University of Bahrain
Deanship of Scientific Research



Master Program in Environment
and Sustainable Development

Effect of Window Performance on Energy Conservation in Building in Bahrain

جامعة البحرين
المكتبة
LIBRARY
University of Bahrain

Thesis Submitted in Partial Fulfillment for the requirements of the Degree of Master of Science in Environment and Sustainable Development

By:
Hameeda Hassan Ali
Student # 19942498

Supervisor
Dr. Hussain Al Madani

2007

جامعة البحرين
المكتبة
LIBRARY
University of Bahrain

DECLARATION

I declare that this work is the result of my own investigation and that it has not already been accepted in substance for any degree, nor is it being currently submitted for any degree.

Signed: Hameeda Hassan Ali	**Date:** .....

The Thesis defense committee considers the Thesis titled:

EFFECT OF WINDOW PERFORMANCE ON ENERGY CONSERVATION IN BUILDING IN BAHRAIN

Submitted by Hameeda Hassan Ali to the Deanship of Scientific Research satisfactory and acceptable for the Master of Environment and Sustainable Development.

Thesis Defence Committee :

.....	
Dr.Hussain Al-Madani **Supervisor**	Dean College of Engineering
.....	
Prof. Saeed A.Rahaim **Internal Examiner**	Department of Civil and Architectural Engineering
.....	
Prof. Najem M. Al-Najem **External Examiner**	College of Engineering & Petroleum, Kuwait University

Abstract

Effect of Window Performance on Energy Conservation in Building on Bahrain

By Hameeda Hassan Ali

Bahrain is a group of islands in the Arabian Gulf with relatively high population density. The geographical nature of Bahrain facilitates the country with a hot and humid weather most of the times through out the year. This results into a high power demand for air conditioning purpose.

When considering the annual growth of the electrical power demand in the country, it could be predicted that the country must install new power stations with more capacity than the existing stations to meet the power demand.
The main objective of this study is to determine the electrical energy saving due to using advance glazing units in the residential buildings in Bahrain and to study the effect of this conservation measure on the consumers, the environment and the national economy.

The study use Energy-10 computer software, for modeling and simulation of energy flow to examine measures to reduce the thermal load. For the calculation a typical metrological year (TMY) and a typical model of Bahrain traditional house are used. The measures examined are various types of glazing, building orientation & shape effect, shading and reducing infiltration.
The analysis of the simulation show that the best position for rectangular house is to have its long side and maximum number of windows facing south direction, also with respect to the glazing type show that the reflective double glazing with vinyl frame is the best option with reduction in cooling load of 14.8%, it also reduce the life cycle cost by BD 782.000, in addition it reduce the carbon dioxide emission by about 8.7%.

ACKNOWLEDGMENT

I wish to thank on the top of the list the supervisor Dr.Hussain Al-Madani, who was encouraging me and supporting me to finish this work, and he was so patient with me at some hard times through which I really needed his support.

Sincere thanks go to the following for tracking down material in the library's, to ministry of electricity and water, ministry of housing, central statistics organization.

Moreover, I would like to thanks Mr. Norm Weaver, chief of Energy - 10 development team for his help & continuous cooperation.

Special thanks go to my family & friends who were always ready to support me.

TABLE OF CONTENT

TITLE	PAGE
ABSTRUCT	i
AKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	iii
LIST OF FIGURES	v
LIST OF TABLES	vi
CHAPTER ONE: INTRODUCTION	1
1.0 General Introduction	1
1.1 Location	1
1.2 Weather	1
1.3 Population	2
2.0 Problem definition	2
3.0 Objective of the study	9
4.0 Research Methodology	9
5.0 Data Collection and Analysis	9
6.0 Organization of Thesis	10
CHAPTER TWO: REVIEW OF LITETURE	11
2.1 Introduction	11
2.2 Literature Review	11
CHAPTER THREE: WINDOW AND GLAZING	15
3.1 Window and Glazed Surface Background	15
3.2 Building Design and Fenestration	15
3.2.1 Holistic building design	16
3.2.2 Fenestration design	17
3.3 Heat transfer fundamentals	18
3.3.1 Mechanisms of heat transfer	18
3.4 Heat Transfer process through glass	20
3.4.1 Solar heat gain	22
3.4.2 Performance indicators	25
3.5 Center glass versus whole unit	28
3.6 Condensation prevention	28
3.7 Glazing Technologies	30
3.7.1 Glass and tints	30
3.7.2 Low E and reflective coatings	31
3.7.3 Plastic glazing	32
3.7.4 Gas fills and vacuums	33
3.7.5 Directionally selected material	34
CHAPTER FOUR: ENERGY-10 SOFTWARE	36
4.0 Introduction	36
4.1 Energy 10 software features	38

(Cont.....)

TITLE	PAGE
4.2 Weather data	39
4.3 Brief history of integrated design	39
4.4 Structure of Energy -10	40
4.5 Output report	41
CHAPTER FIVE: METHOD OF APPROCH	45
5.0 Methodologies	45
5.1 Select base case building	46
5.2 Define base case parameter and operating condition	48
5.3 Perform energy use analysis of the above case	51
5.4 Define window design as a conservative measure	52
5.5 Perform energy use analysis of each design case	53
5.6 Conduct economic analysis of the optimum case	53
CHAPTER SIX: RESULTS AND DISSCUSION	54
6.0 Introduction	54
6.1 Results	54
6.1.1 Effect of house shape and orientation	54
6.1.2 Effect of window glazing	58
6.1.3 Effect of window shading and reducing infiltration	66
6.1.4 Economical effect of applying optimum design	68
6.2 Environmental concerns	69
CHAPTER SEVEN: CONCLUSION & RECOMMENDATION	72
7.1 Conclusions	72
7.2 Recommendations	73
REFRENCES	75
GLOSSARY	78
NOMENCLATURE	79
APPEDICES	80
Typical metrological year (TMY) data Appendix (A)	80
Simulation output of building shape & orientation effect Appendix (B)	84
Simulation output of building glazing effect Appendix (C)	89
Brief of Bahrain ministerial regulation for use of insulation Appendix (D)	108

LISTS OF FIGURES

FIGURE	TITLE	PAGE
1.1	Annual Electricity Consumption per Capita	3
1.2	Installed Capacities with Maximum Demand	4
1.3	Electricity Cost & Price	4
1.4	Fraction each Sector Contributes of Total Electricity Consumption in Bahrain	5
1.5	Electrical Consumption per Capita in Gulf Region	8
3.1	Modes of Radiation for a Typical Wood Window Section	21
3.2	Solar Spectrum	23
3.3	Effect of Light on Glass	23
3.4	Energy Intensity and Wavelength	25
3.5	Conditions for Window Condensation	30
4.3.1	Annual Electrical use Breakdown Model	41
4.3.2	Annual Cost Breakdown Model	42
4.3.3	Monthly Electric Demand Peaks Model	42
4.3.4	Annual Emission Results Model	43
4.3.5	Monthly Average Energy Use Model	44
5.1	Base Case Plan View	47
5.2	Wall Construction Layers	48
5.2	Roof Construction Layers	49
6.1	Annual Energy Uses for Reference Case	55
6.2	Annual Energy Uses for Reference Case Rotated 90^0	56
6.3	Annual Energy Uses for Reference Case Rotated 180^0	56
6.4	Annual Energy Uses for Reference Case Rotated 270^0	57
6.5	Building Rotation Angle and Annual Cooling Load	58
6.6	Annual Energy Use and Cooling Load for Glazing Code Number 5b	59
6.7	Annual Energy Use and Cooling Load for Glazing Code Number 5b*	60
6.8	Annual Energy Use and Cooling Load for Glazing Code Number 25b	61
6.9	Annual Energy Use and Cooling Load for Glazing Code Number 25b*	62

LISTE OF FIGURES (Cont....)		
FIGURE	**TITLE**	**PAGE**
6.10	Annual Energy Use and Cooling Load for Glazing Code Number 2k	63
6.11	Annual Energy Use and Cooling Load for Glazing Code Number 29b	63
6.12	Annual Energy Use and Cooling Load for Glazing Code Number 40b	64
6.13	Window Glazing Unit and Resulting Cooling Load	65
6.14	Effect of Number of Glazing Layers in Reducing Cooling Load	66
6.15	Annual Energy Use and Cooling Load for Glazing Code Number 5k, Fully Shaded &AC/h=0.4	67
6.16	Monthly Electrical Demand Peaks for Glazing Code Number 5k, Fully Shaded & AC/h = 0.4	68
6.17	Percentage Reduction in Annual Emission	70

LISTE OF TABLE

TABLE	TITLE	PAGE
1.1	Capacities of Power Stations	6
1.2	Power Station Percentage Share of Total Capacities	7
1.3	Annual Electricity Consumption for Residential Building in Bahrain	7
1.4	Electrical Consumption & Production (per capita)	8
1.5	Gulf Region Electrical Generation Ability (per capita)	8
5.1	Properties of Wall Construction Layers	48
5.2	Properties of Roof Construction Layers	49
5.3	Summary of the Base Case Condition	50
5.4	Window Systems Properties	52
6.1	Economical Analyses	71

CHAPTER ONE

INTRODUCTION

1. General Introduction

1.1 Location

Bahrain is located on the southern shore of the Arabian Gulf between latitude 25^0 32' and 26^0 20' North and longitude 50^0 20' and 50^0 50' East.

Bahrain (from the Arabic word for "two seas") , and it is comprises an archipelago of thirty-three islands situated midway in the Arabian Gulf close to the shore of the Arabian Peninsula. The main islands are about twenty-four kilometers from the east coast of Saudi Arabia and twenty-eight kilometers from Qatar.

The total area of the islands is about 691 square kilometers. The largest island, accounting for 83 percent of the area, is Bahrain, which has an extent of 572 square kilometers. From north to south, Bahrain is forty-eight kilometers long; at its widest point in the north, and it is sixteen kilometers from east to west.

Around most of Bahrain is a relatively shallow inlet of the Arabian Gulf known as the Gulf of Bahrain. The seabed adjacent to Bahrain is rocky and, mainly off the northern part of the island, covered by extensive coral reefs. Most of the island is low-lying and barren desert. [CIA, (2005) World fact book]

1.2 Weather

Bahrain has two seasons: an extremely hot summer and a relatively mild winter. During the summer months, from April to October, afternoon temperatures average 40° C and can reach 48° C during June and July. The combination of intense heat and high humidity makes this season uncomfortable.

In addition, a hot, dry southwest wind, known locally as the *qaws*, periodically blows sand clouds across the barren southern end of Bahrain toward Manama in the summer. Temperatures moderate in the winter months, from November to March, when the range is between 10° C and 20° C. However, humidity often rises above 90 percent in the winter. From December to March, prevailing winds from the southeast, known as the *shammal*, bring damp air over the islands. Regardless of the season, daily temperatures are fairly uniform throughout the archipelago. [Central Statistics Organization, (2004) Statistical Abstract, Bahrain]

Bahrain receives little precipitation. The average annual rainfall is seventy-two millimeters, usually confined to the winter months.

1.3 Population

In 1992 an estimated 520,000 people lived in Bahrain. This number included 363,000 Bahraini citizens and 157,000 foreign nationals. Citizens accounted for 66 percent of the total population, a decline from the 70 percent they represented in the 1981 census and the 82.5 percent they represented in 1971.

The unofficial estimate indicated that the population had increased by 57 percent, or at an average annual growth rate of 5.2 percent, since 1981. In 1992 the growth rate was 3.1 percent. The non-Bahraini community, which grew from 112,000 in 1981 to 157,000 in 1992, increased by 67 percent, whiles the number of citizens increased by 52.5 percent in the same eleven-year period. See Figure 1.1

The age distribution also was skewed: about 80 percent of the foreign population was more than fourteen years of age, but less than 60 percent of citizens were more than fourteen. For the total population, 33.4 percent were in the age-group of zero to fourteen; 62.8 percent were in the age-group of fifteen to fifty-nine ; and a mere 3.8 percent were in the age-group of sixty years and older. [CIA, (2005) World fact book]

2. Problem Definition

In Bahrain Ministry of Electricity and Water is responsible for generation, transmission, and distribution of electricity throughout Bahrain

The public supply of electricity in Bahrain started in May 1931 with the commissioning of the first power station of Ras Roman with capacity of 0.2 Mw while the consumption was 0.09 Mw, since that time man has not been able to get along without electricity.

Presently, installed capacity is barely able to meet current consumption, with the country population growth of 5.2% annually and economic development leading to rapid power demand increase. [Ministry of Electricity and Water, (2001) Water Annual Report, Bahrain]

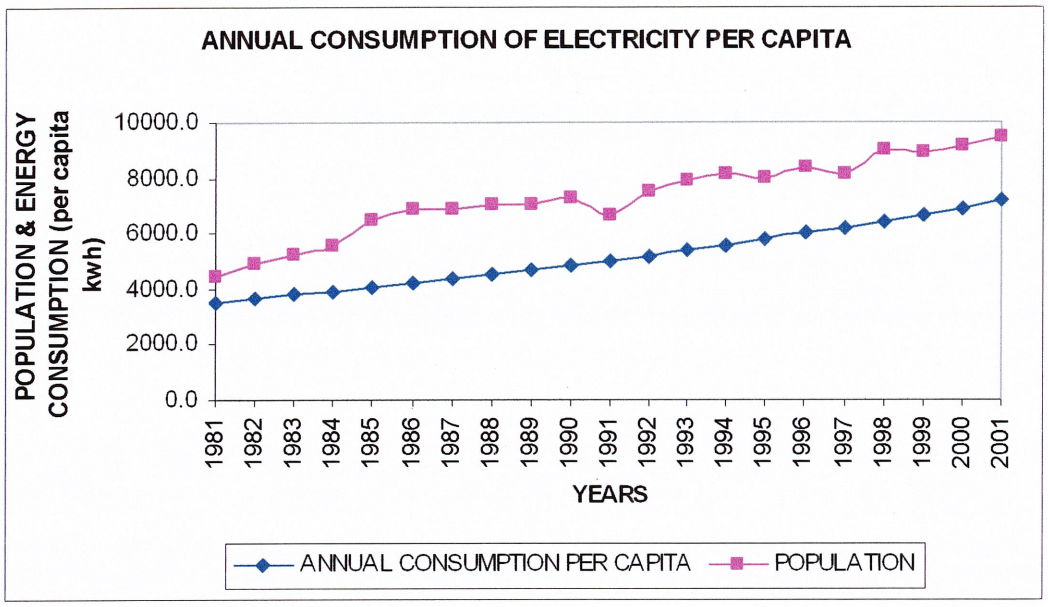


FIGURE 1.1 Annual Electricity Consumption per Capita

In the year 2003, Bahrain had an estimated electrical generating capacity of 1.44 GW and produced 7.3 billion kWh. Historically power demand showing almost a linear growth in peak electricity demand as shown in Figure (1.2), adding to that domestic power prices are expected to remain at the lower level set by government in 1992 in an attempt to help low income groups, see Figure (1.3) the yearly average growth in energy consumption was estimated to be 7%, this trend indicates that the government faced with problem of installing new capacity, which is too costly and the country will not be able to subsidize the electricity in the same way.[CIA, (2005) World fact book]

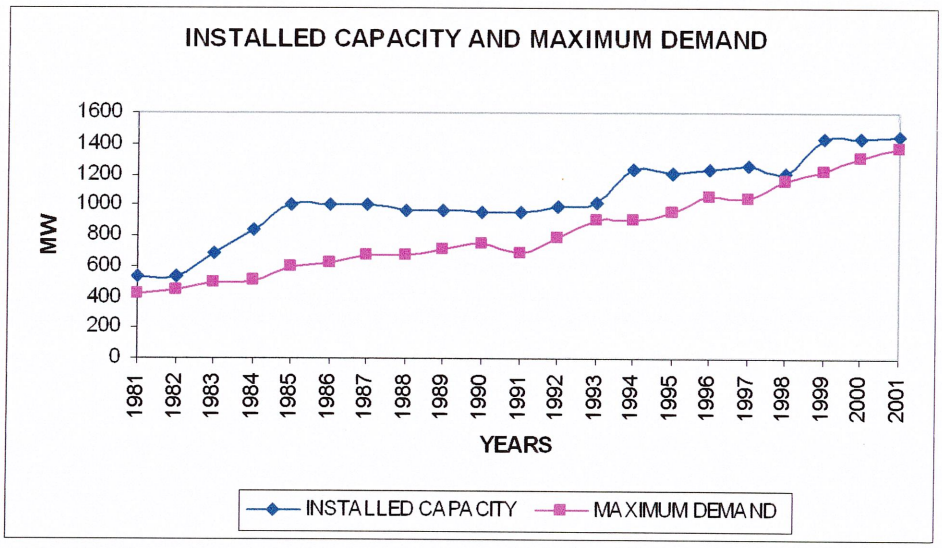


FIGURE 1.2 Installed Capacities with Maximum Demand

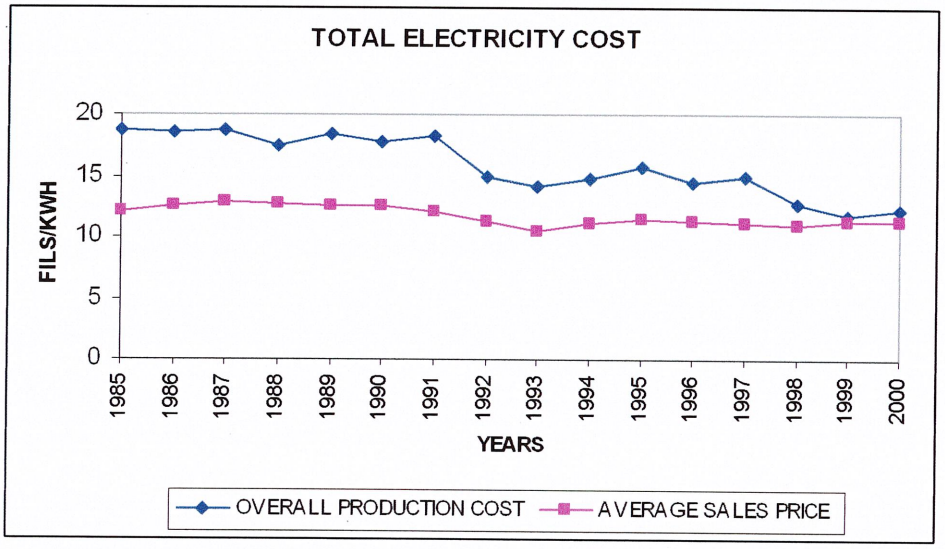


FIGURE 1.3 Electricity Cost \ Price

As a result; government is faced to find out a better strategy than increasing the installed capacity as the only solution. Recently some rules were established to control the new constructions in order to reduce the power consumption that goes mostly for air conditioning.

Bahrain gets its power from two combined water and power production complexes (Hidd and Sitra) and three smaller electricity plants only (Riffa, Manama and Muharaq). Table (1.1) shows the different power stations in Bahrain and their installed capacity. Table (1.2) shows the percentage share of each power station in the overall power production for year 2001. [Ministry of Electricity and Water (2001), Annual Report, Bahrain]

The average energy consumption for the last five years indicates that 54% of the total energy consumption goes for domestic use, 29% of the total for commercial use, 16% of total for industrial use and only 1% for agricultural , as shown in Figure (1.4)

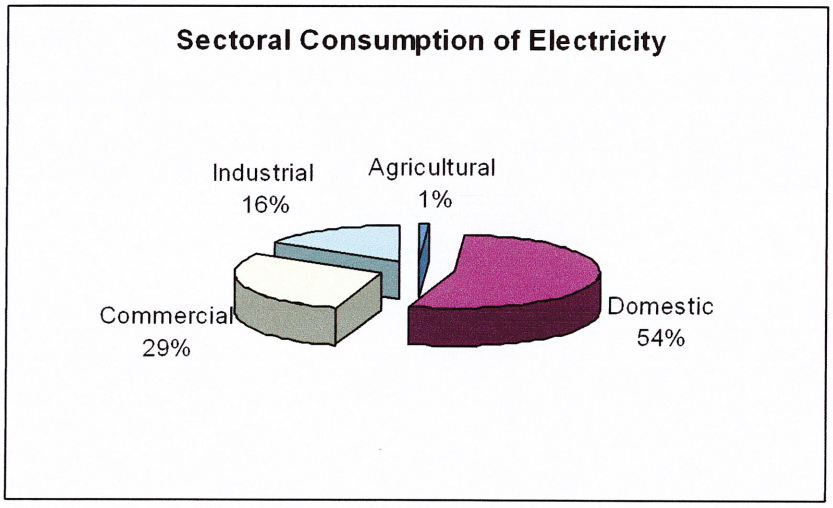


FIGURE 1.4 Sectors Percentage Consumption of Total Electricity used in Bahrain

Since, the domestic sector alone consumes about 54%, hence it is appropriate to have an over view on the different electricity consumption devices, which is shown in Table 1.3, it is also important to mention that it is the effect of the user's mentality plays an important role on these figures that are given in the table 1.1. It also depends on the family activities and homework organizations.

TABLE 1.1 Capacities of Power Stations

Unit	Type	Year of commissioning	Fuel	Capacity (MW)
MANAMA POWER STATION				
B5	Gas Turbine	1958	Gas	5.0
B6	Gas Turbine	1959	Gas	5.0
B7	Gas Turbine	1960	Gas	5.0
B8	Gas Turbine	1961	Gas	5.0
B9	Gas Turbine	1964	Gas	5.0
B10	Gas Turbine	1965	Gas	5.0
C1	Gas Turbine	1966	Gas	10.0
C3	Gas Turbine	1970	Gas	10.0
C4	Gas Turbine	1972	Gas	10.0
JB1	Gas Turbine	1975	Gas	16.0
JB2	Gas Turbine	1975	Gas	16.0
MUHARRAQ POWER STATION				
AEG1	Gas Turbine	1976	Diesel	15.0
AEG2	Gas Turbine	1976	Diesel	15.0
SITRA POWER STATION				
TA1	Steam Turbine	1975	Gas	25.0
TA2	Steam Turbine	1975	Gas	25.0
TA3	Steam Turbine	1977	Gas	25.0
TA4	Steam Turbine	1977	Gas	25.0
GT5		1984	Gas\Diesel	25.0
RIFFA POWER STATION				
G1	Gas Turbine	1978	Gas\Diesel	48.0
G2	Gas Turbine	1978	Gas\Diesel	48.0
G3	Gas Turbine	1979	Gas\Diesel	48.0
G4	Gas Turbine	1980	Gas\Diesel	48.0
G5	Gas Turbine	1983	Gas\Diesel	75.0
G6	Gas Turbine	1983	Gas\Diesel	75.0
G7	Gas Turbine	1984	Gas\Diesel	75.0
G8	Gas Turbine	1984	Gas\Diesel	75.0
G9	Gas Turbine	1984	Gas\Diesel	75.0
G10	Gas Turbine	1984	Gas\Diesel	75.0
G11	Gas Turbine	1984	Gas\Diesel	75.0
HIDD POWER STATION				
G11	Gas Turbine	1999	Gas	136
G12	Gas Turbine	1999	Gas	136
TOTAL		**31 units**		**1209**

[Ministry of Electricity and Water (2001), Annual Report, Bahrain]

TABLE 1.2 Percentage share of total capacity

Power Station	Percentage Share of Total Capacity
MANAMA POWER STATION	7.60
MUHARRAQ POWER STATION	2.48
SITRA POWER STATION	10.34
RIFFA POWER STATION	57.07
HIDD POWER STATION	22.49

[Ministry of Electricity and Water (2001), Annual Report, Bahrain]

TABLE 1.3 Annual Electricity Consumption for Residential Building in Bahrain

End use	Winter (kwh/month)	Summer (kwh/month)	Annual (kwh/year)
Water heaters	425	0	3000
Lighting	125	125	1500
Space heating	145	0	600
Refrigerators	125	125	1500
Washers	80	80	1000
Others	210	210	2500
Space cooling	0	2660	14400
TOTAL	1100	3200	24500

[Ministry of Electricity and Water (2001), Annual Report, Bahrain]

Most residence are air conditioned with window units, air conditioning consumes at least 58.8 % of the total annual residential use of electricity.

According to 2001 census data, of the total annual electricity consumption of 6779Gwh, of which 3661 Gwh was used in residential sector. The average electricity use during months January, February & March is 1258 Gwh, assuming that this is used for non air conditioning use and that is remain the same through out the year, the annual air conditioning consumption in the residential sector will add up to 2403 Gwh . This air conditioning electricity use accounts to 66 % of the annual residential consumption. [Ministry of Electricity and Water (2001), Annual Report, Bahrain]

With the expansion in the transmission and distribution networks and to apply the latest technologies for optimal operation of the electric system, the ministry has completed a project to upgrade and develop the control centers of both Electricity and water networks. The upgrade included development of the power system control center and distribution control center by replacing the old hardware and related software with new up to date technologies.

A comparison can be established between Bahrain and other countries of the Arabian Gulf cooperation council as on Table 1.4, 1.5 and Figure 1.5 [CIA, (2005) World fact book]

Table 1.4* Electrical Consumption & Production

County	Consumption (kwh / person)	Production (kwh / person)
Kuwait	12,538.5	13,480.3
Qatar	9,983.19	10,734.3
Bahrain	8,453.61	9,089.92
Oman	2,873.08	3,089.27
Saudi Arabia	4,307.67	4,633.2

Table 1.5** Electrical Generation Ability (per Capita)

Country	Electrical generation ability (kwh)
Kuwait	3.6387
Qatar	1.73802
Bahrain	1.45276
Oman	0.69953
Saudi Arabia	Not available

Notes:

* Discrepancy between the amount of electricity generated and consumed is accounted for as loss in transmission and distribution.

** Per capita figures expressed per population.

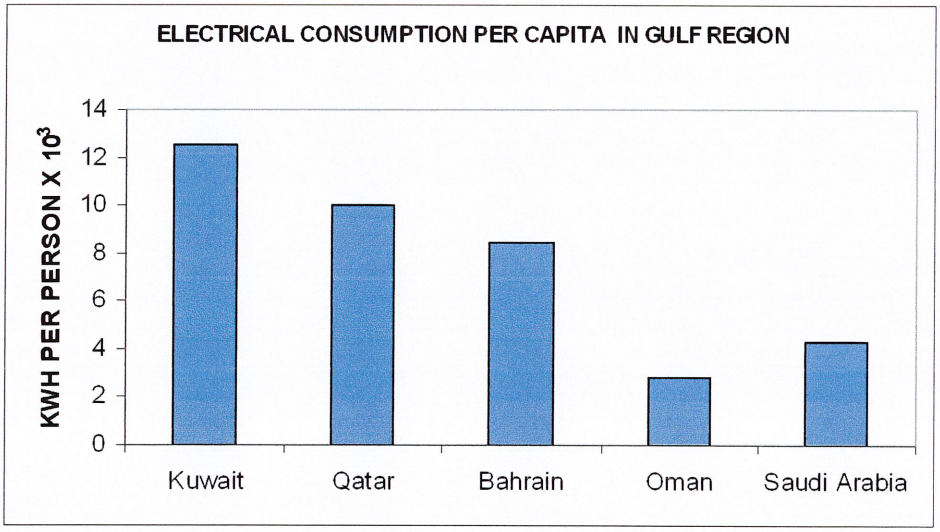


FIGURE 1.5 Electrical Generation Ability (per capita)

3.0 Objective of the Study

The main objectives of the study are:

1. To determine the electrical energy saving when using advance glazing units in the residential buildings in Bahrain.

2. To study the effect of this conservation strategy on consumer, environment and national economy.

4.0 Research Methodology

- **Window System Survey.**

  This part covers the preliminary study of the types of windows mostly used, glazing & coating, framing material, shading techniques. Advantages and disadvantages of each with respect to weather conditions and cost.

- **Software and Energy Analysis.**

  The Energy 10 Building Energy Simulation Program is used to simulate the building thermal behavior and the energy consumption. A comparison between the actual case and different glazing options with respect to energy saving and cost saving are studied. [Energy – 10 Software Manual, 1993]

5.0 Data Collection and Analysis

- Sample from the residential sector in Bahrain is taken and the overall description of that building entered into the simulation program.
- Types of the local window frames, glazing incorporated in the building.
- Typical metrological year (TMY) using weather maker software used as input file for Energy 10 simulation.
- Cost benefit analysis is used to analyze the data based on market as will as electrical energy prices.

6.0 Organization Thesis

This thesis presented through the following main chapters:

Chapter Two: Literature Review

Chapter Three: Describes the parts consists the window unit, the mechanisms of heat transfer through glazing and also provide information on some of the glazing systems currently available.

Chapter four: Illustrates the capability of energy 10 software

Chapter Five: Describes the selected building characteristics and the steps employed in the method of approach.

Chapter Six: Results and Discussions

Chapter Seven: Conclusions and Recommendations

References

Glossary

Appendices

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

It used to be said that "windows are little more than holes in the insulation." It is true to some extent that poorly insulated and drafty windows in certain climate defeat the purpose of wall insulation. However, modern high performance windows are almost as good as opaque insulated wall sections, at least in term of total energy saving over long periods of time. In some cases, they can be shown to actually out perform insulated walls. Of course, they have the priceless additional benefits of providing views to the outdoors and natural daylight illumination indoors which is important issues of quality and comfort.

Windows are not directly energy consuming devices. Sometimes they cause the building to use more energy than would be the case without them, and at other times they actually reduce the building's need for energy. When windows let heat escape on cold winter nights (causing the heating system to use more energy) and when they admit solar radiant heat on hot summer afternoons (causing the air cooling system to use more energy) they increase the building's energy cost.

On the other hand they can reduce energy use; one way is to admit solar radiant heat into the building on a cold winter day. The solar radiation directly heats the building's interior, and this heat is used to displace energy that would otherwise be purchased for heating the house.

The main purpose of a building and its windows is to provide comfort to the occupants as the sun moves through the sky, as the outdoor air temperature and humidity vary, and as wind and rain come and go. If comfort can be achieved while reducing the building's energy use and lowering monthly utility bills, so much the better.

2.2 Literature Review

In March1998 an information dossier which is one of a series reporting on the experience gained during the design, construction and monitoring of buildings, with principle of:

- Reducing energy consumption by 50% compared with traditional buildings.
- Reduce CO_2 emissions by up to 70%.
- Avoiding air conditioning, or minimizing its energy use.

Have included case studies investigating on successful window design, with aim of minimizing energy consumption at the same time as providing a comfortable internal environment all year round.

For that purpose, the function of the window is defined as to:

- Provide sufficient daylight into the building (without causing glare)
- Keep out excessive solar heat.
- Allow visual contact with the surrounding
- Keep out excessive noise.
- Ensure good weather protection
- Provide good insulation
- Ensure safety
- Allow controllable ventilation air into the building.

The report concludes that the optimum balance between these demands is difficult because many of the demands are directly in contravention with each other, for example:

- A large window area will in general be of benefit in terms of daylight penetration and passive solar, but a problem in terms of heat loss, solar overheating and glare.
- A high insulation value of the glazing will reduce the heat loss in winter, but can increase overheating in summer (depend on the outdoor temperature)
- Non clear glazing keeps out daylight and solar gain thus reducing overheating. At the same time the artificial lighting has to be on for a longer period during the day thereby increasing overheating.
- Poorly designed glazed areas will cause glare forcing the occupants to use of artificial lighting and consequent overheating.

(*Esbensen Consulting Engineer, 1998*)

In 2001 Guardian industries corporation , had prepared an article that examines the energy efficiency impact of different commercial glazing options by using DOE-2 a sophisticated building energy simulation program developed by the US department of energy to model the energy consumption and energy cost. The analysis made for 6 story building with 20,000 sq ft of glazing distributed equally around the building, the model simulated different climate conditions in four cites: Chicago, Miami, Tokyo, Bangkok. The result of the study was as follow:

- Glazing with low solar heat gain coefficient (SHGC) provides the highest summer peak demand reduction in Chicago, Miami and Tokyo.
- In Chicago which is heating dominated, glazing with low U and SHGC value provide the highest annual saving.
- In Miami, Bangkok and Tokyo, which are mainly cooling dominated glazing with the lowest SHGC, offer the highest annual saving.
- Generally the reflective and low-e coated glass made possible greater reduction in solar heat gain than what was possible with other types.

(*Guardian Industries Corp, 2001*)

Another study represents a cost benefit analysis of energy efficient technologies in the residential sector in Bahrain, the technologies studied include: energy efficient air conditioning, insulating houses, using double glazing reflective window, improve infiltration. The study shows that as much as 19% of air conditioning in large houses can

be saved by using double glazed windows with reflective films. (*Akbari, Morsy and Al Baharna, 1996*)

A study describes how Energy-10 simulation program was used in the design of the environmental technology center for Sonoma State University in California; the starting was with a goal to reduce energy consumption by 80% below the regulated maximum. The author believe that low energy building design works best through a process that starts with energy calculations in predesign that identify the best energy saving opportunities and continues with follow up calculations as the design proceeds. The same applied in this case, the center area was 2200 sq ft , the daytime occupancy assumed to be 4 to 6 hours, with gathering of 100 during special events once a month. Using RANK feature omitting glazing show a reduction of up to 15% compared to omitting the most effective strategies which was use of high efficiency HVAC which contribute to 18% reduction of the annual energy saving. At the end of the schematic design, Energy -10 calculations confirmed that the goal of 16800 Btu/ft2 had been attained an extremely low energy building. (*Dr. Douglas Balcomb, 1998*)

A study in USA investigate the measures used to lower building energy consumption and their cost effectiveness uses TRNSYS computer program for the modeling and simulation of the energy flows of modern houses. The measures examined are: natural and controlled ventilation, solar shading, various types of glazing, orientation, shape of building, and thermal mass.

The result of the study was as follow:

- In summer, ventilation leads to a maximum reduction of annual cooling load of 7.7 % for maintaining the house at 25^0C.
- Window gains are important factor and significant saving can results when extra measures are taken. The saving in annual cooling load for a well insulated house may be as much as 24% when low emissivity double glazing window are used, which are recommended since the payback period is short (3.8 years)
- Overhangs may have a length over window of 1.5 m. in this way; about 7% of the annual cooling load can be saved for a house constructed from single walls with no roof insulation.
- The shape of a building affect the thermal load, the result show that the elongated shape show an increase in the annual heating load , which is between 8.2% and 26.7 % depend on the construction type compared with square shaped house.
- With respect to the orientation, the best position for symmetrical houses is to face the four cardinal points and for an elongated house to have its long side facing south.

(*Florides G.A, Tassou S.A, Kalogirou S.A, Wrobel L.C, 2002*)

Another study on effect of window parameters on indoor thermal environment of buildings in a hot arid climate in Iraq , investigate the effect of size, orientation , glass quality and shading of windows, the study uses a validated mathematical model which simulates the transient thermal behavior of the building. The physical model is a 6 m x 4 m x 3 m high rectangular structure with longer sides facing north and south. The walls of

the room are composed of 30 cm thick masonry bricks. The mathematical model consists of energy balance equations for all inside surfaces of this room and uses time lag, decrement factor and solar temperature concept. The results show that the indoor environment does not improve significantly if the window glazing is changed from single to double. The result further show that a south facing window has the largest potential to improve winter and summer indoor comfort and each meter square area of window can provide winter heating for 2-3 meter square area of the floor. South facing windows improve thermal indoor comfort in summer also. (*N. I. Al-Hamdani, A. I. Ahmad, 1986*)

In another study a solar gain and thermal energy transfer through window is studied for three different sites in Jordan (Amman, Irbid, and Aqaba) using the TRNSYS computer program. Solar and thermal energy is calculated using the monthly average daily data for above mentioned three regions. It is found that for all directions, solar gain is season dependent, and this dependency varies from one direction to another. Calculations are carried out for two cases of glazing location: case (1) glazing flush with the outside of the wall. Case (2) glazing recessed by 15 cm from the outside wall, which represents a window with overhang and sidewalls. The number of glazing layers is taken as 1, 2, and 3 to observe the effect on solar gain as well as on the thermal energy exchange between the inside and outside of the building. The conclusion was that the main feature of solar gain is that it is the opposite for other orientation. It is also concluded that solar radiation from east and west oriented windows is significant and should be taken care of. Also solar gain is reduced by increasing the number of glazing layers. Thermal energy transfer, which is weather dependent, is affected strongly by increasing the number of layers of glazing especially from single to double glazing. *(A.Rousan Akram, Shariah Adnan, 1996)*

Another study investigates the effect of energy conservation measures on the life cycle cost of Kuwaiti residential buildings. A mathematical model using the dynamic methods to calculate heat gain by considering the different factors affecting heat gains or losses is used in this study. The computer model is known as the KESB (Kuwait Energy Use Simulation for Building) which is a modified version of the U.S departments of Energy (DOE-2) program. The life cycle costing analysis for a typical two story residential building that using double glazed window, reduce size to 33% of the original size, relocated window in the southerly and northerly direction and applying shading strategy, the owning and operating costs of the building will reduced by 870 K.D annually for the building owner, and the government would realize a saving of 4287 KD annually for each such house. *(Fereig S.M, Younis M.A, 1985)*

Here in this study, we are evaluating the electrical energy saving that would result due examined use various type of glazing, orientation of window, solar shading, reduce infiltration as to lower building energy consumption and present their cost effectiveness which is main concern to engineers & an important measure for economy. Also the environmental impact due to reduce of emissions considered.

CHAPTER THREE

WINDOWS AND GLAZING

3.1 Window and Glazed Surface

3.1.1 Background

Technological advances in glazing and window assemblies, lighting, and sophisticated energy management controls have complicated glazing systems design. Selecting a window assembly that provides the greatest value or efficiency is difficult considering the multitude of performance criteria that should be considered and evaluated, the number of glazing options to select from, and the profusion of window manufactures on the market. [Carmody, J.and Selkowitz, (1996)]

Windows are defined as the physical openings in a building's exterior envelope. The resulting pattern of the openings is considered fenestration design. Typically provided for natural light, ventilation, and view related purposes, these openings also contribute both positively and negatively to a building's overall performance. This correlation between windows and building performance, coupled with an increasing awareness of resource conservation measures, requires that fenestration schemes be looked at critically, early in the design process. [Carmody, J.and Selkowitz, (1996)]

The evaluation of fenestration alternatives is a complex problem. Design tools are available to aid in the analysis, but they are no substitute for informed designers.

Window and glazing product selection during the preliminary design phase can have profound repercussions throughout the life of a building. Information that helps designers and specifiers to optimize the selection of building components can enhance the functionality of a building, and subsequently reduce its burden on the environment.

It should be recognized that fenestration design is a subset of building design, and therefore is very context sensitive. Unless multiple buildings are being built in the same geographic region, on the same site, with the same orientation, a separate analysis should be conducted for each individual building design. [http://www.wbdg.org/design/windows.php]

3.2 Building Design and Fenestration

The design of a structure for human occupation is a complex task. It involves functional, structural, and mechanical relationships that require the coordination of many expert disciplines. Building material advances, systems advances, and the development of sophisticated computer modeling techniques can expand and enhance potential design solutions. Advanced design solutions require detailed analysis in order to identify material and performance optimization criteria. This identification process is difficult to complete.

3.2.1 Holistic Building Design

The traditional methodology for the product design and delivery process of a building typically includes the architect, who independently completes the initial stages of design; a host of engineers and consultants who "cram and jam" component systems into the architect's design solution; and a return to the architect for coordination and assembly of final documentation and contract administration. This type of inefficient and uncoordinated design delivery process is slowly being replaced by an integrated team approach.

An integrated or holistic design approach includes engineers, planners, and other consultants during the early planning and preliminary design phase. The early involvement of all required disciplines allows for a more integrated building design. It encourages early, open dialogue toward a "site-specific" design through an iterative process involving the various disciplines at the design phase.

Introducing feedback loops into the design process can impact building envelope and fenestration design. The holistic design approach more readily recognizes the vital interaction that takes place between individual building systems. Each building component is more likely to be viewed as a part of a larger whole and not as a separate entity, greatly improving building performance. For example, the optimization of a structure's fenestration design can have a ripple effect on many other building component systems. [Hayter S.J, (2001)]

Mechanical implications resulting from optimizing glazed surfaces:

- smaller chiller plant and reduced run-time
- smaller cooling tower
- smaller distribution system due to load reductions
- smaller heating plant and reduced run-time
- smaller mechanical room requirements

Cost implications:

- increased design costs
- reduced utility costs (energy and demand)-from lighting and heating, ventilation and air-conditioning (HVAC)
- reduced capital cost of HVAC equipment
- possible increase in the capital cost of lighting system

Modifying the process to accommodate early feedback loops can provide great benefits. Typical obstacles to using this approach include:

- holistic design is a more complicated approach and constitutes a significant break from traditional design;
- holistic design requires more analysis from the design team;

- frequently there is no financial incentive for the design team to provide this type of approach;
- the holistic design process requires specialized capabilities that may include the ability to use sophisticated computer software;
- Holistic design requires the architect and owner to involve other disciplines early in the design process.

3.2.2 Fenestration Design

Components

The term "fenestration" describes the physical arrangement of openings in a building's exterior envelope. This typically involves the design and disposition of window assemblies and doors. Component parts of a window assembly include frame, sash, glazing, spacers, and any accompanying hardware. Glazing describes the transparent or translucent component of the window assembly.

As noted previously, the fenestration design of a building can have a quantifiable impact on the energy performance characteristics of a building. It can also have an identifiable impact on the performance of a building's occupants.

Design-behavior research has explored the effects on workers of various elements of workplace environments, such as lighting conditions, noise levels, views from windows, and office furniture arrangements. Such research has focused on the qualitative aspects of the work environment and on workers' perceptions of their surroundings. The quantification of potential gains in worker productivity, however, is difficult and context dependent.

Conversely, the potential energy use impacts of a structure are easily identified and quantified through simulation modeling techniques and can be confirmed through empirical validation.

Windows and Glazing

A brief examination into the historical development of windows reveals that the most basic function of a window opening is for the introduction of natural light and ventilation into the interior of a structure. The advent of clean and efficient mechanical systems has diminished one functional component, ventilation, by reducing natural ventilation requirements. Likewise, the improvement of artificial light sources has decreased the necessity for natural daylighting.

As environmental systems that control, modify, or simulate natural processes improve, the design parameters for windows and glazing systems are modified. In the 1970s, window design was focused toward mitigating unwanted solar heat gains and increasing

window insulating abilities in response to the energy crisis. In the 1990's, the advancement of control technologies has encouraged a new building design paradigm of "smart" systems and neural networks that physically interact to provide comfortable interior spaces. For example, lighting systems can now be configured to automatically modulate depending on the amount of natural light within a space.

Improvements in fenestration system components (advanced glazing, improved glass coating and edge sealing techniques, suspended films, improved window frames, and sealant technologies) have substantially altered how windows function and impact interior spaces.

However, these technological advances have not substantially altered the window's basic, historic function, and windows are once again being recognized for their daylighting abilities and their potential to provide energy savings and fresh air.

3.3 Heat Transfer Fundamentals

This section reviews basic heat transfer fundamentals as they relate to glazing technology, specification, and performance.

3.2.1 Mechanisms of Heat Transfer

Heat transfer is the movement of energy that results from a temperature differential. The three basic mechanisms, or modes, of heat transfer are conduction, convection, and radiation.

Conduction

In general, conduction is the flow of energy across a solid, gas, or liquid due to thermal diffusion between molecules. An everyday example is a pot on a stove becoming hot after contact with the burner. Molecules vibrate according to their energy level (temperature), and this energy is transferred from molecule to molecule through the solid from higher to lower temperatures. The amount of energy transferred by conduction is directly proportional to the temperature difference (referred to as _*T* or "ΔT") and a material property called the thermal conductivity (*k*). Conductive heat transfer is also inversely proportional to the thickness of the material (*L*). These relationships to heat transfer (*Q*) can be stated mathematically as:

$$\mathbf{Q_{cond} = k\ (\Delta T/L)}$$

Where;

Q_{cond} = rate of heat transfer by conduction

K = thermal conductivity of the material

ΔT = temperature difference between the two surface.

L = thickness of the material

For a given amount of heat transfer, a material that is very conductive (has a high *k*-value) or thin (small *L*) will be more effective at transferring thermal energy and will result in a lower temperature difference. Alternately, a material that is a good insulator (low *k*-value) or very thick (large *L*) will suppress heat transfer and will result in a larger temperature difference across the solid.

Glass is a good conductor of thermal energy because of its relatively high *k* and low thickness (*L*)*. Air is a relatively poor conductor, which is why double-pane glazing (containing a blanket of air) provides additional insulation. The air acts as a thermal break to reduce thermal bridging between good conductors (the glazing panes). Some types of gas fills (argon) can further reduce the conductive properties of glass and often replace air in insulated glazing units. [Duffie J.A. and Beckman W.A, (1991)]

Convection

Convective heat transfer is the term used to describe the heat transfer that occurs between a solid and a fluid, or a solid and a gas, at different temperatures. Convection consists of both conductive heat transfer and heat transfer resulting from the bulk motion of a fluid or gas. Convective heat transfer is directly proportional to the convection coefficient (*h*), which can be viewed as a measure of the ability of the fluid or gas to impart its thermal energy to or from the surface. As the *h*-value of a surface/fluid interface increases, the temperature of the surface will approach that of the fluid. The mathematical relationship for convective heat transfer (Q_j) is given below.

$$\mathbf{Q_{conv} = h\ (\Delta T)}$$

Where;

Q_{con} = rate of heat transfer by convection.

h = convection coefficient.

ΔT = temperature difference

Convection is dependent on many factors, the most important of which is the velocity of the fluid or gas over the solid surface. This is demonstrated by blowing on a hot object to cool it quickly before touching it. Convection can be further described as either natural or forced. Natural convection occurs when the motion of the gas or liquid is driven by differences in density (caused by temperature differentials within the entity).

The force of gravity pulls the heavy fluid/gases down, which pushes the lighter fluid/gases up (that is, hot air rises, cool air falls). Forced convection is when the motion of the fluid or gas is externally induced (e.g., by a fan or the wind).

Heat transfer is usually higher for forced convection than for natural convection, because the velocity of the fluid/gas is often greater. Therefore, we blow on a hot object to cool it faster than the naturally rising hot air could. In typical glazing systems, convective heat transfer occurs between all gas/solid interfaces. [Duffie J.A. and Beckman W.A, (1991)]

Radiation

Radiative heat transfer is the exchange of electromagnetic energy between surfaces of different temperatures. Radiative energy is emitted by any piece of matter that has a finite temperature. (A finite temperature is any temperature above absolute zero. Even very cold surfaces emit radiant energy, although very little.)

Physically, radiant energy leaves a surface via electromagnetic waves and travels until it is incident on another surface. If a surface "receives" more radiative energy than it "emits," its temperature will increase (omitting other forms of heat transfer), and vice-versa.

One can experience a net positive radiative heat exchange when sitting near a wood-burning stove or radiant heater. The "heat" does not need air to travel through, and can in fact travel through empty space (e.g., sunlight). The equation that describes emitted radiation from a surface (Q) is

$$Q \text{ emitted} = \varepsilon\sigma T^4$$

Where

ε = emissivity (a measure of a material's ability to emit radiant energy); equal 5.67×10^{-8}

For a given temperature, materials with high ε values radiate more effectively than those with small values. [Duffie J.A. and Beckman W.A, (1991)]

3.4 Heat Transfer Process through Glass

All surfaces emit radiant energy levels according to their mean temperature. That is, a high-temperature surface emits high levels of radiant energy; a low-temperature surface emits low levels of radiant energy.

From this fact it can be concluded that other nearby objects also emit their radiant energy back toward the surface in question. This incident radiant energy on a surface can be absorbed by the surface, reflected off the surface, or transmitted through the surface.

For glass, most of the incident radiant energy is transmitted through the surface, although reflection and absorption are also factors (their values being dependent upon the spectral properties of the glass type). These modes of radiation are illustrated in Figure 3.1 for a typical wood window section, along with other heat transfer modes.

The radiative energy exchange for the illustration is the net energy transferred from the warmer room surfaces to the cooler exterior surface of the glazing. Actually, both surfaces emit energy toward each other. However, since the room surfaces will be warmer than the glazing surfaces, the resultant net radiant heat transfer is from the room to the glazing. This does not consider the effects of incident sunlight from the outdoors, which may tip the balance.

In a separate process, convection also causes energy to be transferred from the warm interior air temperature to the glazing. Heat transfer then occurs across the glazing itself via conduction, and at the outdoor surface, convection and radiant emission again take over as the dominant modes of heat transfer, transferring thermal energy to the outdoors.

Infiltration can also be a factor in the heat transfer process of the below assembly. Infiltration is the exchange of air through cracks in the window assembly.

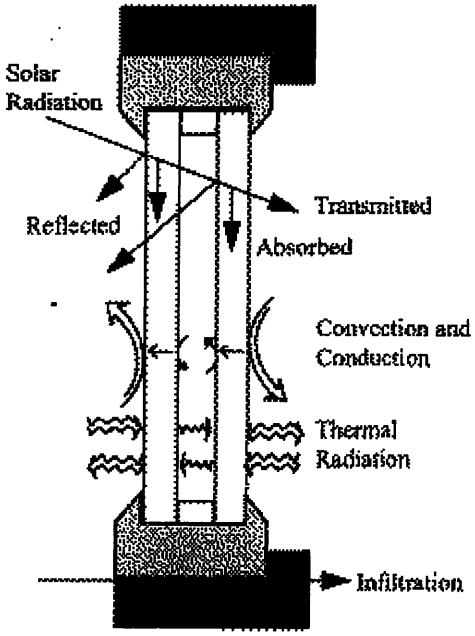


FIGURE 3.1 Modes of Radiation for a Typical Wood Window Section. [Deal, Brian M, Nemeth Robert J, (1998)]

Along with the described modes of heat transfer, three glazing-related factors must be considered when evaluating the overall energy performance of a building:

1. Interior glass surface temperature (T_i)

2. Solar gain from incident sunlight coming through the window/glazing system

3. The ability of the window/glazing system to prevent infiltration.

These values will vary depending on some physical forces

- indoor and outdoor temperatures (T_i and T_o)
- amount of incident solar radiation (Q *solar*)
- indoor and outdoor air pressure differential
- Characteristics of the glazing (thermal properties, radiative properties, air-tightness, etc).

The processes outlined above not only illustrate how energy is gained or lost through glazing, but are also important to understand the performance of advanced glazing technologies. These technologies, often involve material properties that enhance or suppress heat transfer, depending upon the design intent of the glazing system. To complete the discussion of the physics involved in glazing design, the properties of thermal radiation and the ways in which it contributes to solar gain are discussed in the following sections.

3.4.1 Solar Heat Gain

Solar radiation can be characterized by its wavelength, intensity, and direction. The visible and invisible portions of solar radiation can be identified within certain wavelength regions or spectrums. The energy in solar radiation varies with wavelength, so that the amount of energy delivered within each spectrum differs. The majority of solar radiation energy exists in the wavelength spectrum between about 0.3 and 3.0 μm, although some of it is attenuated in the earth's atmosphere.

Figure 3.2 illustrates the different wavelengths that exist in the solar spectrum near the surface of the earth. The solar spectrum can be broken into three main groups: ultraviolet (UV), infrared, and visible light.

Ultraviolet energy is mostly invisible and embodies only about 7 percent of the energy in sunlight. Infrared energy is also invisible and contains about 46 percent of the energy in the solar spectrum. The visible spectrum contains about 47 percent of the energy in the solar spectrum. Figure 3.3 illustrates the relationship between energy intensity and wavelength in the three spectrums near the surface of the earth. Peak intensity is reached at about 0.45 m in the green portion of the visible spectrum.

Solar heat gain is the measure of total heat gain (visible, infrared and UV) from sunlight that passes through a glazed surface and is eventually dissipated to the indoors. The amount of sunlight that a glazed surface receives is largely dependent on its size, solar

orientation and the time of day the measurement is taken. However, different glazing types possess unique solar heat gain characteristics.

Advances in glazing and coating technologies have resulted in products that can selectively transmit or reflect certain wavelengths of light. A spectrally selective glazing unit possesses optical properties that behave differently in one part of the spectrum than in others. Therefore, glazing can be chosen to either transmit or reject solar heat.

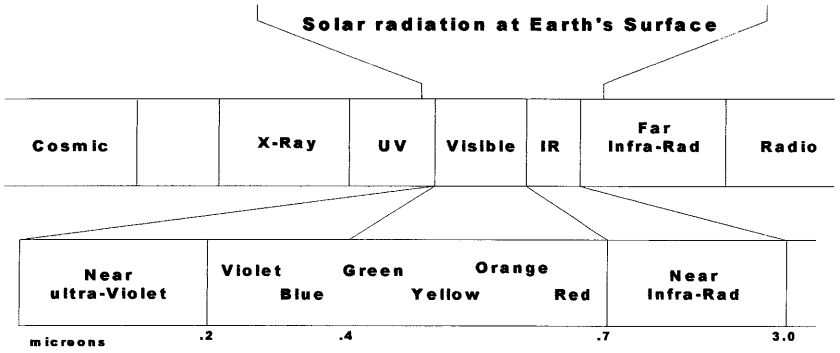


FIGURE 3.2 The Solar Spectrum. [Deal, Brian M, Nemeth Robert J, (1998)]

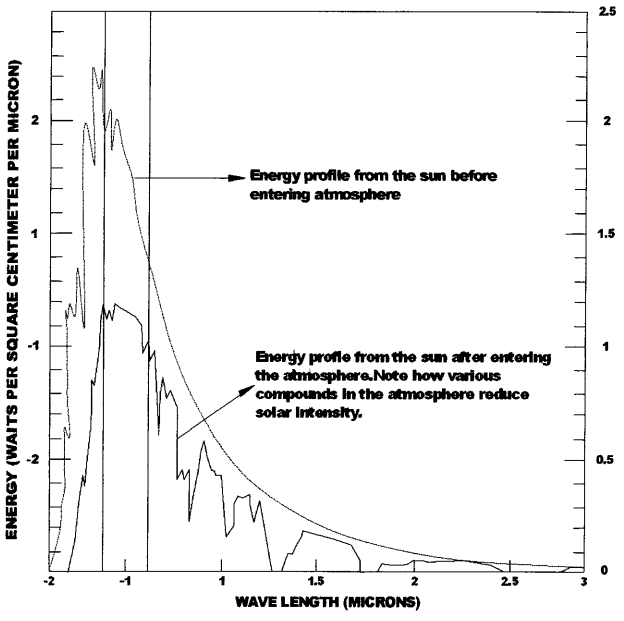


FIGURE 3.3 Energy Intensity and Wavelength. [Deal, Brian M, Nemeth Robert J, (1998)]

Almost all architectural glass blocks have long-wave radiation (far infrared) emitted by surfaces at temperatures below 121 °C. This characteristic is instrumental in producing the greenhouse effect. The greenhouse effect is caused by exterior visible and near infrared light that is transmitted through a glazed surface and is absorbed by interior surfaces. [Guardian Industries Corporation, (2001)]

This energy heats up the interior objects and is re-emitted at a much longer wavelength. The longer wavelength energy cannot escape the interior by transmission through the glass, because, as mentioned, glass blocks long-wave radiation. This long-wave radiation is then absorbed by the glass and re-emitted to both sides of the glass surface, reheating the objects within the space and effectively "trapping" large portions of the energy inside.

As noted previously, the three main radiative properties of glass are transmittance, reflectance, and absorptance. Together they describe what can happen to radiative energy when it is incident to, or falls upon, a pane of glass.

The radiative energy is transmitted through the glass, reflected by the glass, or absorbed by the glass. Values that are typically assigned to the three properties range between 0.0 and 1.0 and reflect the percentage of incident radiant energy that is transmitted, absorbed, and reflected.

For example, if we consider a sheet of clear glass and combine all of the possible wavelengths and directions of incoming sunlight, the solar properties are roughly as follows: transmittance (0.86), reflectance (0.08), and absorptance = (0.06). Note that these three properties must add up to 1.0 to account for all the radiant energy.

If 86 percent of the available solar energy is transmitted, the transmittance is said to be equal to 0.86 (Figure 3.4). If 6 percent is absorbed, the absorptance is 0.06. Likewise, if 8 percent is reflected, the reflectance is equal to 0.08. At any time, the sum of these radiative properties must equal 1.

The properties can vary considerably depending on glass thickness, number of panes of glass, amount of impurities, texture, and any coatings or tints that have been added. The properties will also depend on the wavelength and direction of the incoming light.

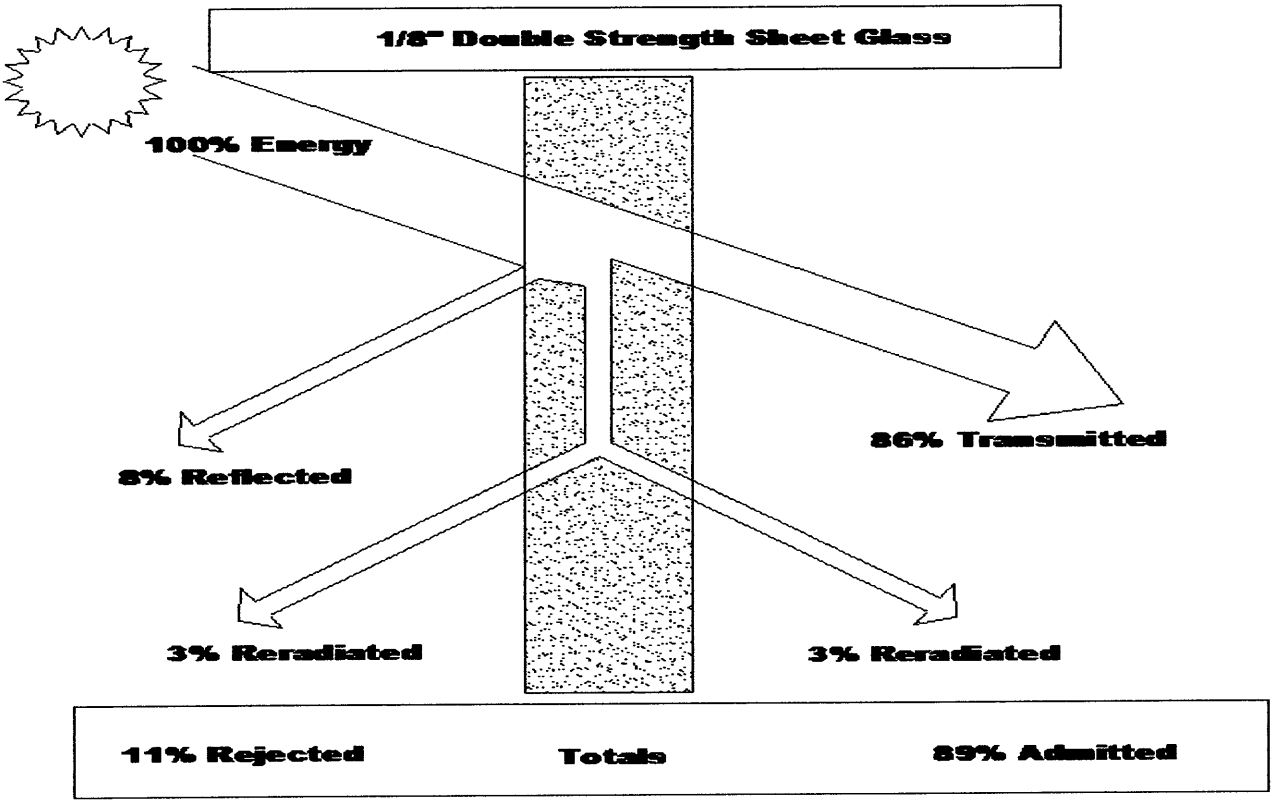


FIGURE 3.4 Effect of Light on Glass. [Deal, Brian M, Nemeth Robert J, (1998)]

3.4.2 Performance Indicators

R-value (1/U), shading coefficient (SC), and solar heat gain coefficient (SHGC) are performance indicators that must be considered to effectively evaluate heat transfer behavior.

Energy flows through fenestration via conductive and convective heat transfer caused by temperature difference between outdoor and indoor air, net long wave above 2500 nm radiative exchange between the fenestration and its surrounding and between glazing layers and short wave below 2500nm solar radiation incident on the fenestration product, either directly from the sun or reflected from the ground or adjacent objects.

Simplified calculations are based on the observation that temperature of the sky, ground, and surrounding objects _ hence their radiant emission_ correlate with the exterior air temperature. The radiative interchanges are then approximated by assuming that all radiating surfaces including the sky are at the same temperature as the outdoor air. With this assumption, the basic equation for the instantaneous energy flow Q through a fenestration is

$$Q = U\, A_{pf}\, (t_{out} - t_{in}) + (SHGC)\, A_{pf}\, E_t$$

Where

Q = instantaneous energy flow, W

U = overall coefficient of heat transfer (U-factor), W/ (m^2.K)

A_{pf} = Total projected area of fenestration, m^2

t_{out} = exterior air temperature, ^0C

t_{in} = Interior air temperature, ^0C

SHGC = Solar heat gain coefficient, nondimensional

E_t = incident total irradiance, W/m^2

U and SHGC are instantaneous performance indices. The principal justification for the above equation is its simplicity, achieved by collecting all the linked radiative, conductive and convective energy transfer process into U and SHGC. These quantities vary because:

1. Convective heat transfer rates vary as fractional powers of temperature difference or free stream speeds.
2. Variations in temperature caused by weather or climate are small on the absolute temperature scale (0R) that controls radiative heat transfer rates.
3. Fenestration system always involves at least two thermal resistances in series.
4. Solar heat gain coefficients depend on solar incident angle and spectral distribution.

Also the shading coefficient was defined to be the ratio of the solar heat gain coefficient for standard reference glazing at the same angle of incidence and spectral distribution:

$$SC = \frac{SHGC\ (\partial)_{test}}{SHGC\ (\partial)_{ref}}$$

The single pane clear and many single pane tined glazings, this ratio remains constant as the solar spectral shape varies and as the angle of incidence varies. Thus, a single number can be used to convert from the reference SHGC to the SHGC for the tinted glazing at the angle of incidence selected. Due to its lack of sensitivity to angle of incidence, the same SC value works for beam radiation at any angle of incidence, as well as for diffuse radiation. This meant that the complicated calculation of solar heat gain transmission through glass could be done once and tabulated.

In cold weather conditions it is desirable to suppress conductive, convective, and radiative heat transfer from the high-energy indoors to the low-energy outdoors. However, it is also desirable to enhance the solar radiative heat transfer from the outdoors (sun) to the indoors.

Therefore, when considering a glazing performance indicator, it is important to know what modes of heat transfer are being measured by that indicator. Because glazing systems can differ greatly and their surrounding thermal environments are constantly changing, performance indicators do not remain constant and might vary slightly in an actual application.

If we disregard solar radiation, air leakage, and moisture condensation, the rate of heat transfer through a glazing system is proportional to the difference in air temperature between the outdoors and the indoors as expressed by the equation:

$$\mathbf{Q = UA\ (\Delta T)}$$

Where;

Q = total rate of heat transfer (kw/hr)

U = overall heat transfer coefficient, or **U-value** (kW/ (hr m^2 °C)

A = Surface area of glass (m^2)

T = temperature difference between the two surface (°C)

The U-value is a measure of that system's ability to transfer energy under the above assumptions. It is the rate of energy (kw) flowing through a 1 m^2 piece of material or assembly with a 1 °C difference in temperature between sides for 1 hr.

U-value can be thought of as a "nonsolar" performance indicator that combines the effects of conduction, convection, and thermal radiation caused by the indoor-outdoor temperature difference.

It should be noted that U-values do not take into account the ability to transmit solar radiation. For comparison purposes and for code compliance, U-values are measured under standardized thermal conditions, because the actual U-value for a glazing system will change as conditions around it change. A designer may sometimes encounter a "summer" U-value (when heat flow is primarily from outside toward the inside) and a "winter" U-value (when heat flow is primarily from inside toward the outside). [Deal, Brian M, Nemeth Robert J, (1998)]

Also, different regions of a glazing system will have different U-values. Reported U-values are sometimes a combination of the U-values measured at the center-of-glass, edge-of-glass, and the frame. Sometimes only the center-of-glass U-value is offered.

Care must be taken when comparing U-values to ensure that they were calculated in a consistent manner. The most accurate information is the measure of the total window system. Good sources of U-values for windows are given in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers' (ASHRAE 1998) "Handbook of Fundamentals" [Deal, Brian M, Nemeth Robert J, (1998)]

Another thermal performance indicator is the R-value. The R-value is the inverse of the U-value and is thus a measure of the system's ability to resist heat transfer

3.5 Center Glass versus Whole Unit

When determining the energy performance of glazed surfaces, it is important to note the entire assembly of the window unit. Prior to 1989, the ASHRAE method for determining overall window R-value was based on estimating the losses associated with the particular glazing type (typically calculated at the center of the glass component). A correctional factor was then applied for the frame R-value. Frames were assumed to slightly improve the overall R-value of the window assembly.

Recent technological improvements in glazing thermal performance have created the opposite condition. Glazing is now typically the most thermally efficient component of the window system, with edges and frames reducing the overall R-value. The new calculation method has, in some cases, reduced reported R-values from 1989 levels.

3.6 Condensation Prevention

Air can hold varying amounts of water vapor or moisture. The warmer the air is, the more moisture it can hold. The amount of moisture in the air, expressed as a percentage of the maximum amount the air could hold at a given temperature, is called its relative humidity. For health and comfort, indoor air should contain some moisture. The relative humidity should generally be between 30 percent and 40 percent at normal room temperature. [Garvin S.L. (1998); Environmental Conditions in Window Frames with Double Glazing Units, Construction and Building Material, Vol. 12, pp 289-302]

The relative humidity of air can be increased by adding more moisture or by reducing the temperature. When the relative humidity reaches 100 percent, the air can hold no more moisture and water begins to condense from it. The temperature at which this condensation occurs is called the dew point temperature of the air. When moist air comes in contact with a cold surface in a house, it may be cooled to its dew point temperature, resulting in condensation on the surface. [Garvin S.L. (1998); Environmental Conditions

in Window Frames with Double Glazing Units, Construction and Building Material, Vol. 12, pp 289-302]

Windows do not cause condensation. Typically, however, windows are the first and most obvious place that condensation in a building occurs. This is because windows generally have a lower thermal resistance than insulated walls, ceilings, and floors. As a result, their insides temperatures are usually lower than those of other surfaces in a building during cold weather.

If the air in a building is humid enough, water will condense from it when it is cooled at a window surface. Condensation is most often thought of as a cold-climate, winter problem. However, in hot humid weather, moisture can condense on the outside surface of a poorly insulated window in an air-conditioned building.

Left unchecked, condensation can damage window frames, seals, and interior shades. Water can deteriorate the surrounding paint, wallpaper, plasterboard, and furnishings. In severe cases, it can seep into adjoining walls, causing damage to the insulation and framing.

The indoor air coming into contact with energy-efficient windows is less likely to be cooled to its dew point temperature because the inside surface temperatures remain higher during cold weather than do those of windows with single glazing, traditional metal spacers, and metal frames.

Figure 3.5 illustrates conditions under which condensation will form on the center of the glass of three glazing types with widely varied U-factors. The graph shows clearly that the risk of condensation at the center of the glass is reduced as the insulating value of the glass increases. Even at an outdoor air temperature of -34 °C, the indoor air relative humidity must be nearly 50 percent before condensation will form on the triple glazing with two low-e coatings. On the other hand, at an outdoor temperature of -29 °C, condensation will form on the single glazing at an indoor relative humidity of only 18 percent.

Figure 3.5 shows outdoor air temperature and indoor air Relative humidity combinations at which condensation will occur on the center of the glass for single glazing, double glazing, and triple glazing with two low-e (e = 0.15) coatings. On or above each curve, the conditions are right for condensation. Below each curve, condensation will not occur on that glazing type as long as the glazing is exposed to room air circulation. Results are based on winter conditions: 21.1 °C indoor air temperature, 15 mph outdoor air velocity, and no incident solar radiation.

Condensation is even more likely to occur at window spacers and frames, which are usually less isolative than the corresponding glazing. With so many insulating glazing types available, efforts to prevent condensation have shifted toward the development of better insulating spacers and frames.

glass, and depending upon the interior and exterior climatic conditions, some of this unwanted heat may be transferred to the building interior.

Absorptance levels depend on the absorbing material (tint) and the thickness of the glass. Thicker glass provides more absorptance and transmits less visible light.

The application of tints lowers the shading coefficient of clear glass because some of the light and solar heat is reflected and absorbed. Common tints available are gray, bronze, blue, green, and combinations of these shades. Characteristics of these tints are summarized below.

- Gray glass transmits approximately equal amounts of visible light and infrared.
- Bronze glass transmits less visible light and more infrared than gray glass.
- Blue and green glasses transmit more visible light and less infrared than gray glass.

Tinted glass alone can only reduce a shading coefficient to about 0.65. Combining tints with other glazing technologies such as reflective surfaces and coatings can further reduce shading coefficients (SC_c) or improve the coolness index (K_e). To be most effective (reduce interior heat gain), the tinted glass pane should be used as the exterior pane of a double-pane or insulated glass system.

Mirrored glazing is a form of tinted glazing consisting of metallic particles that reflect visible radiation. The SC_c and the solar heat gain coefficient ($SHGC_c$) of this type of glazing should be evaluated carefully before specification. It can reduce the indoor natural light considerably, creating dark, unpleasant interior spaces

Translucent coatings allow for the transmission of most of the visible light, but disperse or scatter the light and distort the view. Translucent coatings can be placed within the glass, embossed on the surface, or applied as a surface film. They are useful for applications where indirect daylight and privacy are desired. Translucent glass alone may have little, if any, effect on the SC_c or T_{vis} of the glass. As with tinted glass, it can be added to a system to enhance properties or meet specific needs.

Spectrally selective tints are created to be naturally selective to visible light. These tints are more selective in the visible and near-infrared spectrum than traditional tints and maintain relatively low SC_c and high T_{vis}. The addition of selective coatings (low-e) can increase the K_e, whereas reflective coatings can decrease the K_e. Coatings on suspended films between glass offer even more flexibility in K_e targets. [Deal, Brian M, Nemeth Robert J, (1998)]

3.7.2 Low-E and Reflective Coatings

Low-emissivity coatings were developed in the early 1970s primarily by the Massachusetts Institute of Technology (MIT) and introduced into the market around 1980. Most low-e coatings have relatively high T_{vis} and reflect 40 to 70 percent of

infrared. Put loosely, low-e lets in light but blocks the heat. Various low-e coatings allow different amounts of UV radiation, ranging from a 0.05- to 37-percent reduction.

A low-e coating is a microscopically thin, virtually invisible, metal or metallic oxide coating deposited on a glazed surface. The coating may be applied to one or more of the glazing surfaces facing an air space in a multiple-pane window or to a thin plastic film inserted between panes.

The coating limits radiative heat exchange between panes by reflecting heat back into the home during cold weather and back to the outdoors during warm weather. This effect increases the insulating value of the window.

Many solar control films are commercially available to retrofit existing windows. They may be low-e, tints, and/or reflective. Most retrofit films will improve the performance of the glazing but are typically not as effective as glass that is coated during manufacture. The SC_c and the T_{vis} are usually the target characteristics to be altered by adhering these films. All films, even those sold as clear, will affect the T_{vis} to some extent. Correct installation and durability are two important issues when considering retrofit films.[Deal, Brian M, Nemeth Robert J, (1998)]

3.7.3 Plastic Glazing

Plastics glazings were originally used for safety glass. They are less brittle and lighter in weight than glass, and they block essentially all UV radiation. Plastics are common for skylights where lightweight, safety glazing, or molded shapes are desirable. They can also be formed in structured and textured sheets. Many of the same coatings and additives discussed in this chapter can be applied to plastics. However, even though low-e coatings can be applied to plastic suspended films, they currently cannot be applied to plastics used as the structural glazing itself.

Plastic glazing deficiencies include degradation of the plastic over time and exposure to weather, greater thermal expansion, flammability, and low melting temperatures. These are important issues when considering plastic. [Deal, Brian M, Nemeth Robert J, (1998)]

Several types of plastic glazing are currently available:

- Acrylic glazing has good light transmittance and longevity. It tends to be soft and easily scratched. It can be frosted for translucence and privacy. Typically it is used in skylights. Acrylic is easily molded to a variety of shapes.
- Polycarbonate is similar to acrylic, harder, and less likely to scratch. It is a UV-stabilized material for use in vertical and overhead glazing. It has added properties to optimize its strength and thermal characteristics.
- Fiber-reinforced plastic consists of a double layer of plastic combined with fiberglass mesh or insulation. It is commonly seen as corrugated roofing panels that offer a translucent and flexible protection. Panels filled with fiberglass insulation are often used where a high thermal resistance combined with

translucent glazing is preferred. Exposed surfaces of some products may be susceptible to erosion.

3.7.4 Gas Fills and Vacuums

Historically, double- and triple-pane window voids were air-filled. Even though the air fill creates the insulating effect of multipane units, conduction and convective currents can develop. With the emergence of alternative gas fills, the heat transfer properties of multipaned glazings have decreased.

The most common alternative gas fills are inert gases. Many safe and naturally occurring gases have a significantly lower thermal conductivity than air. By hermetically sealing these gases between two layers of glass, the conductance of the window can be decreased. The most commonly used gas is argon, which is easily extracted from the atmosphere. Krypton is more effective, particularly in small spaces, but is more costly to obtain and use than argon.

When combined with special coatings, gas-filled units can achieve very high insulating values. For small thickness, the replacement of air with argon can effectively add about R-1 to the unit performance. An ideal air space should be 0.5 in. The wider the thickness of the fill space, the less advantageous the alternatives to air become. If the airspace is too wide, convective currents can develop within the multipane unit, minimizing its effectiveness.

An alternate to gas fill is creating a vacuum, or evacuated space, between the panes of glass. Although not fully developed, this system theoretically has no convective or conductive heat exchange between the panes of glass. The long-term integrity of the seals at the glass edges and the structural stability of the unit have not been perfected to make this a viable alternative. The seal must be able to keep air density within the unit to less than 1 millionth of normal atmospheric pressure. An air density of only 10 times this amount is sufficient to re-establish conduction to normal levels. The current technology consists of two panes of glass about a half millimeter apart with vacuum between the panes. Tiny invisible glass spheres or silica foam within the evacuated space keep the unit from collapsing. Note that even using a vacuum does not eliminate conduction through the window spacers, or prevent radiative exchange through the glazing, or decrease air infiltration.

Using transparent insulation has great potential for translucent and semitranslucent glazing with high R-values. Several types of transparent insulation are not currently available commercially; however, others have been used for many years. The three major types of transparent insulation (fiberglass, aerogel, and honeycomb) are described below.[Deal, Brian M, Nemeth Robert J, (1998)]

- Translucent fiberglass insulation is sandwiched between two panels of reinforced fiberglass. The density and thickness can be changed to modify the properties of the product. This product is currently available.

- Aerogel is made from 4 percent silica foam and 96 percent air. Microscopic cells of foam entrap gas, preventing convection, but allowing light to pass. This material creates a haze due to the scattering of light from the air pockets. It has the potential of reaching R-20 per inch. Radiation and conduction through aerogel are also reduced. This product is available in Europe, and a similar product is being developed in the United States.
- Honeycomb or capillary structures absorb solar radiation and re-radiate or transmit it directly indoors. Inner walls function like low-temperature wall heaters, creating a passive heating system.

3.7.5 Directionally Selective Materials

Directionally selective materials reject or redirect incident solar radiation based on a geometric relationship between incoming light and the material. These glazings can redirect light to a predetermined location. Examples of these glazings are glass block, silk-screened glazings, prismatic devices, enclosed louvers, holographic films, and imbedded structures.

Frit is the most common angle-selective coating. Frit consists of a ceramic coating screen (translucent or opaque) printed in small patterns on a glass surface. The pattern used on the glass controls the light based on its angle of incidence. The color of frit controls the reflection or absorption and the control of view or visual privacy. Visual transparency can also be controlled by applying frit to both sides of the glass in such a way that at some angles it appears transparent, while at other angles it appears opaque. Angle-selective materials can be thought of as a series of fins or overhangs within a piece of glass, which filter or block light.

Prismatic systems redirect light by the principles of refraction. Refraction is the "bending" of light as it passes through a material. A common example is the apparent "bending" of a pencil as it is immersed in water. A common prismatic device is the Fresnel lens, made of microscopic prismatic materials embedded within the glass to focus light. Depending on the application, Fresnel lenses can focus light inward or outward. Other than Fresnel lenses, prismatic systems have limited commercial availability.

Another type of directionally selective glazing in the research and development stage is holographic films. Holographic films consist of diffractive structures of photopolymers or embossed films that are applied to glass to direct light deep into a space. Light is redirected and remixed as desired, or as a function of the angle of incidence and wavelength of the light. If the film is applied to the upper portion of a pane of glass, light that falls on that area is redirected. Holographic devices work in a way similar to traditional light shelves but are able to redirect for desired light penetration. Holographic film offers reduced maintenance compared with light shelves, but does not provide shading of lower portions of glass. Glass will appear darker in areas where film is applied but will remain undistorted.

Current goals are to produce a product that will direct sunlight falling on the device toward the ceiling, deep into the room, which will reflect glare-free, diffused light into work spaces.[Deal, Brian M, Nemeth Robert J, (1998)]

CHAPTER FOUR

ENERGY 10 SOFTWARE

4.0 Introduction

Designing low energy building has been developed to help architects, engineers, builders and their clients create energy efficient and environmentally sensitive buildings, for that approach there are two techniques; the first is passive solar design techniques such as day lighting and shading; the second is the conventional energy saving measures such as insulation and high efficiency lights.

Sixteen of these techniques collectively called Energy Efficient Strategies (EES); are described below. Understand them is mandatory to work effectively with Energy -10. [National Renewable Energy Laboratory USA, (1993)]

SL NO	STRATEGY DESCRIPTION	SL NO.	STRATEGY DESCRIPTION
1	Daylighting	9	Lighting control
2	Glazing	10	Economizer Cycle
3	Shading	11	Solar Hot Water Heating
4	Energy Efficient Lighting	12	Evaporative Cooling
5	Insulation	13	HAVC Controls
6	Air Leakage Control	14	High Efficiency HVAC
7	Thermal Mass	15	Exhaust Air Heat Recovery
8	Passive Solar Heating	16	Natural Ventilation

Daylighting: properly conceived, natural daylight can greatly reduce building energy use and operating cost by:
(1) Allowing artificial lights to be dimmed or turned off.
(2) Reducing summer cooling caused by heat generated from artificial lights.

In most instances, electricity use is reduced and peak electrical demand charges are lowered. Equally importance, daylight can improve the aesthetic quality of a building and the productivity of the work environment. These combined benefits make daylighting one of the most important strategies featured in Energy -10, but only when properly designed and properly integrated with other strategies.

Glazing: Of the various components of the building envelope, glazing has the single largest effect on heating, cooling and lighting. Your choice of glazing will largely determine the level of solar radiant gain, the degree of daylight transmission and, in conjunction with frame design, the insulating value of a window. Perhaps more than any other building product, glazing technology has progressed dramatically over the last decade and needs to be considered carefully during building design.

Shading: External window shading is an excellent way to prevent unwanted solar heat gain. Shading can be provided by natural landscaping or by building elements such as awnings, overhangs and trellises. Some shading devices can also function as reflectors, or light shelves, which bounce natural light for daylighting deep into building interiors.

Energy Efficient Lighting: Energy efficient lamps and ballasts can be bought off the shelf, are easy to install and offer short payback. In passive solar buildings, the question should not be whether to provide efficient lamps and ballasts, but rather, what lamp/ballast combination integrates best with the other strategies, such as daylighting, shading, and HAVC control.

Lighting controls: Lighting controls are desirable in an energy efficient building because they adjust the light output of electric fixtures in response to variations in operation, occupancy and available natural illumination. The major types of controls considered here are switching controls and occupancy sensors. Daylight dimming controls are addressed under energy efficient strategy A.

Insulation: A well insulated envelope reduces energy use, enhances comfort and reduces the size of the passive solar system and associated thermal storage. Refer to appendix (D) for Bahrain building thermal insulation regulation.

Air Leakage Control: An air retarder system (ARS) reduces air leakage into the building, protects the insulation system and increases the life of the envelope structure and finishes. By acting as an infiltration barrier, an ARS limits the amount of unwanted, outside air which must be conditioned. When well conceived and properly detailed, air retarder membranes can save both heating and cooling energy.

Thermal Mass: Dense building materials with the right mix of thermal conductivity and heat capacity, such as brick, concrete and concrete block, store and release considerable amounts of energy when they rise and fall in temperature. When properly incorporated in a building, these thermally massive elements are an important aspect of passive solar design. In a passive solar heated building, thermal mass can absorb solar heat during the day and release it in the evening, when it is needed. During the cooling season, thermal mass can be cooled during off peak hours, mechanically or (in some climates) by night venting, to reduce the need for cooling in the morning and to decrease the required size of cooling equipments.

Passive Solar Heating: Passive solar heating in its various forms, can be used to reduce the need for fossil fuel in practically any building type. Entry of direct solar radiation can also create sunny, pleasant, and architecturally interesting interior environments.

Natural Ventilation: During the cooling season the natural circulation of outside air through buildings can often result in the creation of comfortable conditions without dependency on mechanical cooling equipment.

Exhaust Air Heat Recovery: During periods of occupancy, warm, conditioned air is replaced with cold outside air to maintain acceptable indoor air quality. With a heat recovery system, 50 percent or more of the heat in the exhausted air can be transferred to the incoming stream of outside air.

High Efficiency HVAC: Various types of efficient heating and cooling equipment can be matched with the needs and operational patterns of a particular building to provide mechanical heating and cooling in a cost effective manner. Often the use of energy efficient equipment can offer additional benefits, including utility rebates or reducing first cost (e.g., condensing heating appliances do not need chimney).

HAVC Controls: a variety of systems can be used to monitor indoor and outdoor conditions, and to control the operation of building mechanical system. Proper uses of building automation reduce energy consumption and electrical peak demand.
Evaporative Cooling: the term "evaporative cooling" applies to all processes in which the sensible heat in an air stream is exchanged for the latent heat of water droplets or wetted surface. Evaporative cooling design can take many forms including landscaping, use of water sprays, and the use of several types of simple mechanical devices. Evaporative cooling methods which use visible and audible water sprays can add excitement and "thermal delight" to a space.

Solar Hot Water heating: in many climates, active solar water heating can eliminate the need to operate conventional heating equipment for service hot water, or for space heating, during much of the year.

Economizer Cycle: Central air conditioning system can use large quantities of cool, dry outside air to provide a cooling effect without operation of a mechanical cooling cycle.

4.1 "ENERGY – 10" Software

ENERGY-10 is a conceptual design tool for low-energy buildings. It is the software component of a project called Designing Low-Energy Buildings with ENERGY-10, which is being conducted for the U.S. Department of Energy (DOE). The program does hour-by-hour simulations for a typical year.

The use of the program is intended primarily for residential and smaller non-residential buildings—generally less than 10,000 square feet (1,000 square meters)—that can be characterized by one or two thermal zones.

The ENERGY-10 program has been carefully and thoroughly reviewed by knowledgeable engineers and analysts, and to the best of our knowledge is accurate and error free.

ENERGY-10 helps on design energy efficient buildings, the evaluations are comprehensive, based on hour-by-hour calculations through all 8,760 hours of the year,

using simulation analysis. Also can be used to develop a "performance target" for the building based on information available

The ENERGY-10 tool is a good choice for selecting appropriate strategies and defining a performance target because it has been programmed to automate the steps required, reducing the process time

4.2 Weather Data

ENERGY-10 reads weather data from a data file that you select from files with an .ET1 extension. Only files located in the WEATHER subdirectory can be accessed in this way.

4.3 Brief History of Integrated Design

Energy efficiency has historically and rightfully been considered the most important attribute of a sustainable building. Although the impact on the environment from constructing the building can be significant, the accumulated environmental impact of energy consumption, which repeats every year throughout the lifetime of the building, usually adds up to 5 to 10 times the consequences of the initial construction. These impacts include on-site emissions that result from burning fuel and off-site emissions at the power plant that are a consequence of generating the electricity used in the building.

It is well documented that annual energy consumption can be reduced by 40% to 70% by employing energy-efficient strategies. Energy efficiency calls for a whole-building design approach, with the designer selecting and integrating at the outset those strategies that are most effective in each particular situation. ENERGY-10 will help you achieve these savings quickly and routinely.

One of the most important findings of the experience in integrated design is that building construction cost is not increased. Many strategies do incur added costs, such as added insulation or better window glazings. However, these same strategies usually lead to major decreases in the installed capacity of HVAC equipment required to meet peak summer and winter loads. This equipment is very expensive, often accounting for 15% to 20% of the construction cost of a nonresidential building. Reducing the installed HVAC capacity by 30% to 40% can free up money that can be used to pay for the added cost of the other strategies that made it possible to downsize the HVAC equipment.

It has been demonstrated repeatedly that the cost savings is about equal to the cost increases, leading to a building that costs no more to construct, yet uses half the energy to operate. Significantly, peak electrical loads are also significantly reduced. HVAC costs are usually larger in climates with large cooling loads because of the relatively high cost of cooling and air-distribution equipment, compared to heating equipment

Integrated design has been costly for two main reasons: [Hayter S.J, (2001)]]

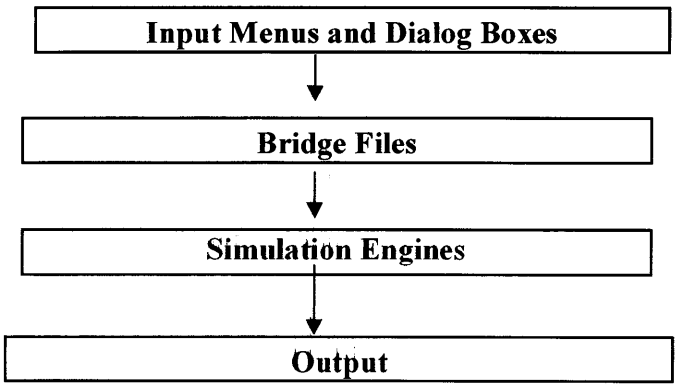
- It has been time consuming. Proper evaluation of options is a complex process that involves many trade-offs between issues. Accounting for all the important effects requires a detailed hour-by-hour simulation. For example, the process should include simultaneous evaluation of daylighting, the thermal effects of the reduced lighting loads, and the resulting HVAC and time-of-day effects on demand charges. Without this evaluation, the interactions between heating, cooling, and daylighting cannot be understood.

- Energy efficiency must be included in the design from the start, beginning in pre-design and receiving particular attention during schematic design. Traditional detailed evaluation tools, such as the large programs available for thermal and daylighting simulation, are not suitable. Because existing tools have been so difficult to use, they have been employed late in the design process—when it's too late to affect the result.

Interest in whole-building design, or integrated design, returned in the 1990s, driven by a healthy concern for the environment.

4.4 Structure of the Energy-10

ENERGY-10 has been programmed in Visual C++ 6.0. It is made up of several main groups of program modules, as the schematic shows. The arrows show the general trend of information flow from top to bottom.



Input Menus and Dialog Boxes—this is what the user sees (plus the summary information and the output graphics). Much of this is generated by the et.exe program, which contains the building database that holds information about the two buildings.

Bridge Files—the initial step in doing a simulation is to generate these files. The main files are the two *.INP files that are the input files for the CNE simulation engine

Simulation Engines—the daylighting simulation engine written by LBNL incorporates the split-flux routine used in the DOE-2 computer program. This simulation is run first and writes an output file (*.FC) .which is then used in the thermal simulation.

Output—Results are displayed graphically based on reading the *.BHR files and also in the Summary Information table.

4.5 Output Reports

Reports are mostly graphical, although some tabular data can be accessed from.

Comparative Bar Graphs—bar graphs that show Bldg-1 and Bldg-2 results side by side. Several options are available. If the simulation was for less than a full year, the results are for the simulation period.

Some example for the options of simulation figures are represented below:

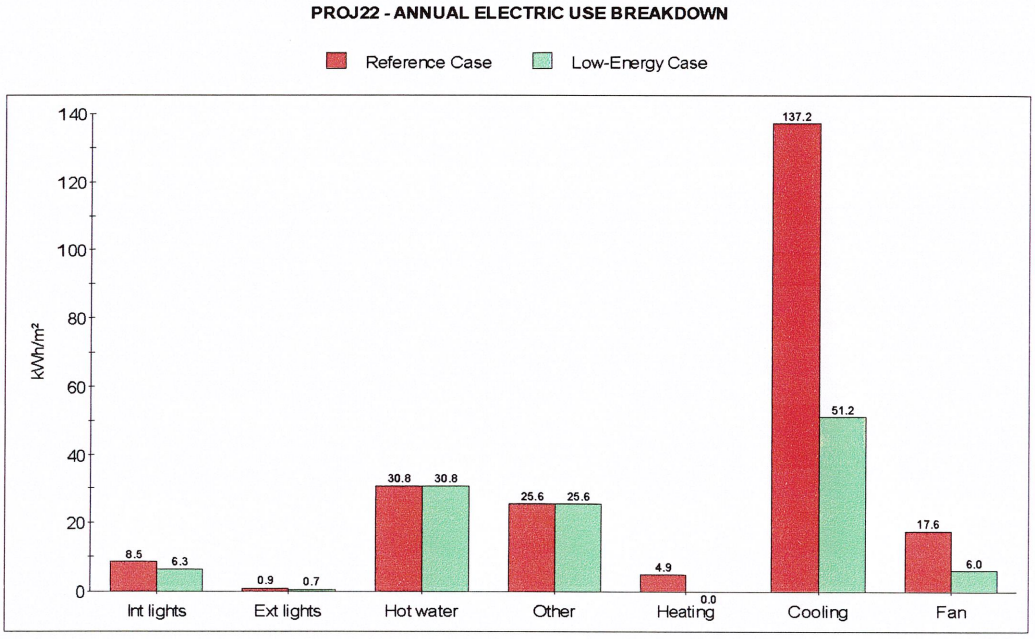


FIGURE 4.3.1 Example for Annual Electric Use Breakdown

Energy—Total annual energy use, plus breakouts by heating, cooling, fan, and "other" uses (everything else).

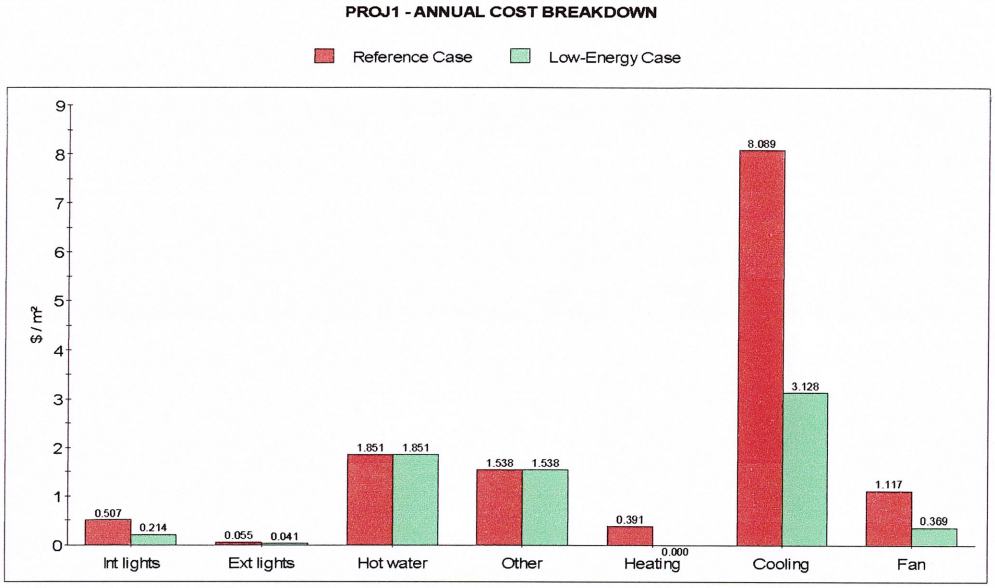


FIGURE 4.3.2 Example for Annual Cost Breakdown

Utility Cost—Total annual energy cost, plus breakouts by fuel, electric consumption.

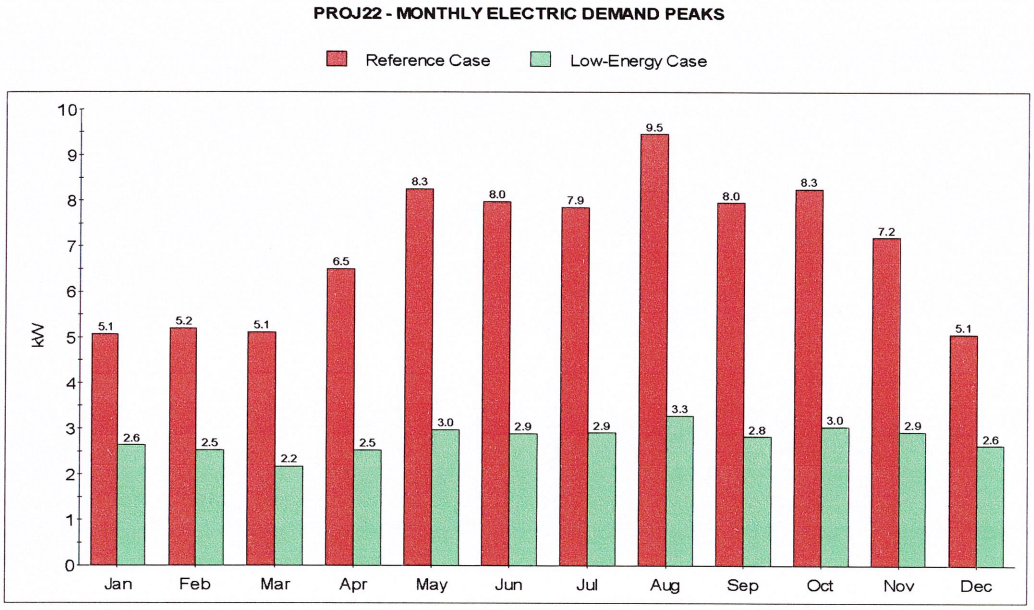


FIGURE 4.3.3 Example for Monthly Electric Demand Peaks

Monthly Kwh Peak—Peak electric consumption in each month. This refers to the monthly peak of electric use averaged over one hour.

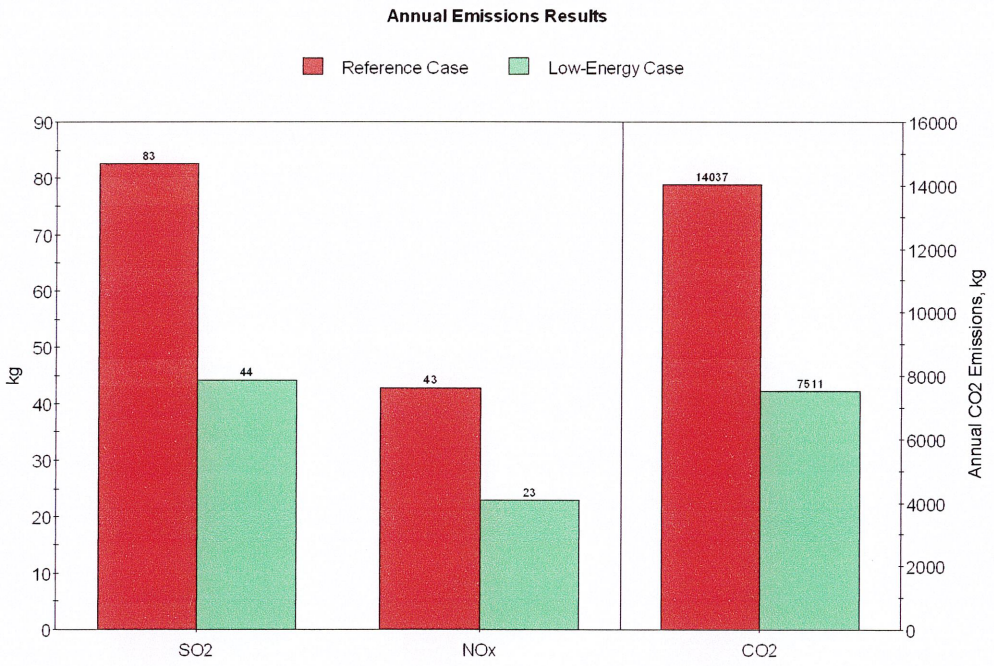


FIGURE 4.3.4 Example for Annual Emission Results

Emissions—CO2, SO2, and NOx annual emissions as a result of building operation.

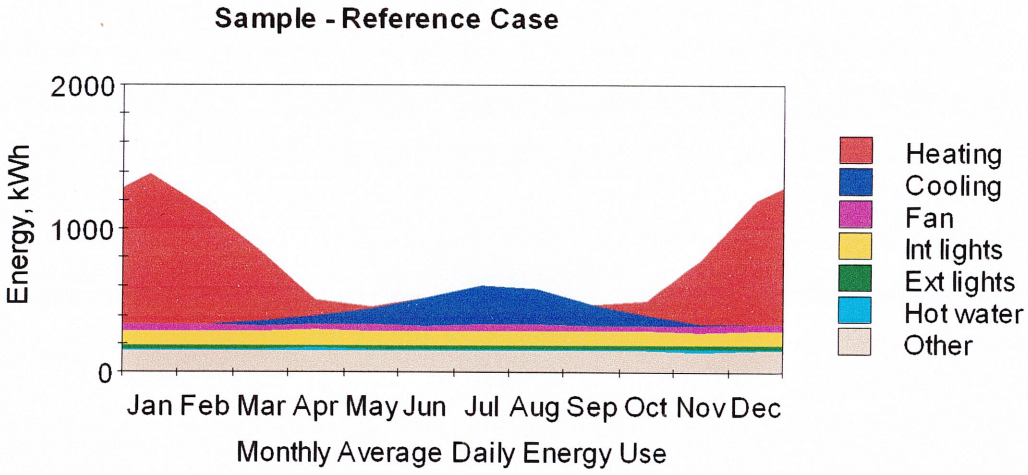


FIGURE 4.3.5 Example for Monthly Average Energy Use

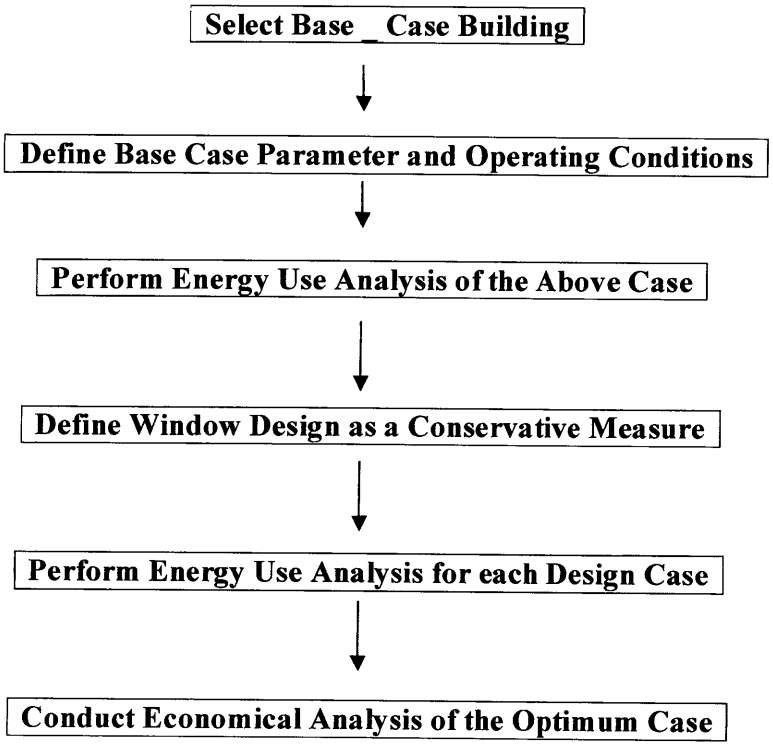
Energy Use Graphs—Monthly average, Actual hourly, or Monthly graphs

CHAPTER FIVE

METHOD OF APPROCH

5.0 Methodology:

The below list of points describe the main steps employed in the method of approach:



Flow chart of the steps employed in the method of approach

5.1 Select Base _ Case Building:

Hamad Town house used as a base case due the following reasons:

- The domestic section consume about 54% of the total electricity use in Bahrain _ refer Figure 1.4, therefore a residential building decided to be a base case.
- Specifically the standard design type L2 house of Hamad Town; which is considered to be one of the major housing projects in Bahrain beside Isa Town & Zayed Town.
- Hamad Town includes around 12000 houses, occupied by around 11.5 % of the total population of different socioeconomic levels.
- The selected unit represents Bahrain traditional house characteristics.
- These houses built by ministry of housing using the typical construction material available in the market and commonly used for other buildings in Bahrain. Refer to Figure (5.1) for the plan view of the selected house.

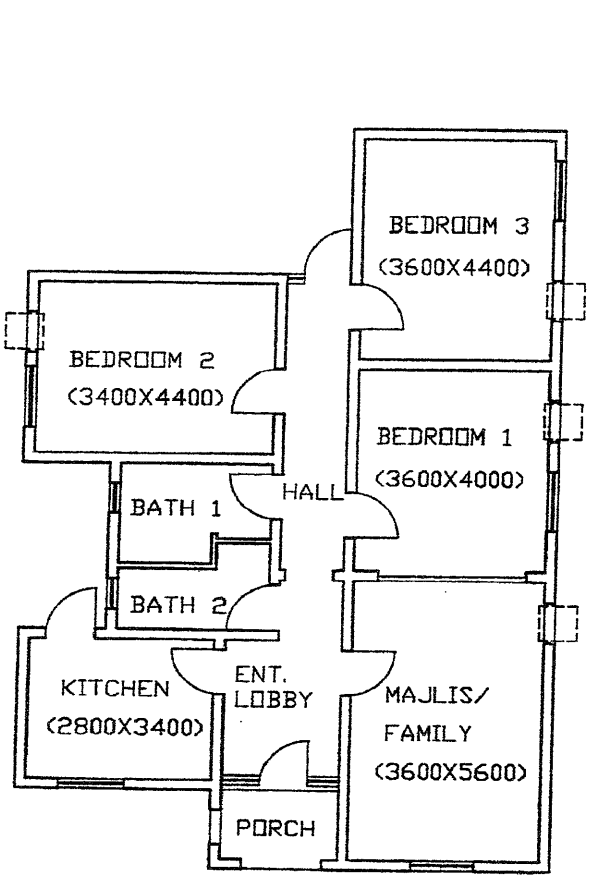


Figure 5.1 Plan View of Model L2 House , Hamad Town

5.2 Define Base Case Parameter and Operating Conditions:

Wall Construction

The building technique in Bahrain for most of the private as well as governmental residential building is the wall bearing method. In the wall bearing techniques outside walls are commonly constructed from hollow concrete blocks, usually with 200 mm thickness, covered on both side with sand cement plasters, the brick are manufactured from washed marine sand and aggregate. Refer Figure (5.2) & Table (5.1), both explain the wall construction layers & material. [University of Bahrain, (1995)]

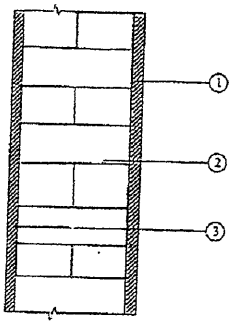


Figure (5.2) Wall Construction Layers

Table (5.1) Properties of the Wall Construction Layers

Layer	Material	Thickness (mm)	Thermal resistance $m^2\,^0C/W$
1	Sand cement plaster	10	0.011
2	Hollow concrete block	200	0.386
3	Sand cement plaster	10	0.011

The overall thermal resistance = R1+ R2 + R3

$$= 0.011 + 0.386 + 0.011$$

$$= 0.408\ m^2\,^0C/W$$

The overall heat transfer coefficient $U = 1/R_t$

$$= 1/0.408$$

$$= 2.45\ W/m^2\,^0C$$

Roof Construction

The roof is a cast solid slab consist of 150 mm concrete slab covered by a layer of water proofing membrane & a top layer of 50 mm cement screed, refer Figure (5.3) & Table (5.2) for roof construction material.[University of Bahrain, (1995)]

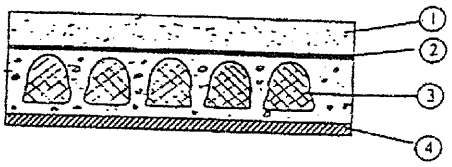


Figure (5.3) Roof Construction Layers

Table (5.2) Properties of the Roof Construction Layers

Layer	Material	Thickness (mm)	Thermal resistance $m^2\,^0C/W$
1	Cement screed	50	0.054
2	Water proofing	3	0.006
3	Cast concrete slab	150	0.155
4	Gypsum finish	10	0.131

The overall thermal resistance = R1+ R2 + R3 + R4

$$= 0.054 + 0.006 + 0.155 + 0.131$$

$$= 0.346\ m^2\,^0C/W$$

The overall heat transfer coefficient $U = 1/R_t$

$$= 1/0.346$$

$$= 2.89\ W/m^2\,^0C$$

Input data and operating Conditions used in the simulation:

Table (5.3) Summarized of the Baseline operating Condition

Shape	Rectangular (15 x 9.5) m
Height	One story 3m high
Volume	312 m^3
External wall area	146 m^2
Roof area	110 m^2
No of windows	7
Windows total area	18 m^2
Glass type	clear 6 mm
Shading	no
No of external doors	3
Area of external doors	5.6 m^2
Lighting	10 w/m^2
People	8
Equipment load	2 kw
A.C system	window units
Infiltration	1 air change/hour
Wall to glass ratio	0.123
Heating thermostat	20.6
Cooling thermostat	26.0

The operating conditions above in addition to the weather data represented in Appendix (A) used in each rum of the program, the only variable changes is the window unit as represented in table (5.4)

5.3 Perform Energy Use Analysis

Evaluation started using the autobuild feature of Energy -10.autobuild automatically generates two building descriptions. The reference case Bldg -1 which is the baseline, this has all the attributes of the building to be studied such as (appropriate internal gain, schedules, the glazing to wall ratio, construction material , building category , climate , building floor area, height of building , and type of heating ventilating and air conditioning (HVAC) system as represented in table (5.3)

To examine the effect of the orientation with respect to climate condition, the model rotated from present orientation in a clock wise direction through 360°

For the simulation output refer appendix (B)

5.4 Define Window Design as a Conservative Measure

The windows systems were changed for comparison purpose. The energy analysis was performed and combined with glazing properties extracted from ASHRE standard.

Table (5.4) Window Systems Properties [ASHRAE Handbook of Fundamentals, (2005)]

Glazing unit & (code number)	**Glass thick (mm)**	**SHGC**	**T_v**	**U-value ($W/m^2.K$)**
Single clear with Aluminum frame (1b)	6	0.78	0.8	6.75
Uncoated double glazing clear with aluminum without thermal break frame (5b)	6	0.63	0.69	3.69
Uncoated double glazing clear with aluminum thermal break frame (5b*)	6	0.61	0.68	2.98
Reflective double glazing with vinyl frame (5k)	6	0.12	0.06	2.69
Low-e double glazing , e=0.05 on surface 2 with aluminum frame (25b)	6	0.34	0.60	2.76
Low-e double glazing , e=0.05 on surface 2 with vinyl frame (25b*)	6	0.33	0.61	1.84
Triple glazing clear with vinyl frame (29b)	6	0.53	0.61	1.79
Low-e triple glazing e=0.1 on surface 2 & 5 with vinyl frame (40b)	6	0.32	0.51	1.28

The visible transmittances (Tv)are center glazing values at normal incidence. A rule of thumb is to select a glazing unit whose visible transmittance is greater than its solar heat gain coefficient, especially if day lighting strategies will be used in the building. For maximum light with minimum solar gain, there are fenestration products available having visible transmittance that is 1.4 times their SHGC.

The total window solar heat gain coefficient listed assume normal incidence.

5.5 Perform Energy Use Analysis for each Design Case

Refer appendix (C)

5.6 Conduct Economical Analysis of the Optimum Case

People work or live differently in different buildings, which can have a big effect on how much energy a given building consumes. It has been estimated that occupant effects can result in an annual energy use that is anywhere from 70% to 140% of the average use in commercial and residential buildings.[National Renewable Energy Laboratory USA, (1993)]

Some building owners keep the thermostat low in the winter and are careful about not leaving doors and windows open in cold weather. They might be the same people who use air conditioning only when necessary and rely on open windows on mild days to keep the building cool by natural ventilation. Others just don't think about it much and would rather rely on their furnace or air conditioner, paying a higher utility bill. Finally, different individuals have different personal comfort zones. People work or live differently in different buildings, which can have a big effect on how much energy a given building consumes.

It has been estimated that occupant effects can result in an annual energy use that is anywhere from 70% to 140% of the average use in commercial and residential buildings. Some building owners keep the thermostat low in the winter and are careful about not leaving doors and windows open in cold weather. They might be the same people who use air conditioning only when necessary and rely on open windows on mild days to keep the building cool by natural ventilation. Others just don't think about it much and would rather rely on their furnace or air conditioner, paying a higher utility bill. Finally, different individuals have different personal comfort zones.[National Renewable Energy Laboratory USA, (1993)]

The life cycle savings from reduced energy use was determined for all options in comparison to the plain single glass windows. The amounts were calculated assuming a constant annual energy saving.

Recurring maintenance and repair, and operation and maintenance, were assumed the same for all options and were not considered, replacement cost is not considered since the windows are expected to last for the economic life of the building, and electrical demand charges were not taken into consideration.

The resulting total annual emission for each case were reported against energy saving.

CHAPTER SIX

RESULTS AND DISSCUSION

6.0 Introduction

Naturally, the main issue concerning the selection of a window is its cost. One can ask at what cost is the point of diminishing returns reached? How much can be spent on a window and still realize a reasonable return on investment? These questions are difficult to answer because of the many factors that must be considered. Building type, orientation, size, and climate are among the factors that must be evaluated. The following section illustrates methodologies that employed to perform the analysis.

6.1 Results:

The simulation results will be presented in this chapter as follow:

- **Section 6.1.1**: Analyzing the effect of building rotation, shape and exposed surface area on reducing the cooling load. *Refer building layout Figure 5.1*
- **Section 6.1.2**: Analyzing different glazing units with respect to the best rotation angle and examine the effect on the building energy performance. *Refer Table 5.3*
- **Section 6.1.3**: Analyzing the effect of reducing the infiltration rate, change thermostat setting and introducing shading to reduce building cooling load.
- **Section 6.1.4**: Analyzing the economical effect due implementation of above energy conservative measure.

6.1.1 Effect of house shape and orientation:

The exposed surface area of a building is related to the rate at which the building gains or loses heat, while the volume is related to the ability of the building to store heat, thus the ratio of volume to exposed surface area is a widely used as indicator of the rate at which the building will heat up during the day and cool down at night.

A high volume to surface ratio preferable for building that is desired to heat up slowly, as it offers small exposed surface for the control of both heat losses and gains. For the simulation results of this part refer appendix (B)

The simulation shows that the total energy use in the present position of L2 house building as 509.5 kwh/m^2 of which 278.2 kwh/m^2 contribute the annual cooling load. Refer figure (6.1)

For 270° rotation from present position, the simulated annual total energy use was 493.2 kwh/m^2 of which 263.7 kwh/m^2 contributes the annual cooling load. Refer figure (6.2)

For 180° rotation from present position, the simulated annual total energy use was 530.8 kwh/m^2 of which 296.7 kwh/m^2 contributes the annual cooling load. Refer figure (6.3)

For 90° rotation from present position, the simulated total energy use was 501.8 kwh/m^2 of which 271.1 kwh/m^2 contributes the annual cooling load. Refer figure (6.4)

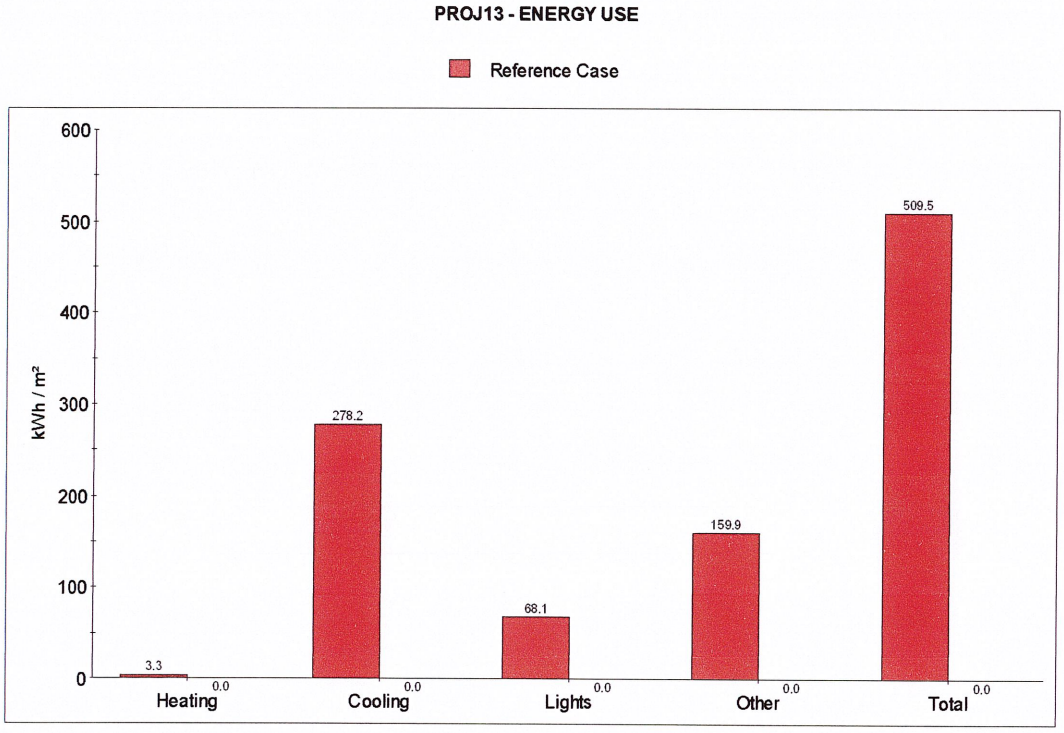


Figure (6.1) Annual Energy Use for Reference Case

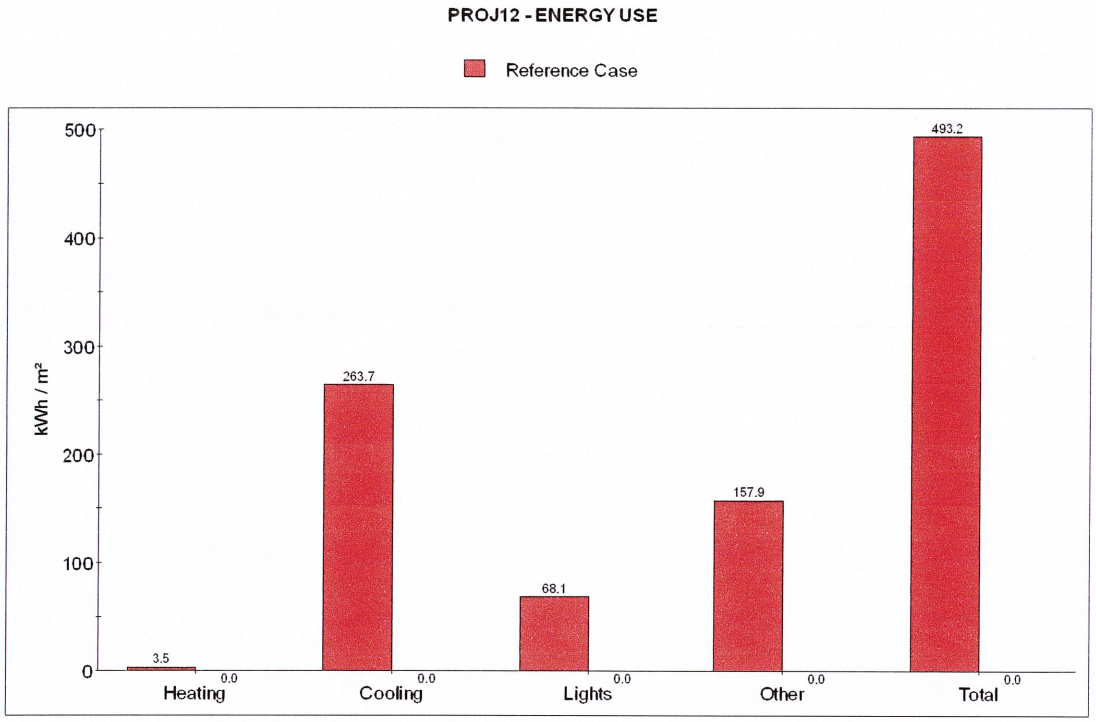


Figure (6.2) Annual Energy Use for Reference Case Rotated 270°

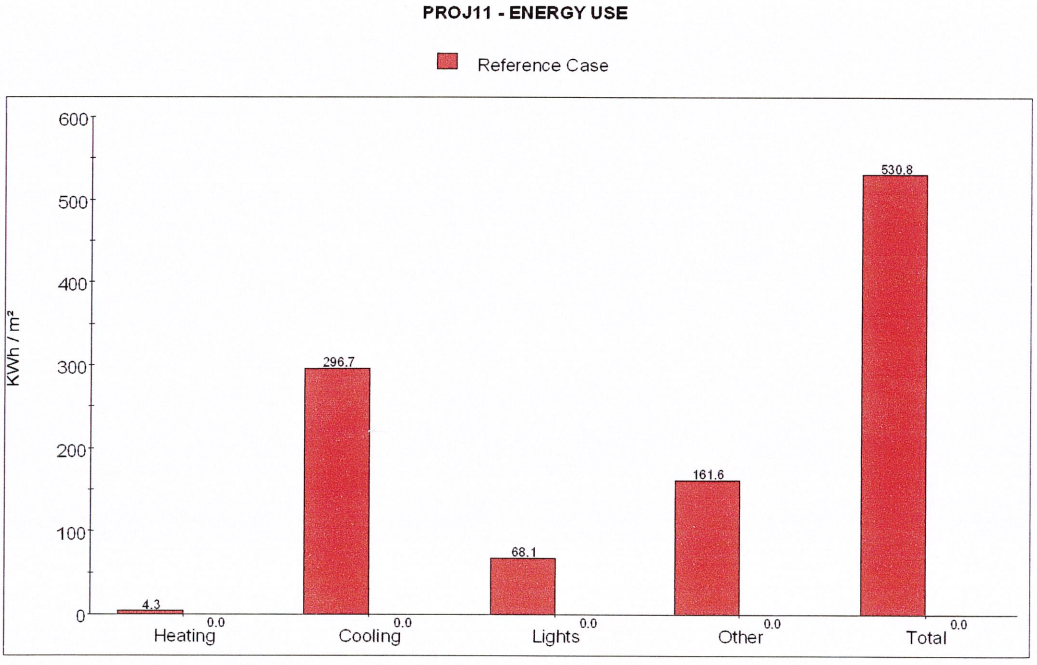


Figure (6.3) Annual Energy Use for Reference Case Rotated 180°

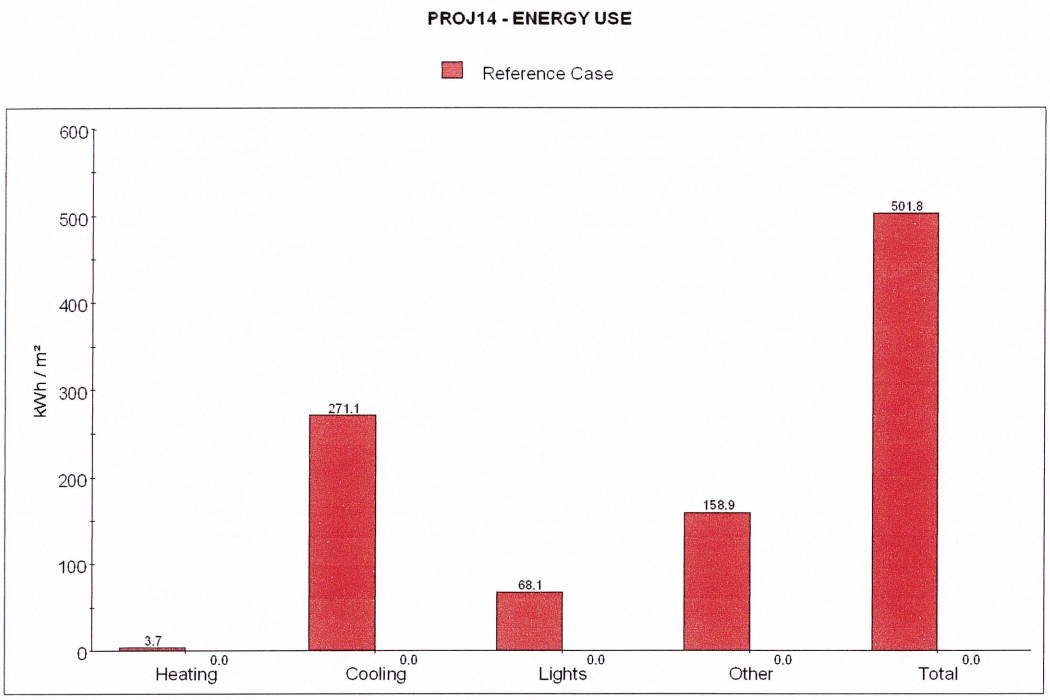
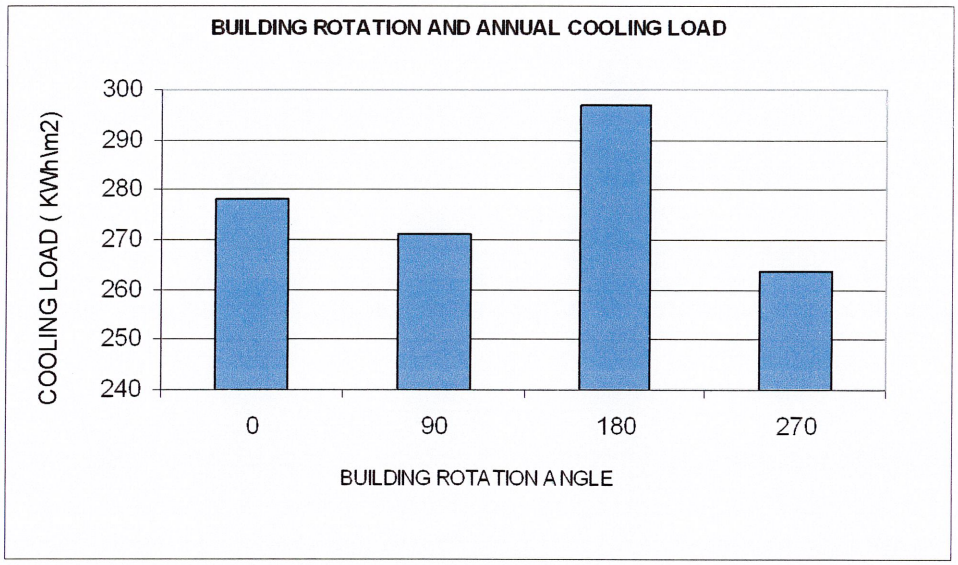


Figure (6.4) Annual Energy Use For Reference Case Rotated 90°

Figure (6.5) summarize the above results with respect to the building long side direction and number of windows in each direction.

Therefore, the best position for a rectangular house is to have its long side and maximum number of windows facing south direction, of course architects can not always orient the buildings at the best position, since orientation is mainly directed by the plot shape and location with respect to roads.



Direction/Rotation	N	E	S	W
	NUMBER OF WINDOWS			
0 deg	0	2	2	3
90 deg	3	0	2	2
180 deg	2	3	0	2
270 deg	2	2	3	0

Figure (6.5) Building Rotation Angle and Annual Cooling Load

6.1.2 Effect of window glazing:

In this section, an analysis of the impact of window glazing on the cooling load is presented. A number of cases are investigated which can partly obstruct solar radiation and offer a wide range of conductance. These cases presented in Table (5.4) which list different types of window glazing.

At that stage the best orientation of the building as represented in figure 6.2 for south facing considered as the new reference case. For the simulation results of this part refer appendix (C)

The simulation shows that the yearly total energy use with uncoated double glazing type with aluminum frame windows as 465.9 kwh/m^2 of which 239.5 kwh/m^2 contributes the annual cooling load. Refer Figure (6.6).

Also the simulation shows that the annual total energy use with Uncoated Double Glazing type but with Thermal Break Aluminum frame as 471.2 kwh/m^2 of which 244.9 kwh/m^2 contribute the annual cooling load. Refer figure (6.7)

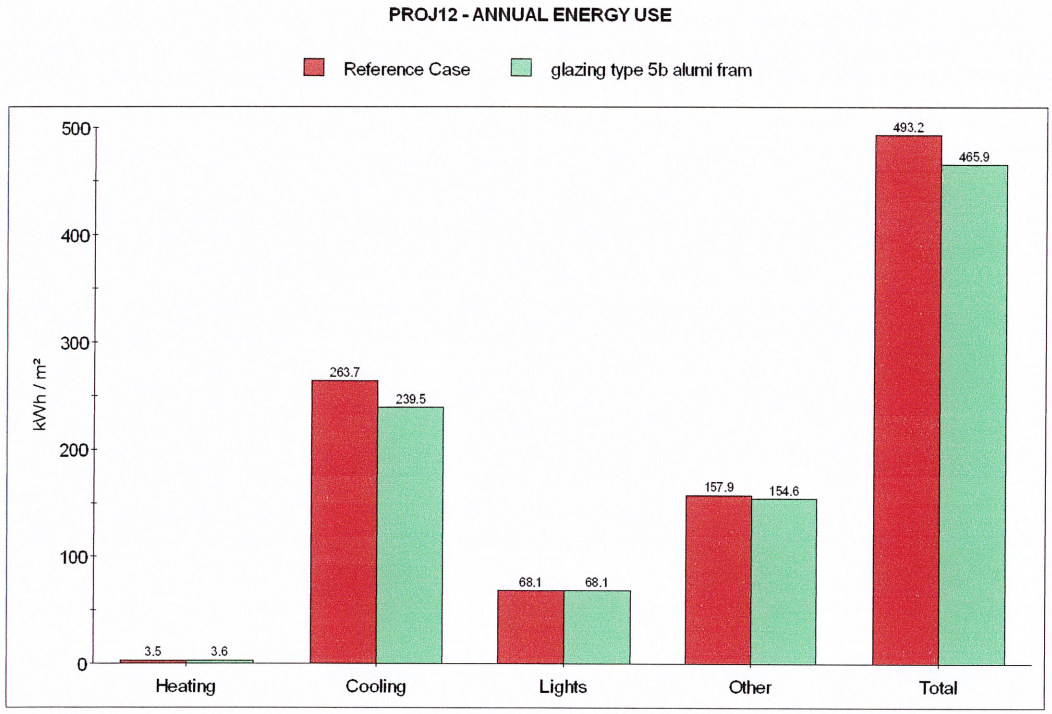


Figure (6.6) Annual Energy Use and Cooling Load for Glazing Code Number 5b

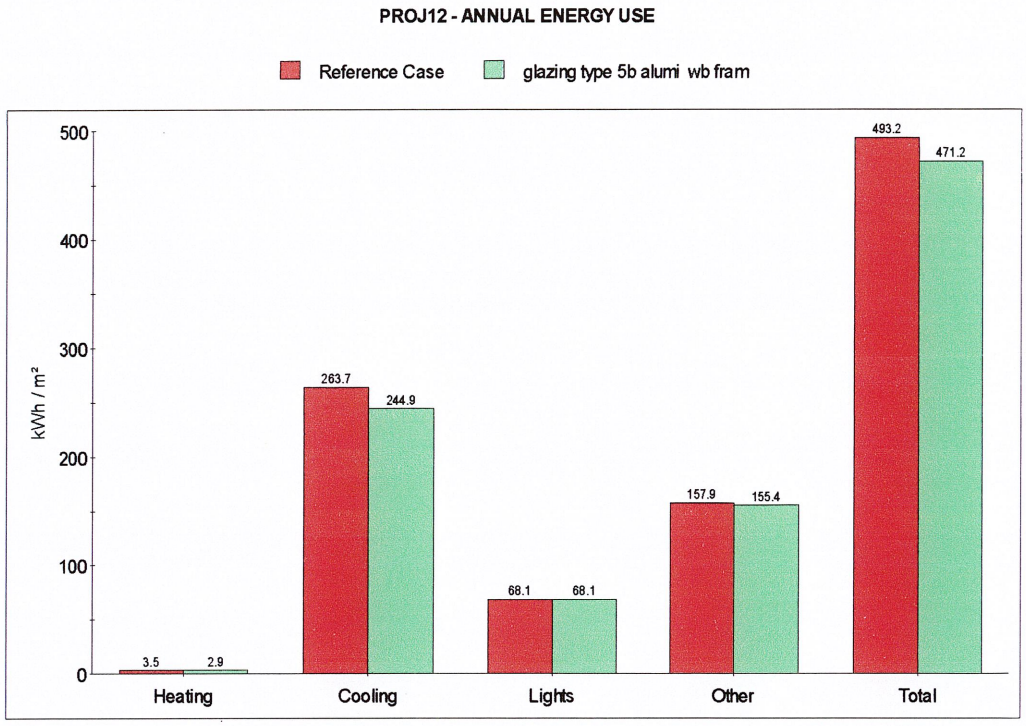


Figure (6.7) Annual Energy Use and Cooling Load for Glazing Code Number 5b*

From the above result we can conclude the effect of changing the frame material and distribution in the whole window performance; in fact this can be represented by the change of the U and SHGC values. The use of the "glass only" U factor can be 10% to 40% batter than the whole window value and this should be avoided.

The reduction of the total annual energy use due to the implementation of two cases above from the single clear glass case can be reported as follow:

- The reduction due to use of double glazing, fixing the frame material "Aluminum" equal to 9.18%.
- The reduction due to the use of Double Glazing, with Thermal Break frame material "Aluminum" reported as 7.04% total, the reduction in this case is less than above by a net of 2.05% due to the high conductivity of the frame material.

Also refer to figures (6.8 & 6.9) where the case of using double low emissivity glazing which is considered as advanced coating technology, with aluminum frame and vinyl frame respectively, here the simulation shows the total energy use of about 458.5 kwh/m^2 & 456.6 kwh/m^2 of which the cooling load contributes 233 kwh/m^2 & 231.8 kwh/m^2 respectively for Aluminum & Vinyl frame. In this case the reduction in the annual cooling load for low emissivity glazing reported as 11.64% of which 0.46 % only due change of frame material which is considered insignificant.

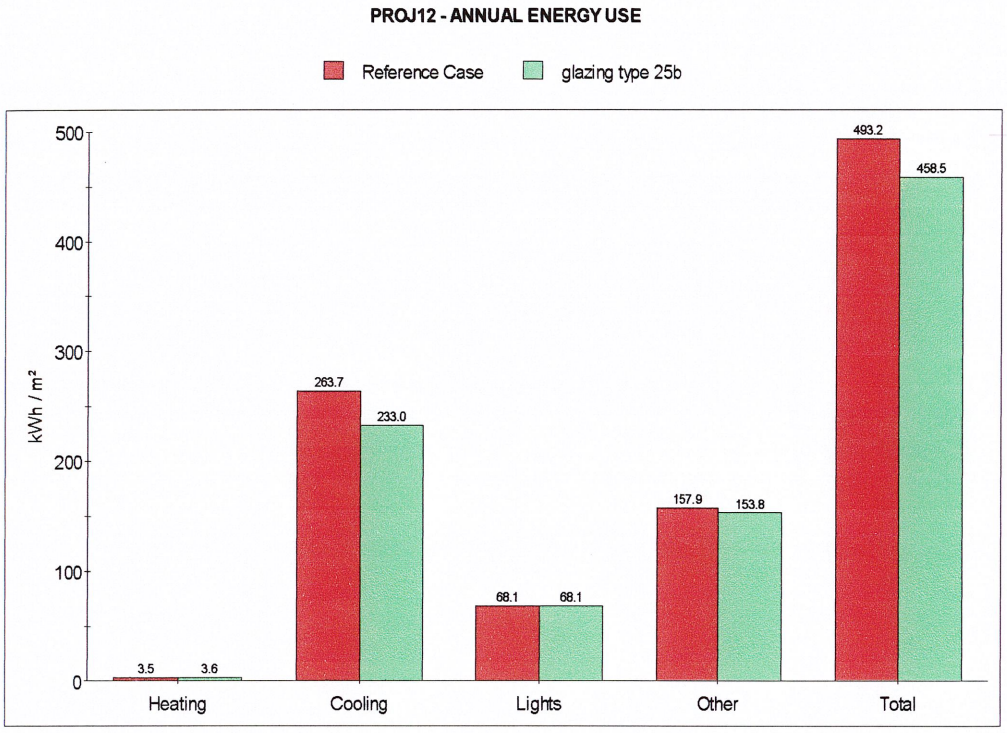


Figure (6.8) Annual Energy Use and Cooling Load for Glazing Code Number 25b

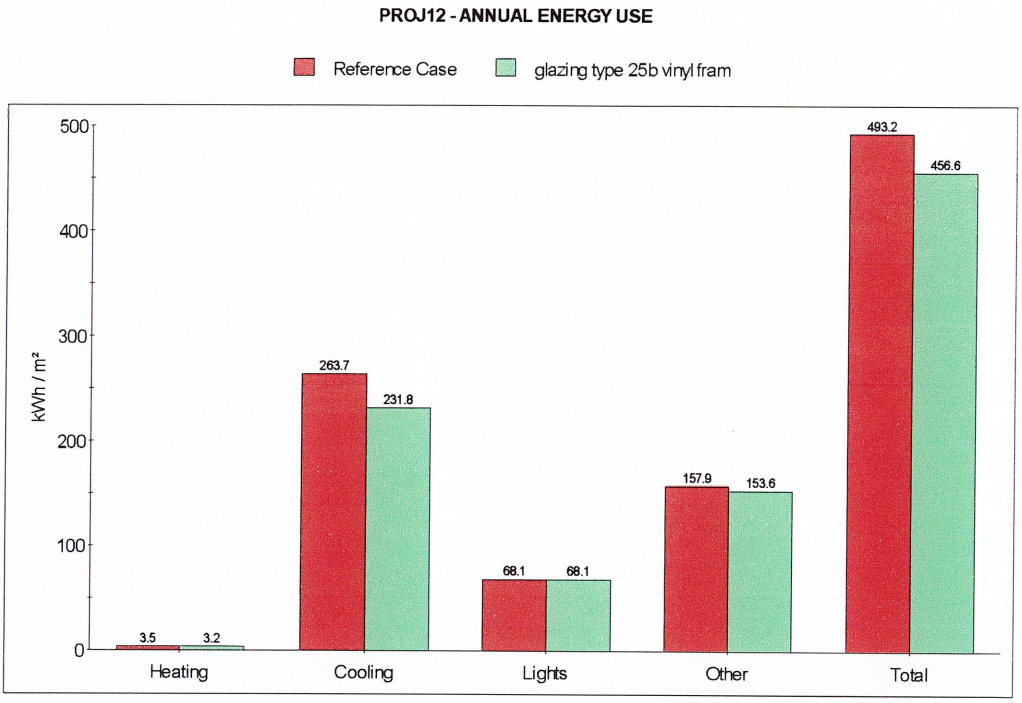


Figure (6.9) Annual Energy Use and Cooling Load for Glazing Code Number 25b*

The simulation shows that the yearly total energy use with reflective double glazing type with vinyl frame windows as 450kwh/m^2 of which 224.7kwh/m^2 contributes the annual cooling load. Refer figure (6.10).The reduction due to the use of reflective double glazing, with less conductive material "vinyl" reported as 14.79%.

Figures (6.11 & 6.12) show also the effect of coating in reducing the total energy use but for Triple Glazing system for Triple Clear & Triple Low-e respectively, the simulation show a reduction in annual cooling load of about 9.5% for the case of using low emissivity glazing compared to 8.6% for the case of clear triple pane.

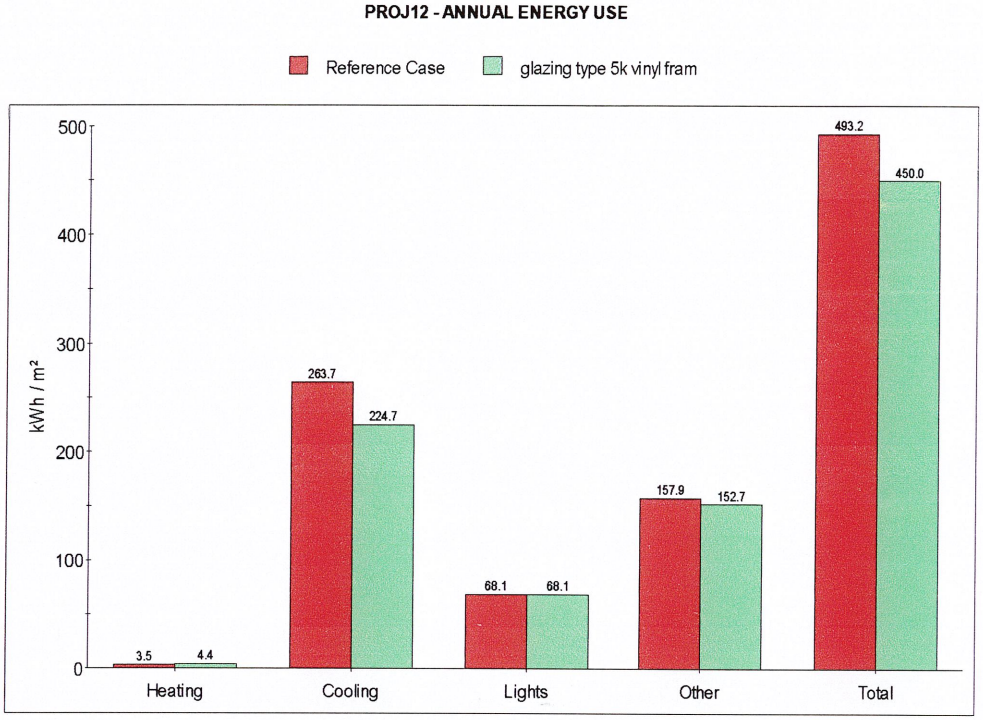


Figure (6.10) Annual Energy Use and Cooling Load for Glazing Code Number 5k

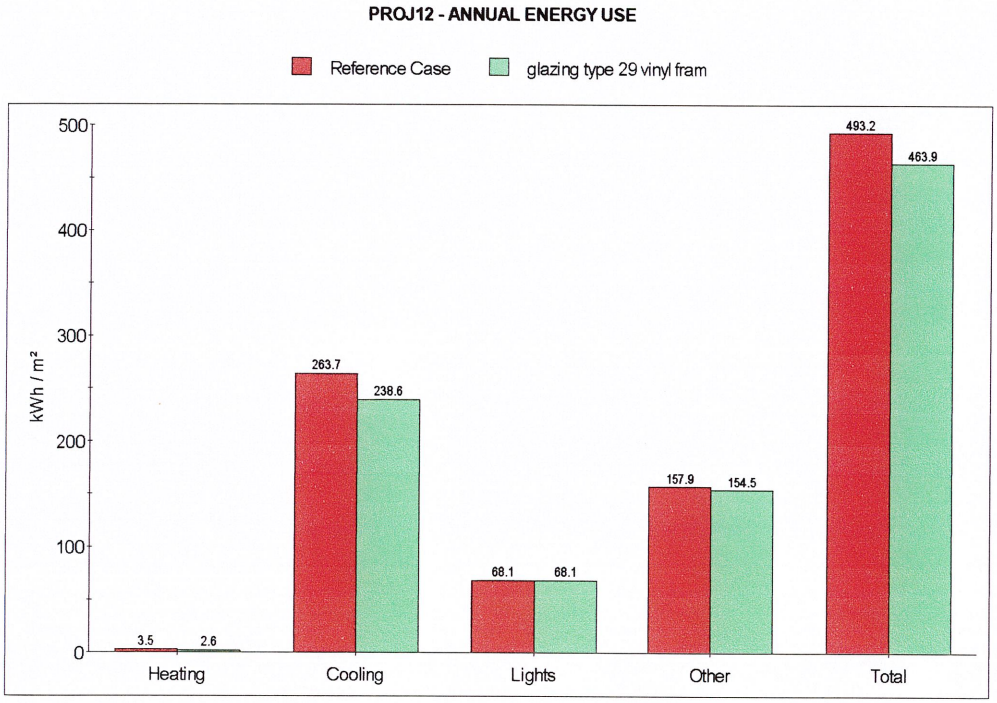


Figure (6.11) Annual Energy Use and Cooling Load for Glazing Code Number 29b

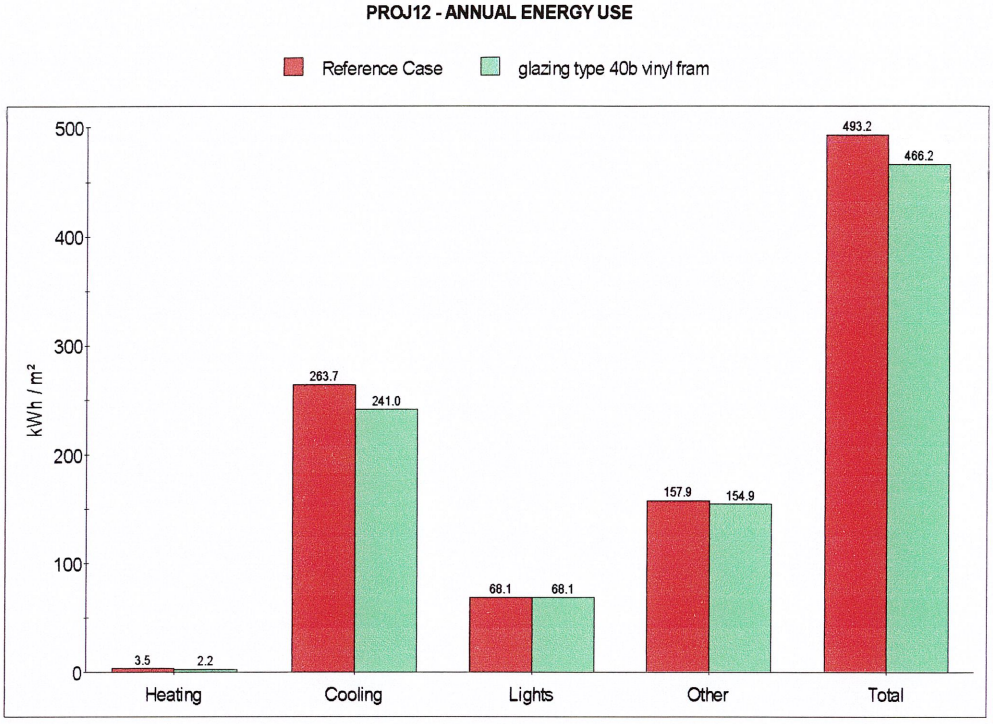


Figure (6.12) Annual Energy Use and Cooling Load for Glazing Code Number 40b

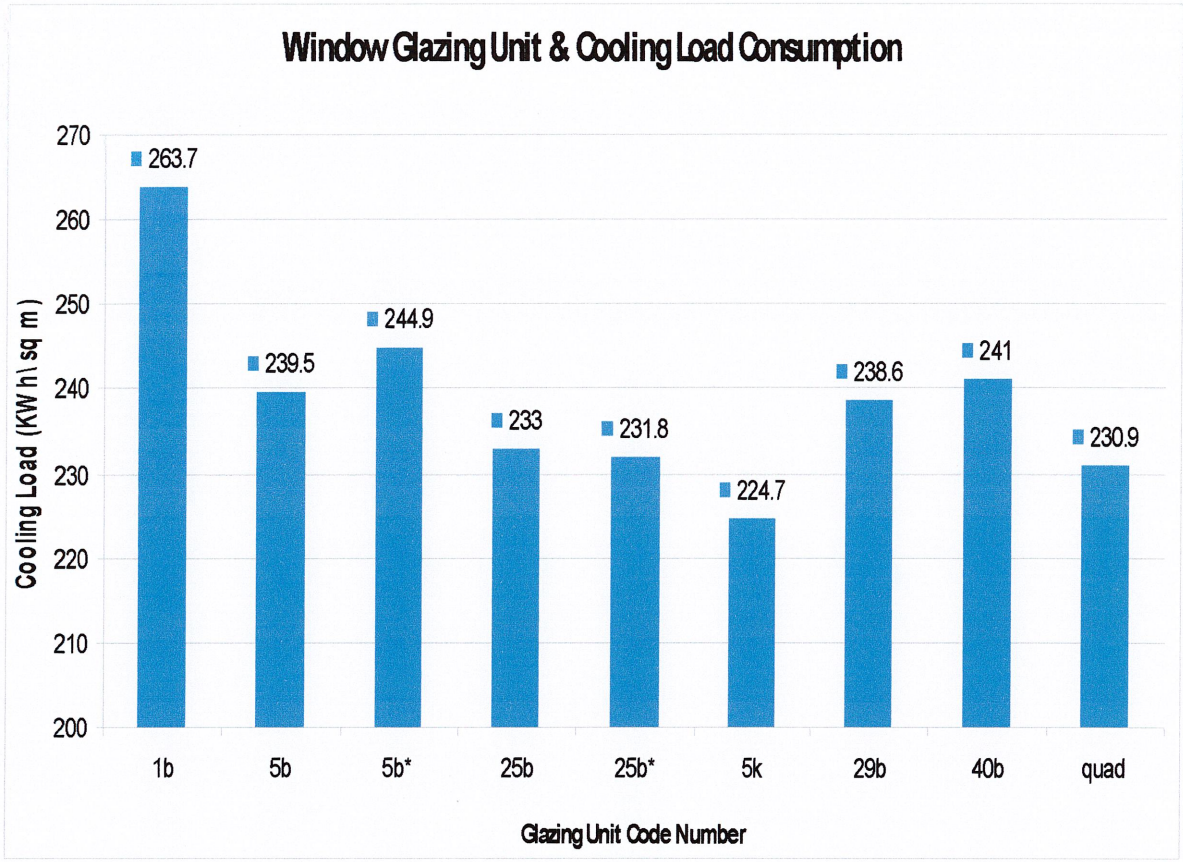


Figure (6.13) Window Glazing Unit and Resulting Cooling Load

Legend

1b	Single clear glass; Aluminum frame
5b	Uncoated double glazing without thermal break, alumnium frame
5b*	Uncoated double glazing with thermal break, alumnium frame
25b	Low-e double glazing, e=0.05 on surface two, aluminum frame
25b*	Low-e double glazing, e=0.05 on surface two, Vinyl frame
5k	Reflective double glazing , Vinyl frame
29b	Triple clear glazing, vinyl frame
40b	Low-e triple glazing, e=0.1 on surface 2 & 5, vinyl frame
quad	Quadruple glass with Vinyl frame

The effect of the number of glazing layers is taken as 1, 2, 3 and 4 to observe the effect on solar gain as well as on the thermal energy exchange between the inside and outside of the building and accordingly the change in the cooling load.

With reference to Figure (6.14) a reduction in the cooling load by increasing the number of glazing layers investigated. The thermal energy transfer and solar gain, which is weather dependent is affected strongly by increasing the number of layers of glazing especially from single to double glazing.

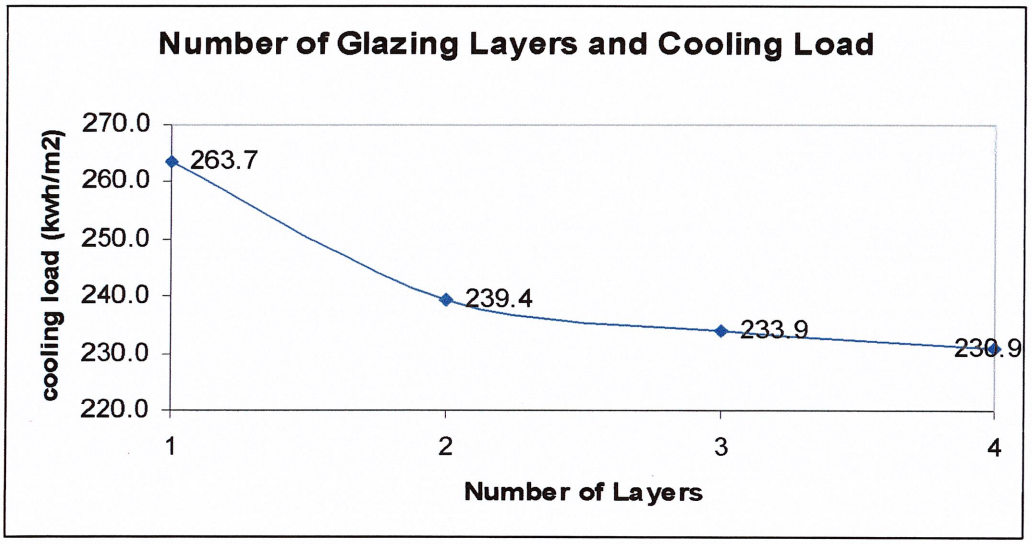


Figure (6.14) Effect of Number of Glazing Layers in Reducing Cooling Load

6.1.3 Effect of window shading, reduced infiltration & thermostat setting:

Putting the above in consideration and concentrating on the performance of the double glazing unit. The simulation of the double glazing with reflective film, vinyl frame, in a fully shaded condition, and reduced infiltration rate investigated further. For the simulation results of this part refer appendix (C).

The Ministry of Electricity and Water in Bahrain recommends an infiltration rate of 1 air change per hour (AC/h) to be assumed. This figure is based on the pattern of the building use and the quality of the construction.

As additional conservation measure, the reduced of the infiltration rate to 0.4 AC/h by well sealed building structure, well fitted windows and doors and a small corridor with a second, internal door behind the outer one to permit as little as possible of inside air to escape or outside air to enter.

The simulation of the above said case shows a total annual energy load of 411.4 kwh/m^2 of which 192.9 kwh/m^2 contributes the annual cooling load. Refer Figure (6.15) this

reduce the cooling load further to about 26.8% with respect to the best building orientation and to about 30.7% with respect to the existing building orientation.

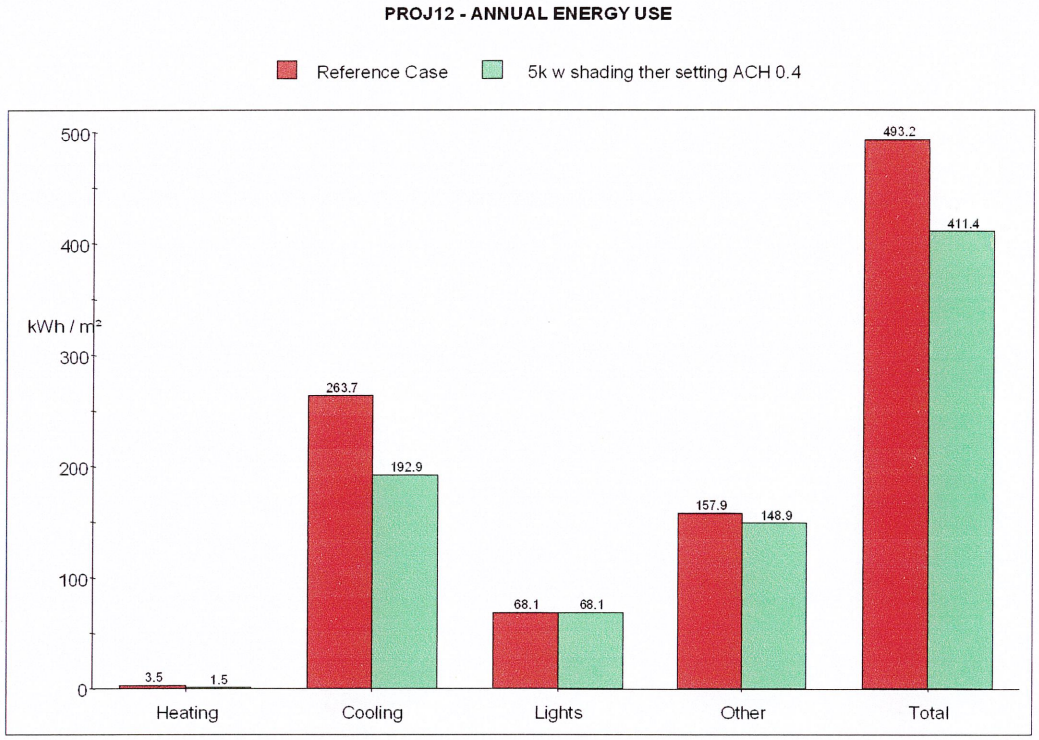


Figure (6.15) Annual Energy Use and Cooling Load for Glazing Code Number 5k, Fully Shaded, AC/h = 0.4

Reducing summer peak demand load for electricity is often as important if not more important than the annual energy reduction. Figure (6.16) shows 10.2% reduction in the peak load results due above conservation measure.

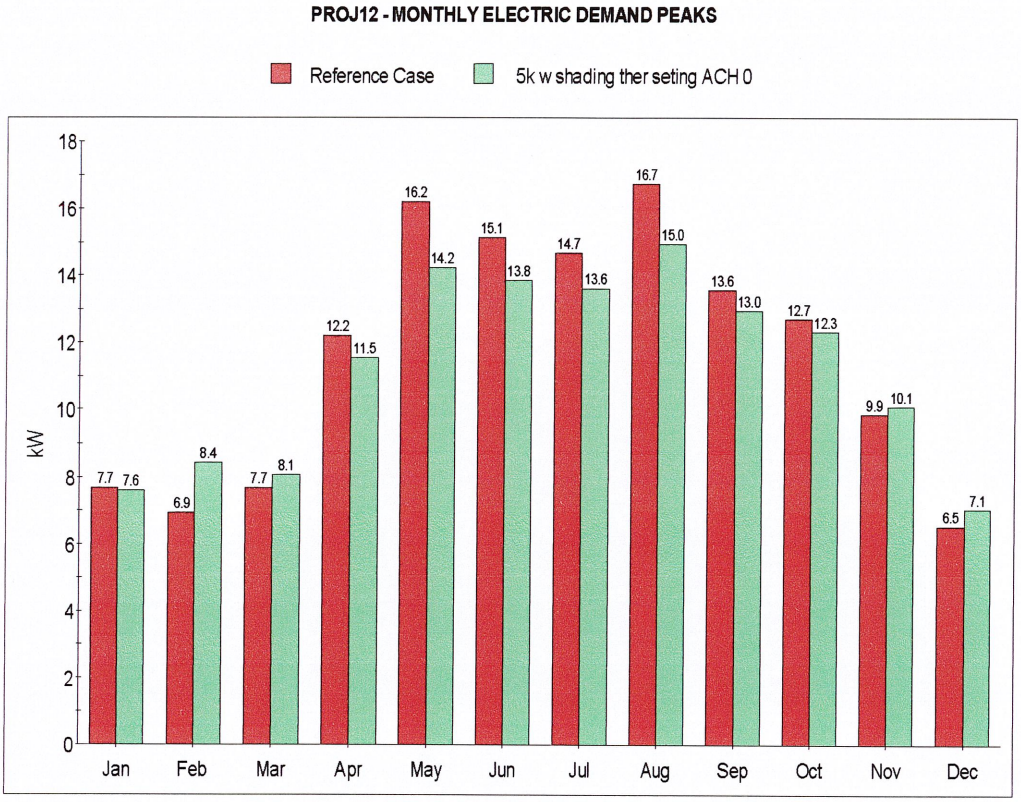


Figure (6.16) Monthly Electrical Demand Peaks for Glazing Code Number 5k, Fully Shaded, AC/h = 0.4

6.1.4 Economical effect of applying optimum design

The introduction of energy conservation measures will benefit both the consumer (the house owner) and the government. The owner basically is responsible for the initial cost of the development, design and construction of the building, annual maintenance, as well as the cost of replacing building components, and he will pay for his energy consumption based on the government rated price of 6 fils/Kwh. Thus the owner will bear the cost of introducing these energy conservation measures; in return he will save in the monthly electricity bill and on the cost of the required air conditioning system and its maintenance. For the government the saving will come from the fact that for every KWh saved, it can save 5.2 fils – which is the difference between the actual cost of electricity generation and the cost paid by the house owner.

Table (6.1) summarize the economical part, result due applying the energy conservation measure. Referring to appendix (C) the life cycle cost of the existing house reduced compared to the best case with a saving value of BD 782.

Considering international oil prices, the government's investment in power stations and their expansion, as well as the costs of power transportation, each KWh costs the governments BD 0.0122, yet it charge the consumer 0.006 BD/KWh.

Thus, in addition to the owner's saving, the government would stand to gain BD 0.0052 for every KWh saved. Therefore the potential saving for the government resulting from adoption of energy conservation measures for best case equal (50310-41962)*0.0052 = 43.4 BD/year/house.

6.2 Environmental Concerns:

Energy 10 has the ability to convert the energy consumption (fuel and electricity) into emission of CO_2, SO_2 and NO_x resulting from building energy use. Due shortage of the registered information, the pollution coefficient assumed to be the same as the default values related to the United States national average values. Although this may considered as logic less assumption due huge difference in the nature of life and climate between the two places, as far as the analysis is in a percentage and respective basis more than a specific numerical value the assumption is acceptable.

Figure (6.17) show the respective reduced percentage of the emission due applying the conservative measures.

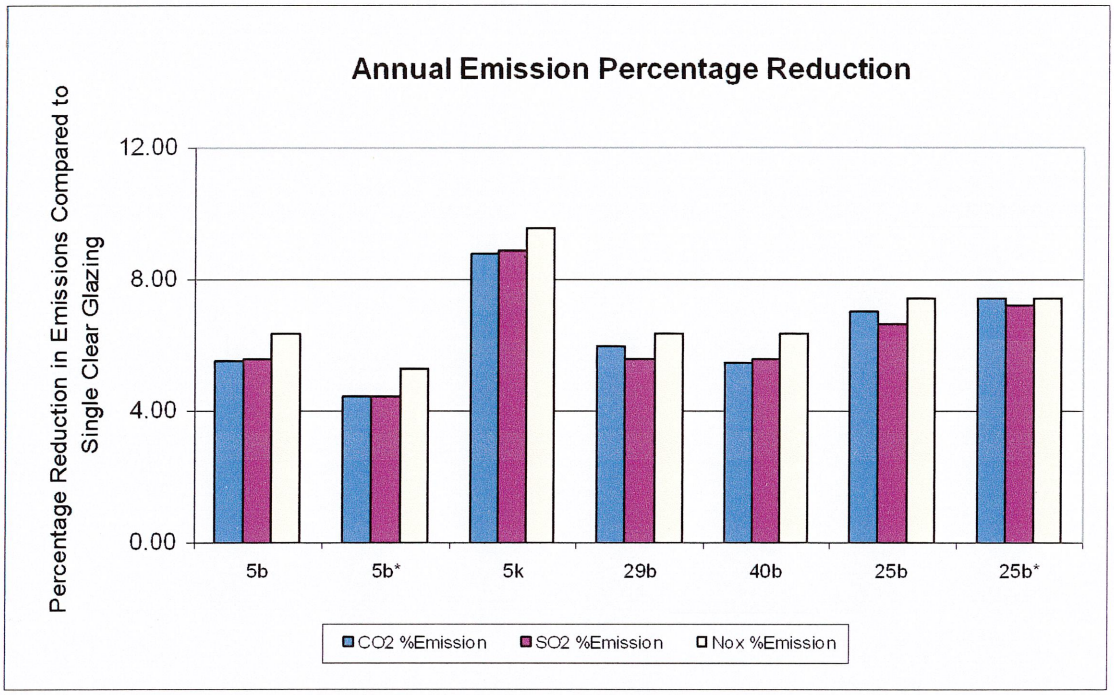


Figure (6.17) Percentage Reduction in Annual Emission

Legend

5b	Uncoated double glazing without thermal break, alumnium frame
5b*	Uncoated double glazing with thermal break, alumnium frame
25b	Low-e double glazing, e=0.05 on surface two, aluminum frame
25b*	Low-e double glazing, e=0.05 on surface two, Vinyl frame
5k	Reflective double glazing , Vinyl frame
29b	Triple clear glazing, vinyl frame
40b	Low-e triple glazing, e=0.1 on surface 2 & 5, vinyl frame

Table (6.1) Summarize the Economical Part

WINDOW SYSTEM	ADDITIONAL EXPENDITURE REQUIRED (BD) COMPARED TO SINGLE CLEAR GLASS	RESULTING LIFE CYCLE SAVING (BD)	PAYBACK PERIOD (YEAR)	BENEFIT/COST RATIO
uncoated double , alumin no b (5b)	90	271	3.74	4.02
uncoated double , alumin w b (5b)	85	208	4.35	3.45
reflective double ,vinyl (5k)	126	446	3.31	4.53
triple clear , vinyl (29b)	162	224	6.32	2.38
triple low e, vinyl (40b)	162	195	6.82	2.2
double low e , alumin no b (25b)	90	369	2.95	5.1
double low e , vinyl (25b)	104	415	3.02	4.98

CHAPTER SEVEN

CONCCLUSION AND RECOMMENDATION

7.1 Conclusion

From the results discussed in the previous chapter it can be concluded that:

1. Due the fact that solar gain is lower in summer than at other times of the year for the south facing window, the orientation for elongated house to have its long side facing south in order to minimize the east and west wall area that has the biggest load contribution. This will reduce the cooling load by about 5.21% as represented by 270 deg rotation of our base case building.

2. Also it can be concluded that solar radiation from east and west oriented windows is significant and should be taken care. It causes increase in the cooling rate by about 6.23% as represented by 180 deg rotation of our base case building.

3. The effect of window uncoated double glazing without thermal break & with aluminum frame will reduce the cooling load by 9.18% and to about 7.18% for thermal break aluminum frame, it is concluded that the difference between the two values of 2.05% is due to the distribution of the high conductivity of aluminum.

4. Changing the material of frame to vinyl or wood instead of aluminum will reduce the cooling load further by 10.13%, from which it concluded that the effect of frame material is not significant and represented by 0.945% reduction in cooling load for uncoated double glazing.

5. The use of advance low-e double glazing with aluminum frame will reduce the cooling load to 11.64% and this will reduce further to 12.10% with vinyl or wood frame, from which it is concluded that the net reduction in cooling load due change of glazing from uncoated double pane to low –e double glazing is 1.98% and due to change of frame material is 0.46%, from which it is predicted that the effect of frame material will reduce further when used with advance glazing technology.

6. The reflective double glazing type with vinyl frame reported the greatest reduction in cooling load to about 14.8%

7. Thermal energy transfer, which is weather dependent, is affected strongly by increasing the number of layers of glazing especially from single to double glazing.

8. Window gains are an important factor and significant savings can result when low conductance and low transmittance window glazing are used. A saving in the annual cooling load of about 14.8% can results depending on the glazing type.

9. Additional conservative measure by reducing the infiltrations rate to 0.4 AC/h and fully shaded east and west windows when using reflective double glazing window can reduce the cooling load further to 26.8%. This considered as the optimum case.

10. Reducing summer peak demand load for electricity is important factor and the uses of the reflective double glazing fully shaded and reduce infiltrations to 0.4 AC/h shows 10.2% reduction in the peak load.

11. Energy conservation has a favorable affect on the environment, the application of the best case condition has been reduced the amount of pollutant gases CO_2, SO_2 and NO_x ,the reduction in emission reported as 8.78%, 8.89% & 9.57% respectively.

12. The conservation of energy is an issue of benefit for both owner and government, for implementing the optimum case concluded here; the life cycle cost reduce about seven hundred eighty two Bahraini dinars and of potential saving to government of about 43.4 Bahraini dinars per year per house.

13. Solar gain and thermal energy transfer through windows, along with the effect of the orientation, location and number of layers of glazing were as expected and were consistent with the latitude and the weather conditions.

7.2 Recommendation

For hot and arid weather like Bahrain the following points summarize our recommendation as approved in previous chapters:

- ***For rectangular shape house, the long side should face south direction with maximum number of windows.***

- ***Minimize as much as possible the number of windows in both west and east directions.***

- *Keep natural shading. Don't cut down shade trees prior to construction. Locate the residence to take free advantage of the tree shading, especially from their upper canopies in both west & east directions. This is a conservative measure free of charge.*

- *The reflective double glazing window with frame made from low heat conductive material like 'vinyl' is highly recommended.*

- *Reduce the infiltration rate by well sealed building structure, well fitted windows and doors and a small corridor with a second, internal door behind the outer one to permit as little as possible of inside air to escape or outside air to enter, significantly reduce the cooling load, Control heat gain and increase occupant comfort.*

- *The overall thermal resistance of the wall and roof construction material used in the construction of the base case building is vary low, the thermal performance can be improve strongly by increasing the thermal resistance of the material to a range of 2.6 to 2.8 $m^2\,^0C/W$*

- *U value and SHGC of the whole window i-e of the glass and frame material shall be considered when performing energy analysis, thus the use of "glass only" values can be 10% to 40% better than the whole product value.*

Future Recommendation:

- *The analysis here in this study indicates that we can save about 26.8% of the electrical use at an average cost of about 6 files per KWh. that is due only using of reflective double glazing window, Keeping natural shading on west & east windows & reducing the infiltration. Moreover in the future studies I recommend to add appropriate residential technologies including:*

    - *Use of more efficient air conditioners.*
    - *Use of wall and roof insulating technique.*
    - *Improve the overall thermal resistance of the wall construction material to a minimum of 1.76 $m^2\,^0C/W$*
    - *Improve the overall thermal resistance of the roof construction material to a minimum of 2.64 $m^2\,^0C/W$*

REFERENCES

A.Rousan Akram, Shariah Adnan, 1996, Solar and Thermal Energy Gain through Windows in Jordan, Renewable Energy, vol.7, No.3, pp251-269.

AL- Hamadani N.I & Ahmad A.I, 1986, Effect of Window Parameter on Indoor Thermal Environment of Buildings, solar & wind technology, vol.4, No.1, pp71-75.

ASHRAE Handbook of Fundamentals, 2005, American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), Atlanta, GA.

Balcomb J.Douglas, 1998, Designing Low Energy Building with Energy -10, National Renewable Energy Laboratory, New Mexico.

Barry C.Field, 2002, Environmental Economics, McGraw-Hill, Irwin, USA.

Brian M.Deal, Robert J.Nemeth, 1998, Energy Conservation Strategies for Window and Glazing Surfaces, US Army Corps of Engineers, USA.

Building Energy Codes Resource Center, Advanced Energy Design Guide Implementation Recommendations: Glazing Design, Article # 1393.

Carmody John & Selkowitz, 1996, Residential Windows: A Guide to New Technologies and Energy Performance, W.W Norton & company.

Central Statistics Organization, 2004, Statistical Abstract, Directorate of Statistic, Kingdom of Bahrain.

CIA world fact book, 2005.

Energy – 10 Software Manual, 1993, Designing Low Energy Building, US. Department of Energy's Office of Building Technology, National Renewable Energy Laboratory, USA.

Energy Efficient Windows, 1994, Energy Efficiency and Renewable Energy Clearinghouse Report, DOE/CH10093-290.

Esbensen Consulting Engineers, 1998, Windows the Key to Low Energy Design, Energy Comfort 2000 Information Dossier Number 5.

G.A.Florides, S.A. Tassou, 2002, Measures Used to Lower Building Energy Consumption and their Cost Effectiveness, applied energy, vol.73, pp299-328.

H.Akbari, M.G. Morsy, and N.S. Al-Baharna, 1996, Electricity Savings Potentials in the Residential Sector of Bahrain, University of Bahrain.

J.Breitenbach; S.Lart; J.L.J. Rosenfeld, 2001, Optical and Thermal Performance of Glazing with Integral Venetian Blinds, Energy and Buildings, vol.33, pp 433-442.

John A.Duffie & William A.Beckman, 1991, Solar Engineering of Thermal Processes, A Wiley interscience publication, USA.

L.Garvin Stephen & Wilson John, 1998, Environmental Conditions in Window Frames with Double Glazing Units, Construction and Building Material, vol.12, pp 289-302.

Miguel Angel Porta Gandara, 2002, Effect of Passive Techniques on Interior Temperature in Small Houses in the Dry, Hot climate of Northwestern Mexico, Renewable Energy, vol.26, pp121-135.

Ministry of Electricity and Water Annual Report for 2001.

Ministry of Work and Housing, 1998, Thermal Insulation in Building, Technical Affairs Directorate, Kingdom of Bahrain.

Ross McCluney, 1993, Choosing the Best Windows for Hot Climates, Innovative housing 93 Conference, pp366-375.

S.W.Fereig & M.A.Younis, 1985, Effects of Energy Conservation Measures on the Life Cycle Cost of Kuwaiti Residential Buildings, Energy and Buildings, vol.8, pp71-78.

Sharples Steve; Stewart Lorraine & R.Tregenza Peter, 2001, Glazing Daylight Transmittances: A Field Survey of Windows in Urban Areas, Building and Environment, vol.26, pp 503-509.

Sheila J.Hayter, 2001, The Energy Design Process for Designing and Constructing High Performance Buildings, National Renewable Energy Laboratory, USA.

Stephen L.Garvin, 1998, Environmental Conditions in Window Frames with Double Glazing Units, Construction & Building Materials, Vol.12, pp289-302.

University of Bahrain, 1995, Energy Conservation in Building in Bahrain, objective (1, 2.1), Kingdom of Bahrain.

Windows, Glass and Energy Conservation, 2001, Guardian Industries Corp.

Internet Sources

- Window Energy Rating and Labeling, http://eandle.lbl.gov/BTP/DOE/
- Windows and glazing, http://www.wbdg.org/design/windows.php
- Understanding glazing properties, http://www.pge.com/pec
- Window& window treatment, http://www.aps.com/aps_services/energysurvey/Default_BUSRES.html

GLOSSARY

- **Clear glazing:** the familiar standard without any type of tint or coating designed to alter the visibility or energy performance of the glass.

- **Tined glazing:** tined glass is often specified as an inexpensive way to reduce solar heat gain through windows. Often referred to as "heat absorbing" glass, tined glazing block solar heat by actually absorbing it in the glass itself. However, while this dose reduces the direct solar heat gain, it also causes the temperature of the glass to rise. The most common colors are bronze, gray and green and they all block solar heat gain in about the same proportion. Black tint is the worst choice for cooling load reduction since it absorbs much more visible energy than heat energy.

- **Reflective glazing:** semitransparent metallic coatings are applied to clear or tinted glass to provide a high level of solar heat control. However, they reduce cooling loads at the expense of daylight transmittance. They can also cause glare problems in the surroundings and unintended heat in surrounding buildings.

- **U value**: the rate of heat flow through a window assembly due to the temperature difference between the two sides of the window. The lower the U value, the greater the insulating value of the window.

- **Shading coefficient (SC):** the ability of glazing to block the sun's radiant heat. The SC is the ratio of solar heat gain of a window compared to single pane 1/8" clear glass. The lower the SC, the lower the solar heat gains through the window.

- **Solar heat gain coefficient (SHGC):** The fraction of solar radiation passing through the window as heat compared to the amount of solar radiation striking the window. The SHGC is becoming a standard performance metric and is becoming more common in the performance ratings of manufacturers. It similar to the shading coefficient in that the lower the SHGC, the lower the solar heat gains.

- **Visible transmittance (Tv):** the percentage of visible light that passes through the window assembly. A high Tv indicates a greater fraction of incident natural light passing through the window. Reducing cooling loads by specifying lower SC and SHGC ratings needs to be considered in conjunction with the visible light transmittance of the glazing choice to achieve a balance between cooling load reduction and the desired natural light environment.

NUMENCLATURE

Q_{cond} = rate of heat transfer by conduction

K = thermal conductivity of the material

ΔT = temperature difference between the two surface.

L = thickness of the material

Q_{conv} = rate of heat transfer by convection.

h = convection coefficient.

ΔT = temperature difference

ε = emissivity (a measure of a material's ability to emit radiant energy)

Equal 5.67×10^{-8}

Q = instantaneous energy flow, W

U = overall coefficient of heat transfer (U-factor), W/ (m^2.K)

A_{pf} = Total projected area of fenestration, m^2

t_{out} = exterior air temperature, ^0C

t_{in} = Interior air temperature, ^0C

SHGC = Solar heat gain coefficient, nondimensional

E_t = incident total irradiance, W/m^2

Q = total rate of heat transfer (kw/hr)

U = overall heat transfer coefficient, or **U-value** (kW/ (hr m^2 °C)

A = Surface area of glass (m^2)

T = temperature difference between the two surface (°C)

R = thermal resistance, m^2 $^0C/W$

APPENDIX (A)

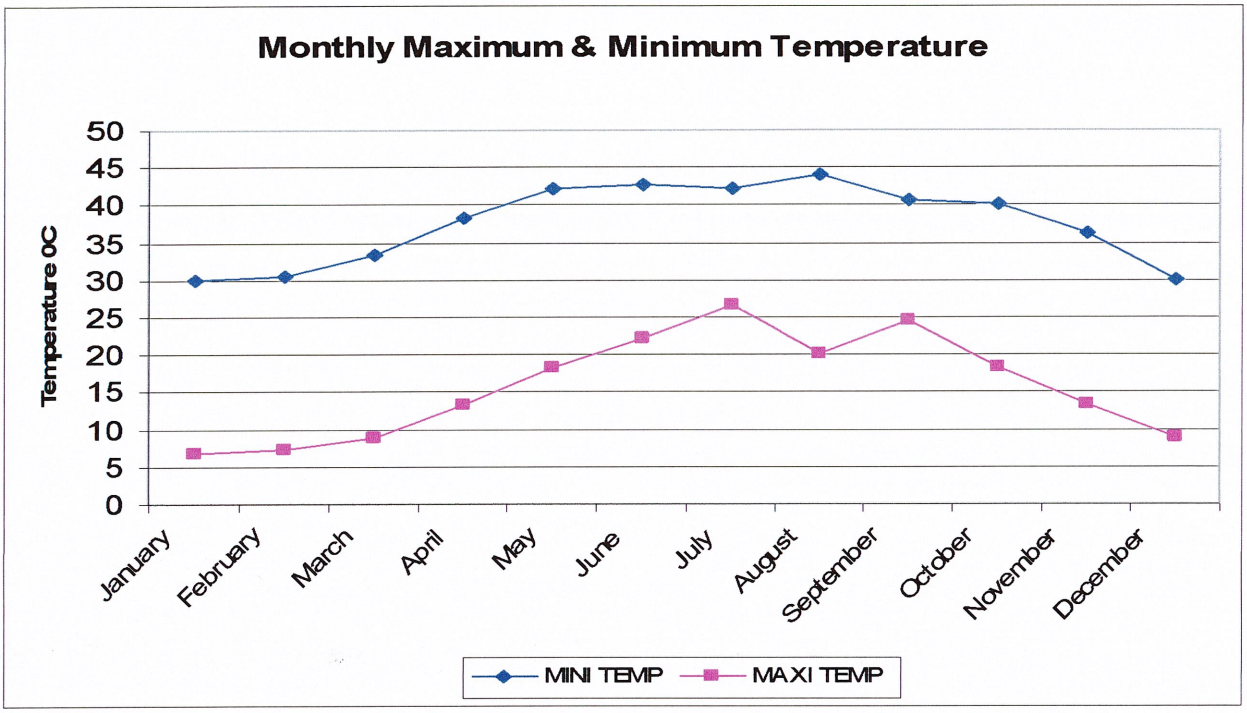
Typical Metrological Year (TMY) Data

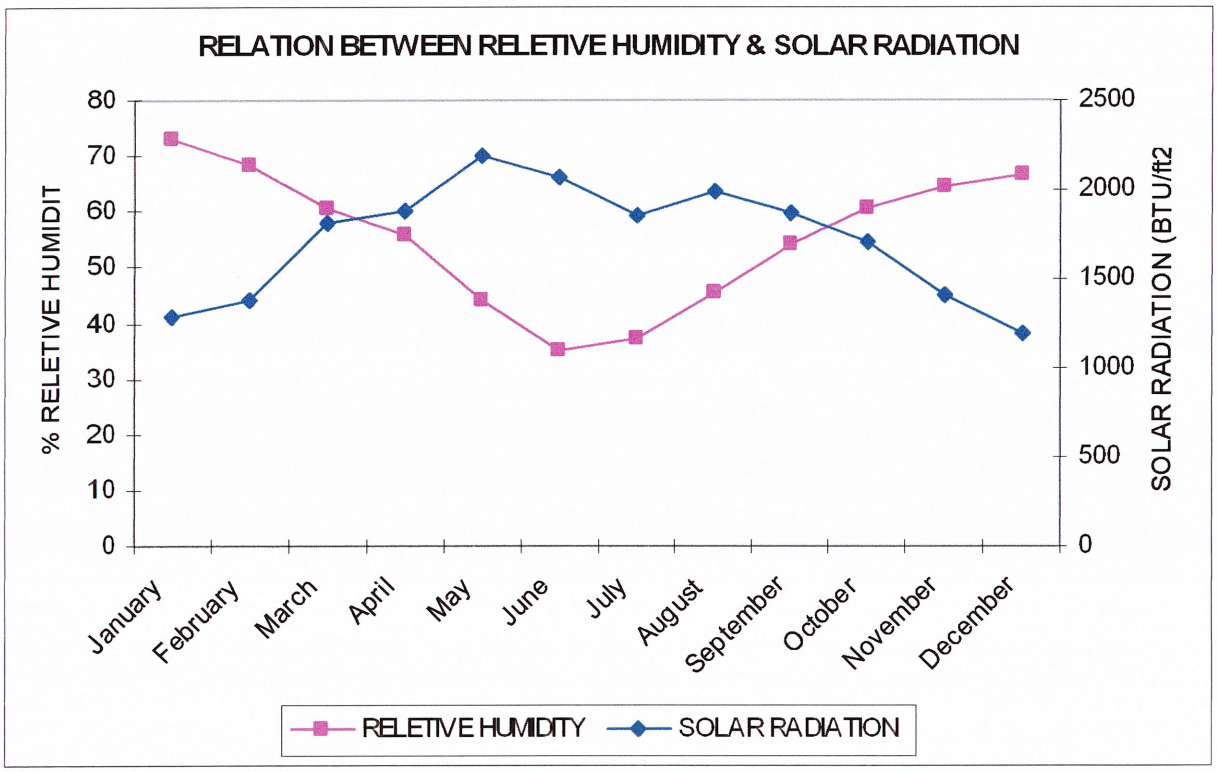
Energy-10 Weather File Summary
Bahrain Int. Airp., Bahrain

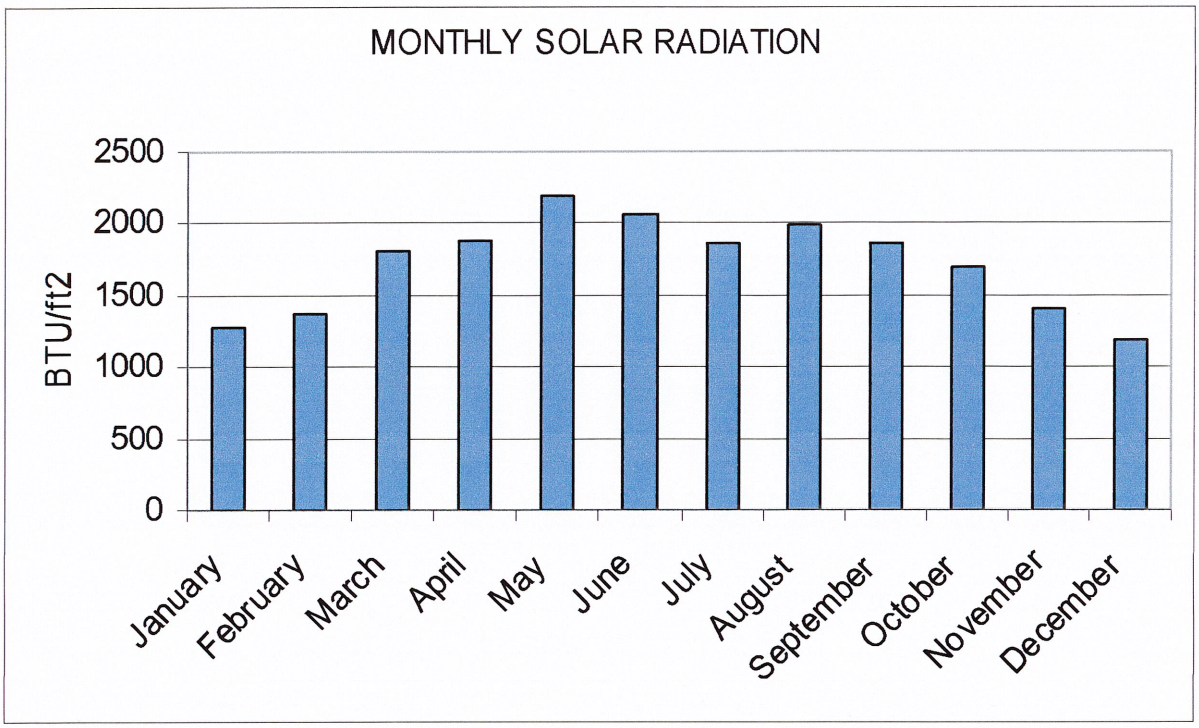
File Name: E:\BAHRAIN.ET1
Comment: Synthetic data from MeteoNorm
Latitude: 26.267
Longitude: -50.65
Elevation: 7 ft
Design Day Dry Bulb (Winter 99.0%): 43.0 °F
Design Day Dry Bulb (Winter 97.5%): 43.0 °F
Design Day Dry Bulb (Summer 2.5%): 110.0 °F
Design Day Wet Bulb (Summer 2.5%): 79.0 °F

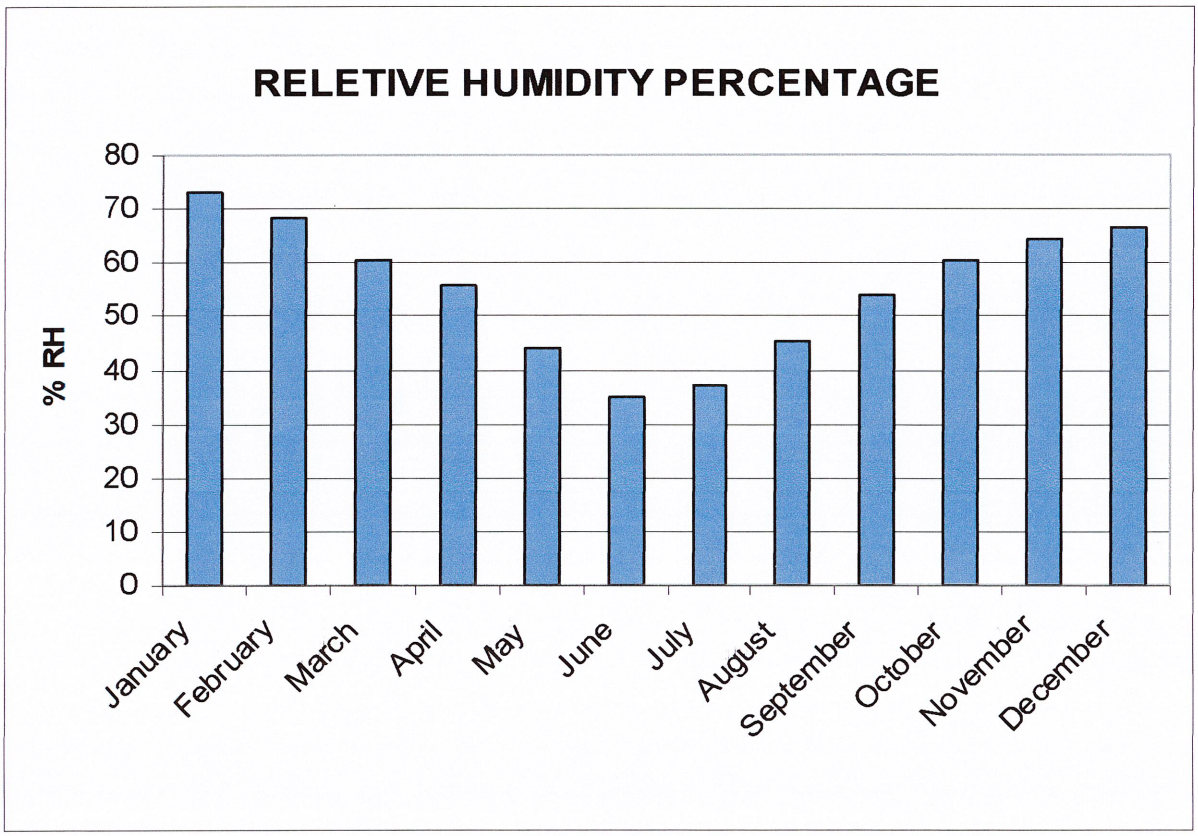
Month	TAA	TMXA	TMNA	TMX	TMN	TWBA	RH	WSA	HS	HDD	CDD
January	63.0	72.9	56.7	86.0	44.0	57.4	73.2	11.7	1278	116	110
February	64.4	73.3	58.1	87.0	45.0	57.7	68.2	12.1	1377	63	83
March	70.2	79.1	63.2	92.0	48.0	61.0	60.5	11.2	1811	31	222
April	77.6	85.2	70.8	101.0	56.0	66.0	55.7	10.3	1872	2	392
May	86.0	91.7	81.0	108.0	65.0	69.4	43.9	11.0	2184	0	662
June	90.7	97.5	84.6	109.0	72.0	69.5	35.2	13.0	2062	0	782
July	93.4	99.8	87.9	108.0	80.0	72.4	37.3	9.7	1856	0	896
August	93.6	100.7	87.3	111.0	68.0	75.8	45.2	9.6	1993	0	899
September	90.5	97.8	85.5	105.0	76.0	76.5	53.9	8.3	1864	0	799
October	84.8	93.3	78.4	104.0	65.0	73.7	60.7	8.9	1697	0	646
November	76.1	85.7	68.6	97.0	56.0	67.1	64.4	9.6	1407	1	364
December	66.8	75.6	60.5	86.0	48.0	59.4	66.4	11.2	1187	32	127
Year	79.7	87.7	73.5	111.0	44.0	67.1	55.4	10.5	1716	243	5979

TAA Average Dry Bulb Temperature, °F
TMXA Average Daily Maximum Dry Bulb Temperature, °F
TMNA Average Daily Minimum Dry Bulb Temperature, °F
TMX Maximum Dry Bulb Temperature, °F
TMN Minimum Dry Bulb Temperature, °F
TWBA Average Wet Bulb Temperature, °F
WSA Average Wind Speed, MPH
HS Average Daily Horizontal Solar Radiation, Btu/ft²
RH Relative Humidity, %
HDD Heating Degree Days, Base 65.0 °F
CDD Cooling Degree Days, Base 65.0 °F


Monthly Maximum & Minimum Temperature
Temperature oC
50
45
40
35
30
25
20
15
10
5
0
January
February
March
April
May
June
July
August
September
October
November
December
MINI TEMP
MAXI TEMP


RELATION BETWEEN RELETIVE HUMIDITY & SOLAR RADIATION
% RELETIVE HUMIDIT
80
70
60
50
40
30
20
10
0
2500
2000
1500
1000
500
0
SOLAR RADIATION (BTU/ft2
January
February
March
April
May
June
July
August
September
October
November
December
RELETIVE HUMIDITY
SOLAR RADIATION


MONTHLY SOLAR RADIATION
BTU/ft2
2500
2000
1500
1000
500
0
January
February
March
April
May
June
July
August
September
October
November
December


RELETIVE HUMIDITY PERCENTAGE
% RH
80
70
60
50
40
30
20
10
0
January
February
March
April
May
June
July
August
September
October
November
December

APPENDIX (B)

Simulation Output of Building Shape & Orientation Effect

Energy-10 Summary Page Oct 10, 2006

Project: PROJ13 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT
..0\PROJ13

Description:	Reference Case	
Scheme Number:	1 / Saved	none
Library Name:	L2 HAMAD TOWNLIB / Not Saved	-
Simulation status, Thermal/DL	valid/NA	-
Weather file:	BAHRAIN.ET1	-
Floor Area, m²	102.0	-
Surface Area, m²	328.4	-
Volume, m³	306.0	-
Total Conduction UA, W/K	597.7	-
Average U-value, W/m²K	10.335	-
Wall Construction	brick wall, R=0.5	-
Roof Construction	cast solid slab, R=0.5	-
Floor type, insulation	Slab on Grade, Reff=1.6	-
Window Construction	4070 single, alum, U=6.75	-
Window Shading	None	-
Wall total gross area, m²	124	-
Roof total gross area, m²	102	-
Ground total gross area, m²	102	-
Window total gross area, m²	18	-
Windows (N/E/S/W:Roof)	0/2/2/3:0	-
Glazing name	single, U=6.30	-

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	-
Rated Output (Heat/SCool/TCool),kW	15/29/39	-
Rated Air Flow/MOOA,L/s	2027/0	-
Heating thermostat	20.6 °C, no setback	-
Cooling thermostat	26.0 °C, no setup	-
Heat/cool performance	eff=100,COP=2.6	-
Economizer?/type	no/NA	-
Duct leaks/conduction losses, total %	11/10	-
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	-
Added mass?	none	-
Daylighting?	no	-
Infiltration, cm²	ELA=1148.8	-

Results:

Energy cost 0.000$/kWh,0.032$/kWh,0.000$/kW		-)
Simulation dates	01-Jan to 31-Dec	00-Jan to 00-Jan
Energy use, kWh	51972	NA
Energy cost, $	1662	NA
Saved by daylighting, kWh	-	NA
Total Electric, kWh	51963	NA
Internal/External lights, kWh	5867/1081	NA
Heating/Cooling/Fan, kWh	338/28371/3740	NC
Hot water/Other, kWh	0/12566	NC
Peak Electric, kW	18.7	NA
Fuel, hw/heat/total, kWh	0/0/0	NC
Emissions, CO2/SO2/NOx, kg	31678/186/97	NA
Construction Costs	138049	0
Life-Cycle Cost	538976288	0

Energy-10 Summary Page Oct 10, 2006

Project: PROJ14 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT
..90\PROJ14

Description:	Reference Case	
Scheme Number:	1 / Saved	none
Library Name:	L2 HAMAD TOWNLIB / Not Saved	-
Simulation status, Thermal/DL	valid/NA	-
Weather file:	BAHRAIN.ET1	-
Floor Area, m²	102.0	-
Surface Area, m²	328.4	-
Volume, m³	306.0	-
Total Conduction UA, W/K	597.7	-
Average U-value, W/m²K	10.335	-
Wall Construction	brick wall, R=0.5	-
Roof Construction	cast solid slab, R=0.5	-
Floor type, insulation	Slab on Grade, Reff=1.6	-
Window Construction	4070 single, alum, U=6.75	-
Window Shading	None	-
Wall total gross area, m²	124	-
Roof total gross area, m²	102	-
Ground total gross area, m²	102	-
Window total gross area, m²	18	-
Windows (N/E/S/W:Roof)	3/0/2/2:0	-
Glazing name	single, U=6.30	-

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	-
Rated Output (Heat/SCool/TCool),kW	15/28/38	-
Rated Air Flow/MOOA,L/s	1943/0	-
Heating thermostat	20.6 °C, no setback	-
Cooling thermostat	26.0 °C, no setup	-
Heat/cool performance	eff=100,COP=2.6	-
Economizer?/type	no/NA	-
Duct leaks/conduction losses, total %	11/10	-
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	-
Added mass?	none	-
Daylighting?	no	-
Infiltration, cm²	ELA=1148.8	-

Results:

Energy cost 0.000$/kWh,0.032$/kWh,0.000$/kW		-)
Simulation dates	01-Jan to 31-Dec	00-Jan to 00-Jan
Energy use, kWh	51185	NA
Energy cost, $	1637	NA
Saved by daylighting, kWh	-	NA
Total Electric, kWh	51176	NA
Internal/External lights, kWh	5867/1081	NA
Heating/Cooling/Fan, kWh	381/27647/3634	NC
Hot water/Other, kWh	0/12566	NC
Peak Electric, kW	18.4	NA
Fuel, hw/heat/total, kWh	0/0/0	NC
Emissions, CO2/SO2/NOx, kg	31199/183/95	NA
Construction Costs	137051	0
Life-Cycle Cost	538976288	0

Energy-10 Summary Page Oct 10, 2006

Project: PROJ11 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT
..180\PROJ11

Description:	Reference Case	
Scheme Number:	1 / Saved	none
Library Name:	L2 HAMAD TOWNLIB / Not Saved	-
Simulation status, Thermal/DL	valid/NA	-
Weather file:	BAHRAIN.ET1	-
Floor Area, m²	102.0	-
Surface Area, m²	328.3	-
Volume, m³	306.0	-
Total Conduction UA, W/K	597.6	-
Average U-value, W/m²K	10.335	-
Wall Construction	brick wall, R=0.5	-
Roof Construction	cast solid slab, R=0.5	-
Floor type, insulation	Slab on Grade, Reff=1.6	-
Window Construction	4070 single, alum, U=6.75	-
Window Shading	None	-
Wall total gross area, m²	124	-
Roof total gross area, m²	102	-
Ground total gross area, m²	102	-
Window total gross area, m²	18	-
Windows (N/E/S/W:Roof)	2/3/0/2:0	-
Glazing name	single, U=6.30	-

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	-
Rated Output (Heat/SCool/TCool),kW	15/30/41	-
Rated Air Flow/MOOA,L/s	2006/0	-
Heating thermostat	20.6 °C, no setback	-
Cooling thermostat	25.0 °C, no setup	-
Heat/cool performance	eff=100,COP=2.6	-
Economizer?/type	no/NA	-
Duct leaks/conduction losses, total %	11/10	-
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	-
Added mass?	none	-
Daylighting?	no	-
Infiltration, cm²	ELA=1148.5	-

Results:

Energy cost 0.000$/kWh,0.032$/kWh,0.000$/kW		-)
Simulation dates	01-Jan to 31-Dec	00-Jan to 00-Jan
Energy use, kWh	54144	NA
Energy cost, $	1732	NA
Saved by daylighting, kWh	-	NA
Total Electric, kWh	54135	NA
Internal/External lights, kWh	5867/1082	NA
Heating/Cooling/Fan, kWh	442/30260/3917	NC
Hot water/Other, kWh	0/12567	NC
Peak Electric, kW	19.1	NA
Fuel, hw/heat/total, kWh	0/0/0	NC
Emissions, CO2/SO2/NOx, kg	33002/194/101	NA
Construction Costs	138304	0
Life-Cycle Cost	538976288	0

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT
:.270\PROJ12

Description:	Reference Case	
Scheme Number:	1 / Saved	none
Library Name:	L2 HAMAD TOWNLIB / Not Saved	-
Simulation status, Thermal/DL	valid/NA	-
Weather file:	BAHRAIN.ET1	-
Floor Area, m^2	102.0	-
Surface Area, m^2	328.3	-
Volume, m^3	306.0	-
Total Conduction UA, W/K	597.6	-
Average U-value, W/m^2K	10.335	-
Wall Construction	brick wall, R=0.5	-
Roof Construction	cast solid slab, R=0.5	-
Floor type, insulation	Slab on Grade, Reff=1.6	-
Window Construction	4070 single, alum, U=6.75	-
Window Shading	None	-
Wall total gross area, m^2	124	-
Roof total gross area, m^2	102	-
Ground total gross area, m^2	102	-
Window total gross area, m^2	18	-
Windows (N/E/S/W:Roof)	2/2/3/0:0	-
Glazing name	single, U=6.30	-

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	-
Rated Output (Heat/SCool/TCool),kW	15/25/34	-
Rated Air Flow/MOOA,L/s	1755/0	-
Heating thermostat	20.6 °C, no setback	-
Cooling thermostat	26.1 °C, no setup	-
Heat/cool performance	eff=100,COP=2.6	-
Economizer?/type	no/NA	-
Duct leaks/conduction losses, total %	11/10	-
Peak Gains; IL,EL,HW,OT; W/m^2	14.64/4.95/0.00/18.62	-
Added mass?	none	-
Daylighting?	no	-
Infiltration, cm^2	ELA=1148.5	-

Results:

Energy cost 0.000$/kWh,0.032$/kWh,0.000$/kW		-)
Simulation dates	01-Jan to 31-Dec	00-Jan to 00-Jan
Energy use, kWh	50310	NA
Energy cost, $	1609	NA
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	NA
Internal/External lights, kWh	5867/1082	NA
Heating/Cooling/Fan, kWh	359/26890/3537	NC
Hot water/Other, kWh	0/12567	NC
Peak Electric, kW	16.7	NA
Fuel, hw/heat/total, kWh	0/0/0	NC
Emissions, CO2/SO2/NOx, kg	30665/180/94	NA
Construction Costs	134653	0
Life-Cycle Cost	538976288	0

APPENDIX (C)

Simulation Output of Building Glazing Effect

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT.270\PROJ12

Description:	Reference Case	glazing type 40b vinyl fram
Scheme Number:	1 / Not Saved	12 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m²	102.0	102.0
Surface Area, m²	328.3	328.3
Volume, m³	306.0	306.0
Total Conduction UA, W/K	597.6	501.5
Average U-value, W/m²K	10.335	8.673
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 triple, vinyl, U=1.28,etc
Window Shading	None	None
Wall total gross area, m²	124	124
Roof total gross area, m²	102	102
Ground total gross area, m²	102	102
Window total gross area, m²	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	triple 40b low-e , U=1.19

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	13/23/31
Rated Air Flow/MOOA,L/s	1755/0	1617/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	ELA=1148.5	ELA=1148.5

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	47555
Energy cost, $	1609	1521
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	47547
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	225/24582/3225
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	15.8
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	28986/170/88
Construction Costs	48569	49169
Life-Cycle Cost	114441	94741

Cost Summary Report

Scheme Name:	Reference Case	glazing type 40b vinyl fram	Difference
Construction	48569.30	49169.00	-599.70
fixed	40799.30	40800.00	-0.70
EE strategies	0.00	599.00	-599.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	5827.50	12819.70
Annual fuel	0.00	0.00	0.00
Annual electric	1609.30	1521.20	88.10
Annual maintenance	815.99	816.00	-0.01

Life Cycle Cost Results	Reference Case	glazing type 40	NetPresentValue
capital	48569	49169	-600
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	22848	1322
maintenance	14096	14096	0
HVAC replacement	27606	8628	18978
tax deductions	0	0	0
Life-Cycle Cost	114441	94741	19700

Internal Rate of Return, IRR,	47.577%
Simple Payback, years	6.82
Benefit / Cost Ratio	33.83

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

Energy-10 Summary Page Oct 12, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT .270\PROJ12

Description:	Reference Case	glazing type 29 vinyl fram
Scheme Number:	1 / Not Saved	11 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	L2 HAMAD TOWNLIB / Not Saved
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m²	102.0	102.0
Surface Area, m²	328.3	328.3
Volume, m³	306.0	306.0
Total Conduction UA, W/K	597.6	510.6
Average U-value, W/m²K	10.335	8.830
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 triple, vinyl, U=1.79,etc
Window Shading	None	None
Wall total gross area, m²	124	124
Roof total gross area, m²	102	102
Ground total gross area, m²	102	102
Window total gross area, m²	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	triple 29b, U=1.93

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	13/24/32
Rated Air Flow/MOOA,L/s	1755/0	1625/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	ELA=1148.5	ELA=1148.5

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	47316
Energy cost, $	1609	1514
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	47308
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	267/24337/3188
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	15.8
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	28840/170/88
Construction Costs	48569	49169
Life-Cycle Cost	114441	94636

Cost Summary Report

Scheme Name:	Reference Case	glazing type 29 vinyl fram	Difference
Construction	48569.30	49169.00	-599.70
fixed	40799.30	40800.00	-0.70
EE strategies	0.00	599.00	-599.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	5827.50	12819.70
Annual fuel	0.00	0.00	0.00
Annual electric	1609.30	1513.54	95.76
Annual maintenance	815.99	816.00	-0.01

Life Cycle Cost Results	Reference Case	glazing type 29	NetPresentValue
capital	48569	49169	-600
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	22743	1427
maintenance	14096	14096	0
HVAC replacement	27606	8628	18978
tax deductions	0	0	0
Life-Cycle Cost	114441	94636	19805

Internal Rate of Return, IRR,	48.409%
Simple Payback, years	6.32
Benefit / Cost Ratio	34.01

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT
.270\PROJ12

Description:	Reference Case	glazing type 25b vinyl fram
Scheme Number:	1 / Not Saved	6 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	missing/NA	missing/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m²	102.0	102.0
Surface Area, m²	328.3	328.3
Volume, m³	306.0	306.0
Total Conduction UA, W/K	597.6	511.4
Average U-value, W/m²K	10.335	8.844
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 double, vinyl, U=1.84,etc
Window Shading	None	None
Wall total gross area, m²	124	124
Roof total gross area, m²	102	102
Ground total gross area, m²	102	102
Window total gross area, m²	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	double 25b arg, U=1.87

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	13/24/31
Rated Air Flow/MOOA,L/s	1755/0	1621/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	ELA=1148.5	ELA=1148.5

Results:

Energy cost 0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW	
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	46295
Energy cost, $	1609	1481
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	46287
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	358/23354/3061
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	15.7
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	28218/166/86
Construction Costs	48569	48955
Life-Cycle Cost	114441	110975

Cost Summary Report

Scheme Name:	Reference Case	glazing type 25b vinyl fram	Difference
Construction	48569.30	48955.00	-385.70
fixed	40799.30	40800.00	-0.70
EE strategies	0.00	385.00	-385.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	17343.70	1303.50
Annual fuel	0.00	0.00	0.00
Annual electric	1609.30	1480.90	128.41
Annual maintenance	815.99	816.00	-0.01

Life Cycle Cost Results	Reference Case	glazing type 25	NetPresentValue
capital	48569	48955	-386
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	22247	1923
maintenance	14096	14096	0
HVAC replacement	27606	25677	1929
tax deductions	0	0	0
Life-Cycle Cost	114441	110975	3466

Internal Rate of Return, IRR,	54.096%
Simple Payback, years	3.02
Benefit / Cost Ratio	9.98

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

nergy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT .270\PROJ12

Description:	Reference Case	glazing type 25b
Scheme Number:	1 / Not Saved	5 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	missing/NA	missing/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m²	102.0	102.0
Surface Area, m²	328.3	328.3
Volume, m³	306.0	306.0
Total Conduction UA, W/K	597.6	527.5
Average U-value, W/m²K	10.335	9.123
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 double, alum, U=2.76,etc
Window Shading	None	None
Wall total gross area, m²	124	124
Roof total gross area, m²	102	102
Ground total gross area, m²	102	102
Window total gross area, m²	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	double 25b arg, U=1.87

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	14/24/32
Rated Air Flow/MOOA,L/s	1755/0	1639/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	ELA=1148.5	ELA=1148.5

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	46505
Energy cost, $	1609	1488
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	46497
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	404/23497/3080
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	15.9
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	28346/167/86
Construction Costs	48570	48903
Life-Cycle Cost	95464	93980

Cost Summary Report

Scheme Name:	Reference Case	glazing type 25b	Difference
Construction	48570.00	48903.00	-333.00
fixed	40800.00	40800.00	0.00
EE strategies	0.00	333.00	-333.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	5827.50	5827.50	0.00
Annual fuel	0.00	0.00	0.00
Annual electric	1609.31	1496.12	113.20
Annual maintenance	816.00	816.00	0.00

Life Cycle Cost Results	Reference Case	glazing type 25	NetPresentValue
capital	48570	48903	-333
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	22473	1697
maintenance	14096	14096	0
HVAC replacement	8628	8628	0
tax deductions	0	0	0
Life-Cycle Cost	95464	94100	1364

Internal Rate of Return, IRR,	51.365%
Simple Payback, years	2.95
Benefit / Cost Ratio	5.10

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT .270\PROJ12

Description:	Reference Case	5k w shading ther seting ACH 0
Scheme Number:	1 / Not Saved	16 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m²	102.0	102.0
Surface Area, m²	328.3	328.3
Volume, m³	306.0	306.0
Total Conduction UA, W/K	597.6	526.4
Average U-value, W/m²K	10.335	9.102
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 double, vinyl, U=2.69,etc
Window Shading	None	fully shaded
Wall total gross area, m²	124	124
Roof total gross area, m²	102	102
Ground total gross area, m²	102	102
Window total gross area, m²	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	double 5k arg, U=2.90

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	12/22/29
Rated Air Flow/MOOA,L/s	1755/0	1557/0
Heating thermostat	20.6 °C, no setback	20.6 °C, setback to 17.8 °C
Cooling thermostat	26.1 °C, no setup	26.1 °C, setup to 28.9 °C
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	ELA=1148.5	ACH=0.4

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	41962
Energy cost, $	1609	1342
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	41954
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	152/19672/2615
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	15.0
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	25577/150/78
Construction Costs	48569	49683
Life-Cycle Cost	114441	92566

Cost Summary Report

Scheme Name:	Reference Case	5k w shading ther seting ACH 0	Difference
Construction	48569.30	49683.00	-1113.70
fixed	40799.30	40800.00	-0.70
EE strategies	0.00	1113.00	-1113.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	5827.50	12819.70
Annual fuel	0.00	0.00	0.00
Annual electric	1609.30	1342.27	267.04
Annual maintenance	815.99	816.00	-0.01

Life Cycle Cost Results	Reference Case	5k w shading t	NetPresentValue
capital	48569	49683	-1114
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	20159	4011
maintenance	14096	14096	0
HVAC replacement	27606	8628	18978
tax deductions	0	0	0
Life-Cycle Cost	114441	92566	21875

Internal Rate of Return, IRR,	48.821%
Simple Payback, years	4.17
Benefit / Cost Ratio	20.64

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT .270\PROJ12

Description:	Reference Case	glazing type 5k w shading
Scheme Number:	1 / Not Saved	14 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m²	102.0	102.0
Surface Area, m²	328.3	328.3
Volume, m³	306.0	306.0
Total Conduction UA, W/K	597.6	526.4
Average U-value, W/m²K	10.335	9.102
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 double, vinyl, U=2.69,etc
Window Shading	None	40 deg latitude
Wall total gross area, m²	124	124
Roof total gross area, m²	102	102
Ground total gross area, m²	102	102
Window total gross area, m²	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	double 5k arg, U=2.90

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	14/24/31
Rated Air Flow/MOOA,L/s	1755/0	1627/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	ELA=1148.5	ELA=1148.5

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	45835
Energy cost, $	1609	1466
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	45827
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	458/22856/2998
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	15.7
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	27938/164/85
Construction Costs	48569	49683
Life-Cycle Cost	114441	94429

Cost Summary Report

Scheme Name:	Reference Case	glazing type 5k w shading	Difference
Construction	48569.30	49683.00	-1113.70
fixed	40799.30	40800.00	-0.70
EE strategies	0.00	1113.00	-1113.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	5827.50	12819.70
Annual fuel	0.00	0.00	0.00
Annual electric	1609.30	1466.17	143.13
Annual maintenance	815.99	816.00	-0.01

Life Cycle Cost Results	Reference Case	glazing type 5k	NetPresentValue
capital	48569	49683	-1114
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	22022	2148
maintenance	14096	14096	0
HVAC replacement	27606	8628	18978
tax deductions	0	0	0
Life-Cycle Cost	114441	94429	20012

Internal Rate of Return, IRR,	39.065%
Simple Payback, years	7.79
Benefit / Cost Ratio	18.96

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT .270\PROJ12

Description:	Reference Case	glazing type 5k vinyl fram
Scheme Number:	1 / Not Saved	10 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m^2	102.0	102.0
Surface Area, m^2	328.3	328.3
Volume, m^3	306.0	306.0
Total Conduction UA, W/K	597.6	526.4
Average U-value, W/m^2K	10.335	9.102
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 double, vinyl, U=2.69,etc
Window Shading	None	None
Wall total gross area, m^2	124	124
Roof total gross area, m^2	102	102
Ground total gross area, m^2	102	102
Window total gross area, m^2	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	double 5k arg, U=2.90

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	14/24/31
Rated Air Flow/MOOA,L/s	1755/0	1627/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m^2	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm^2	ELA=1148.5	ELA=1148.5

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	45895
Energy cost, $	1609	1468
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	45887
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	453/22913/3005
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	15.7
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	27974/164/85
Construction Costs	48569	49036
Life-Cycle Cost	114441	93812

Cost Summary Report

Scheme Name:	Reference Case	glazing type 5k vinyl fram	Difference
Construction	48569.30	49036.00	-466.70
fixed	40799.30	40800.00	-0.70
EE strategies	0.00	466.00	-466.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	5827.50	12819.70
Annual fuel	0.00	0.00	0.00
Annual electric	1609.30	1468.09	141.21
Annual maintenance	815.99	816.00	-0.01

Life Cycle Cost Results	Reference Case	glazing type 5k	NetPresentValue
capital	48569	49036	-467
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	22052	2118
maintenance	14096	14096	0
HVAC replacement	27606	8628	18978
tax deductions	0	0	0
Life-Cycle Cost	114441	93812	20629

Internal Rate of Return, IRR,	64.621%
Simple Payback, years	3.31
Benefit / Cost Ratio	45.17

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT .270\PROJ12

Description:	Reference Case	glazing type 5b alumi wb fram
Scheme Number:	1 / Not Saved	8 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m^2	102.0	102.0
Surface Area, m^2	328.3	328.3
Volume, m^3	306.0	306.0
Total Conduction UA, W/K	597.6	531.3
Average U-value, W/m^2K	10.335	9.188
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 double, alum, U=2.98,etc
Window Shading	None	None
Wall total gross area, m^2	124	124
Roof total gross area, m^2	102	102
Ground total gross area, m^2	102	102
Window total gross area, m^2	18	18
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	double 5b arg, U=2.90

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	14/24/32
Rated Air Flow/MOOA,L/s	1755/0	1658/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m^2	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm^2	ELA=1148.5	ELA=1148.5

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	48064
Energy cost, $	1609	1537
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	48055
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	292/24972/3276
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	16.1
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	29296/172/89
Construction Costs	48569	48882
Life-Cycle Cost	114441	112275

Cost Summary Report

Scheme Name:	Reference Case	glazing type 5b alumi wb fram	Difference
Construction	48569.30	48882.30	-313.00
fixed	40799.30	40799.30	0.00
EE strategies	0.00	313.00	-313.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	17702.56	944.64
Annual fuel	0.00	0.00	0.00
Annual electric	1609.31	1537.46	71.85
Annual maintenance	815.99	815.99	0.00

Life Cycle Cost Results	Reference Case	glazing type 5b	NetPresentValue
capital	48569	48882	-313
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	23089	1081
maintenance	14096	14096	0
HVAC replacement	27606	26208	1398
tax deductions	0	0	0
Life-Cycle Cost	114441	112275	2166

Internal Rate of Return, IRR,	37.631%
Simple Payback, years	4.35
Benefit / Cost Ratio	7.92

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

Energy-10 Summary Page Oct 10, 2006

Project: PROJ12 **Project Directory:** C:\Program Files\Energy10v1_5\L2 HT .270\PROJ12

Description:	Reference Case	glazing type 5b alumi fram
Scheme Number:	1 / Not Saved	7 / Not Saved
Library Name:	L2 HAMAD TOWNLIB / Not Saved	modified / Not Saved
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	BAHRAIN.ET1	BAHRAIN.ET1
Floor Area, m²	102.0	102.0
Surface Area, m²	328.3	328.3
Volume, m³	306.0	306.0
Total Conduction UA, W/K	597.6	540.6
Average U-value, W/m²K	10.335	9.349
Wall Construction	brick wall, R=0.5	brick wall, R=0.5
Roof Construction	cast solid slab, R=0.5	cast solid slab, R=0.5
Floor type, insulation	Slab on Grade, Reff=1.6	Slab on Grade, Reff=1.6
Window Construction	4070 single, alum, U=6.75	4070 double, alum, U=3.69,etc
Window Shading	None	None
Wall total gross area, m²	124	124
Roof total gross area, m²	102	102
Ground total gross area, m²	102	102
Window total gross area, m²	18	14
Windows (N/E/S/W:Roof)	2/2/3/0:0	2/2/3/0:0
Glazing name	single, U=6.30	double˙ 5b arg, U=2.90

Operating parameters for zone 1

HVAC system	DX Cooling with Elect Furn	DX Cooling with Elect Furn
Rated Output (Heat/SCool/TCool),kW	15/25/34	14/24/32
Rated Air Flow/MOOA,L/s	1755/0	1665/0
Heating thermostat	20.6 °C, no setback	20.6 °C, no setback
Cooling thermostat	26.1 °C, no setup	26.1 °C, no setup
Heat/cool performance	eff=100,COP=2.6	eff=100,COP=2.6
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	11/10	11/10
Peak Gains; IL,EL,HW,OT; W/m²	14.64/4.95/0.00/18.62	14.64/4.95/0.00/18.62
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm²	ELA=1148.5	ELA=1148.5

Results:

Energy cost	0.000$/kWh,0.032$/kWh,0.000$/kW	0.000$/kWh,0.032$/kWh,0.000$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	50310	47525
Energy cost, $	1609	1520
Saved by daylighting, kWh	-	NA
Total Electric, kWh	50301	47516
Internal/External lights, kWh	5867/1082	5867/1082
Heating/Cooling/Fan, kWh	359/26890/3537	371/24428/3202
Hot water/Other, kWh	0/12567	0/12567
Peak Electric, kW	16.7	16.1
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	30665/180/94	28967/170/88
Construction Costs	48569	48902
Life-Cycle Cost	114441	111788

Cost Summary Report

Scheme Name:	Reference Case	glazing type 5b alumi fram	Difference
Construction	48569.30	48902.30	-333.00
fixed	40799.30	40799.30	0.00
EE strategies	0.00	333.00	-333.00
HVAC installation	7770.00	7770.00	0.00
Mortgage payment	0.00	0.00	0.00
HVAC replacement	18647.20	17533.30	1113.90
Annual fuel	0.00	0.00	0.00
Annual electric	1609.31	1520.21	89.10
Annual maintenance	815.99	815.99	0.00

Life Cycle Cost Results	Reference Case	glazing type 5b	NetPresentValue
capital	48569	48902	-333
property taxes	0	0	0
mortgage	0	0	0
utilities	24170	22833	1337
maintenance	14096	14096	0
HVAC replacement	27606	25957	1649
tax deductions	0	0	0
Life-Cycle Cost	114441	111788	2653

Internal Rate of Return, IRR,	43.303%
Simple Payback, years	3.74
Benefit / Cost Ratio	8.97

inancial Parameters

Year of Construction	1984
Building life, yr	60
Salvage value, % of original in constant dollars	0.00
Annual property tax, % of value	0.00
Property tax escalation rate, %	0.00
Fuel cost escalation rate, %	0.00
Electric cost escalation rate, %	0.00
Maintenance cost escalation rate, %	1.00
Building resale escalation rate, %	0.00
HVAC replacement cost escalation rate, %	2.00
HVAC replacement cycle	10
Discount rate, %	7.00
Mortgage?	no
mortgage term, yr	0
mortgage interest, %	8.00
down payment, %	100.00
Tax deductible?	
property taxes	no
loan interest	no
utilities	no
maintenance	no
HVAC upgrade	no
depreciation	no
straight line depreciation period, yr	31
incremental tax bracket, %	31.00

APPENDIX (D)

Brief of Bahrain Ministerial Regulation for use of insulation

MINISTERIAL ORDER NO. 8 OF 1999 WITH RESPECT TO BUILDING THERMAL INSULATION REGULATION

Chapter One

Definitions

Article (1)

In the application of the provisions of this Order, thermal insulation means the use of materials having thermal insulation properties so as to help reduce the conduction and transfer of heat from outside a building to its inside in summer and from its inside to its outside in winter.

Schedule No.(1) which is attached to this Order details the technical and engineering glossary required for the implementation of thermal insulation, the defined meanings thereof and the equations indicating the manner of applying its requirements.

Chapter Two

Scope of Application and Requirements of Thermal Insulation of Buildings

Article (2)

Thermal insulation shall be used in all public and private buildings that require airconditioning equipment according to their engineering designs whether such buildings are government offices, commercial or industrial premises, houses, apartment blocks or otherwise.

Article (3)

Use of thermal insulation shall take place according to the requirements, specifications, materials and engineering methods indicated in Schedules (2), (3), (4) and (5), which are attached to this Order in respect of the surfaces and walls of all the buildings that are subject to the provisions thereof whether in respect to the newly constructed buildings or these that are rebuilt after demolition or in respect of the buildings added to the existing ones.

Article (4)

One of the appropriate engineering methods indicated in the attached Schedule (5) shall be followed upon using thermal insulation for surfaces and walls of all the buildings subject to the provisions of this

Order. In case of a desire to use a different insulation method, it shall be imperative to obtain the approval of the concerned authorities specified by the Technical and Engineering Affairs Directorate at the Central Municipal Council, provided that such approval shall be in writing and given before such use.

Article (5)

Building plans submitted with applications for building permits filed with the Municipalities shall conform with the requirements for implementing thermal insulation in buildings as indicated in this Order and the Schedules attached thereto and shall include the duly completed forms indicated in the attached Schedule (6), provided that such plans shall be accompanied by the approval of the concerned authority at the Ministry of Electricity and Water to the use of the thermal insulation method and materials to be used in the building including the type of the exterior window glass therein.

In the cases of using thermal insulation, it shall be prohibited to approve any plans that do not include the requirements referred to in the preceding paragraph or include requirements not compatible therewith.

Article (6)

Temporary facilities and minor additions to existing buildings the area of which does not exceed 70 (seventy) square metres shall be exempted from application of the provisions of this Order.

Chapter Three

General Provisions

Article (7)

The Technical and Engineering Affairs Directorate at the Municipalities Affairs (Central Municipal Council) may in co-ordination with the authorities concerned with implementing the provisions of this Order amend the necessary requirements, specifications, materials and methods of using thermal insulation indicated in the attached Schedules.

Such amendments shall not be valid and effective except upon the approval thereof by the Minister of Housing, Municipalities and Environment.

Article (8)

The Technical and Engineering Affairs Directorate at the Municipalities Affairs (Central Municipal Council) shall develop the necessary mechanism for ensuring the implementation of the provisions of this

Order from the Technical point of view in co-ordination with the officers concerned with thermal insulation at the Ministry of Electricity and Water and the other concerned authorities. The concerned officers at the Municipalities shall ensure applying the decisions adopted in this respect.

A building owner who uses insulation in his building shall not be permitted to connect services to the building save after proving his implementation of all the necessary requirements in this respect according to the provisions of this Order according to a report or certificate issued by the authority to be determined by the aforesaid Directorate or as provided for in the mechanism referred to above.

Article (9)

The application of the provisions of this Order shall commence from the effective date thereof to government buildings and investment commercial and industrial buildings that are more than four storeys high.

An order of the Minister of Housing, Municipalities and Environment shall determine the kinds of buildings and facilities to which this Order shall apply in future and the effective date in respect thereof.

Article (10)

Every violation of the provisions of this Order shall be punishable by the penalty indicated in Article 23 of Legislative Decree No.13 of 1977 with respect to the promulgation of the Law of Constructional Organisation of Buildings.

Article (11)

The Central Municipal Council's Director General shall implement this Order, which shall come into effect six months after the date of its publication in the Official Gazette.

Khalid bin Abdulla Al Khalifa,
Minister of Housing, Municipalities & Environment

Issued on: 1st Rabie'e Al Awal, 1420 Hijra,
Corresponding to: 15th June,1999