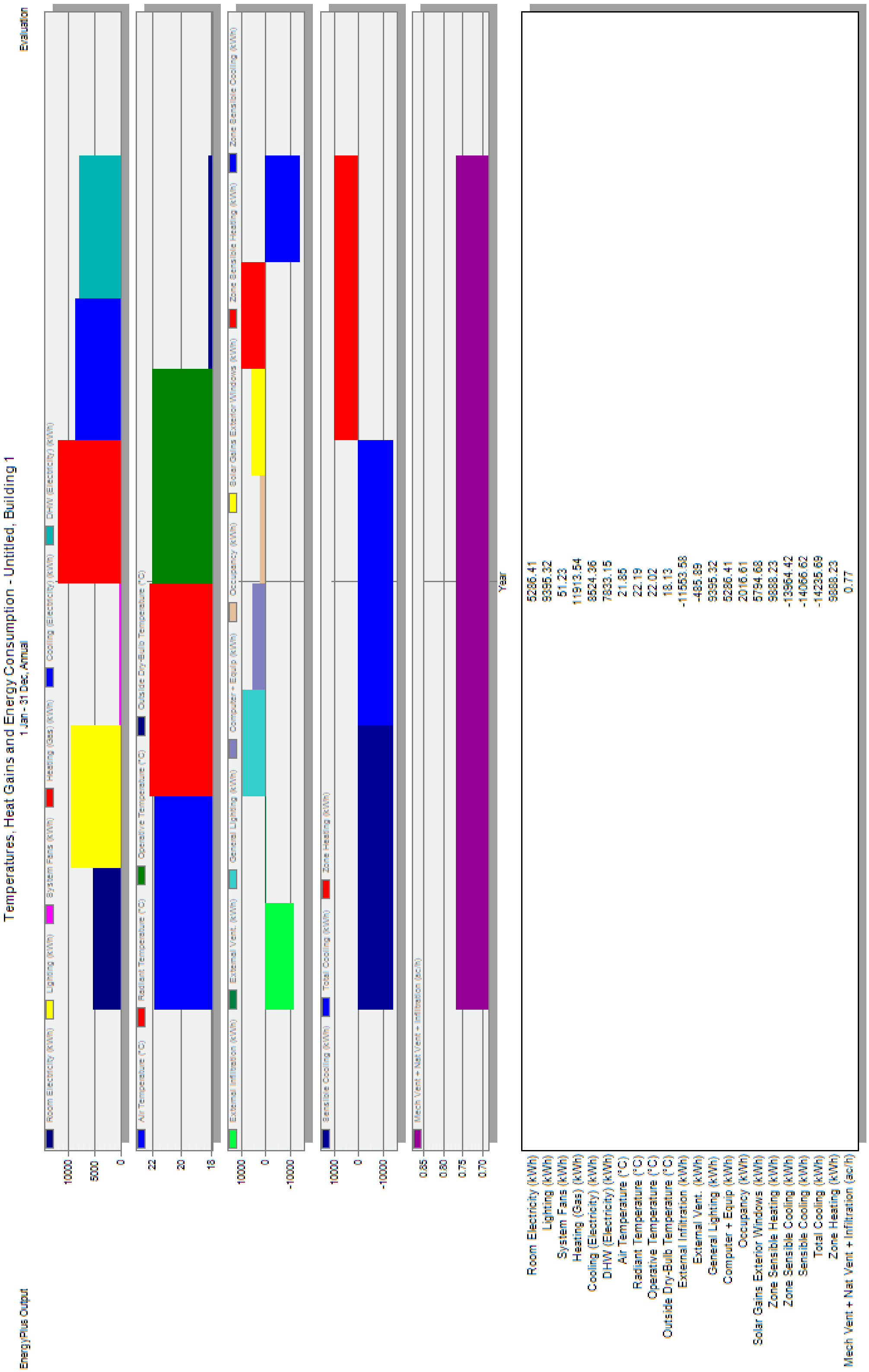
General Lighting (kWh)	8613.45
Computer + Equip (kWh)	4885.92
Occupancy (kWh)	1428.44
Solar Gains Exterior Windows (kWh)	9714.28
Zone Sensible Heating (kWh)	9590.24
Zone Sensible Cooling (kWh)	-14706.54



CO2 (kg)	24028.25

APPENDIX 6:

STIMULATION RESULTS FROM THE CASE STUDY WITH INSULATION AND SHADING

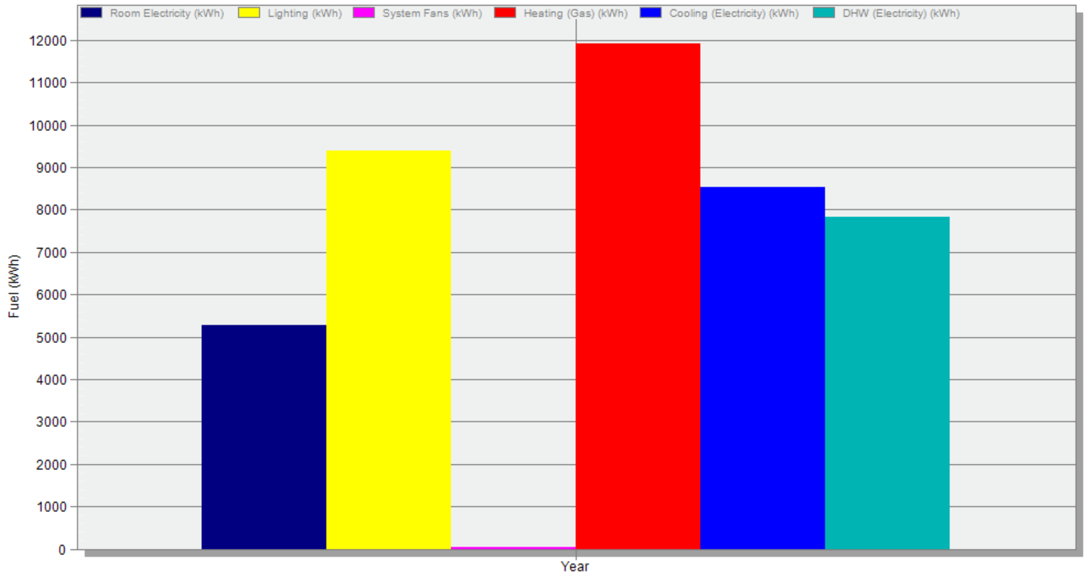


Fuel Breakdown - Untitled, Building 1

1 Jan - 31 Dec, Annual

EnergyPlus Output

Evaluation



Room Electricity (kWh)	5286.41
Lighting (kWh)	9395.32
System Fans (kWh)	51.23
Heating (Gas) (kWh)	11913.54
Cooling (Electricity) (kWh)	8524.36
DHW (Electricity) (kWh)	7833.15

Comfort - Untitled, Building 1

1 Jan - 31 Dec, Annual

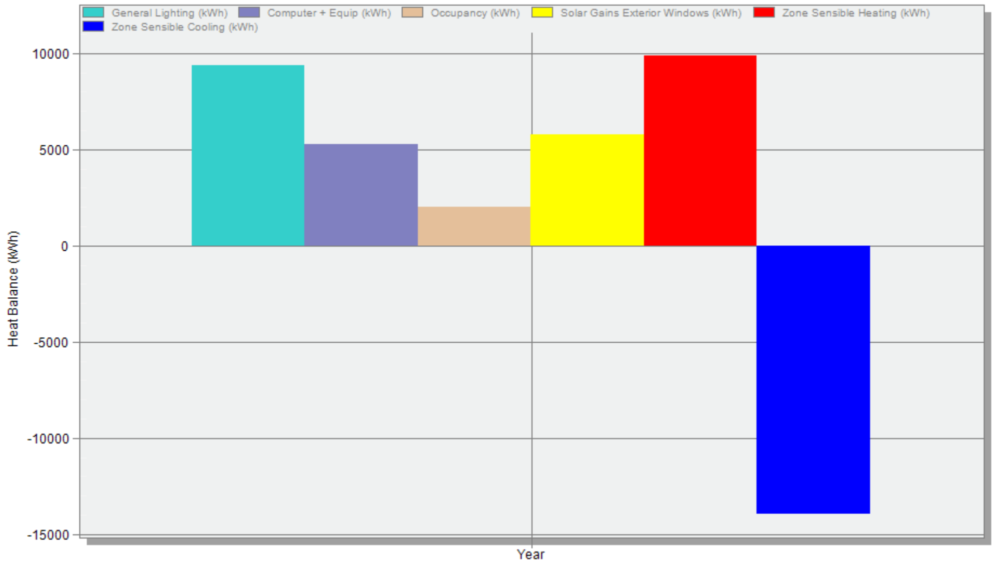
EnergyPlus Output

Evaluation

Air Temperature (°C)	21.85
Radiant Temperature (°C)	22.19
Operative Temperature (°C)	22.02
Outside Dry-Bulb Temperature (°C)	18.13
Relative Humidity (%)	30.87

Internal Gains + solar - Untitled, Building 1

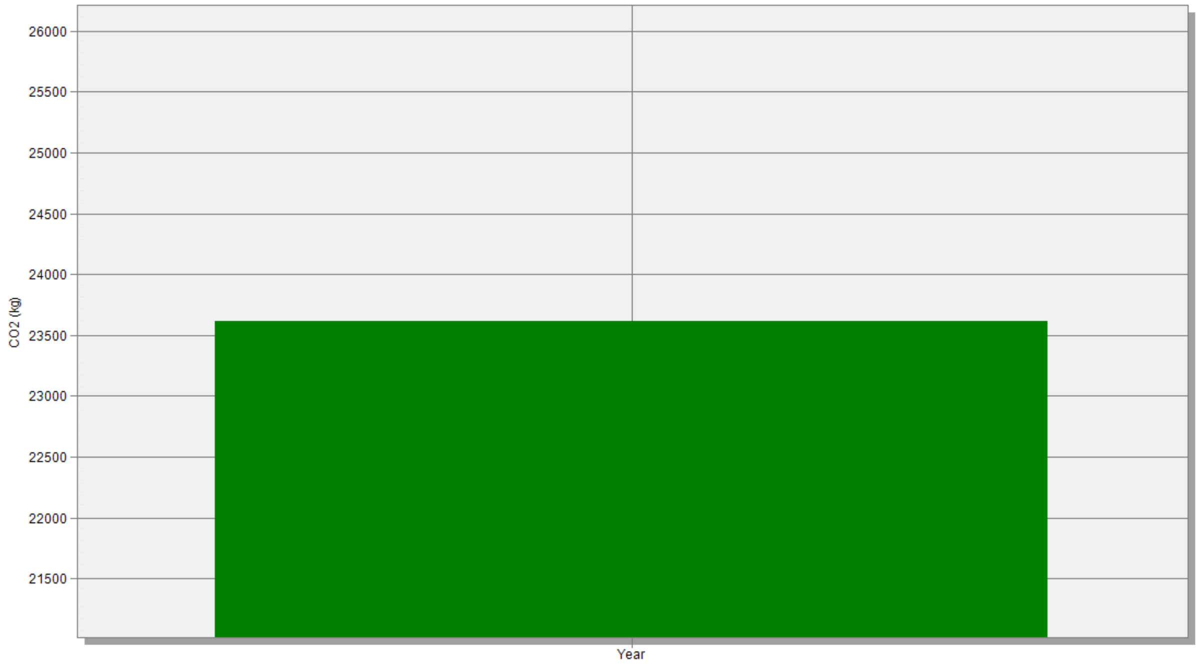
EnergyPlus Output 1 Jan - 31 Dec, Annual Evaluation



General Lighting (kWh)	9395.32
Computer + Equip (kWh)	5286.41
Occupancy (kWh)	2016.61
Solar Gains Exterior Windows (kWh)	5794.68
Zone Sensible Heating (kWh)	9888.23
Zone Sensible Cooling (kWh)	-13964.42

CO2 Production - Untitled, Building 1

EnergyPlus Output 1 Jan - 31 Dec, Annual Evaluation



CO2 (kg)	23620.12